EXPLORING THE SHORT-TERM EFFECTS

OF EFFORT- REWARD IMBALANCE

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Daily and within-day psychological and physiological measurements

OVER HET VERKENNEN VAN DE KORTE-TERMIJN EFFECTEN VAN INSPANNING EN BELONING: PSYCHOLOGISCHE EN FYSIOLOGISCHE METINGEN GEDURENDE DE DAG OVER MEERDERE DAGEN

(MET EEN SAMENVATTING IN HET NEDERLANDS)

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Chapter 1

GENERAL INTRODUCTION

1.1 Scope

The impact of work related stress on well-being and health has been the subject of a vast amount of research. So far, little attention has been given to the assessment of ongoing psychological and physiological processes occurring while actually at work. This is somehow surprising, since substantiating the effects of work stress during prolonged periods in the work environment is needed to underpin the claimed mechanisms linking stress to ill health. The present thesis uses recent theorising as well as developments in instrumentation and methodology to thoroughly test assumptions concerning the effects of work stress in the daily environment.

Several studies have shown Effort-Reward Imbalance (ERI) at work to account for a substantial proportion of the incidence and prevalence of cardiovascular disease (Bosma et al, 1998; Siegrist, 1996a Siegrist 1996b), and other health related problems (Peter et al., 1998). Although interesting from an epidemiological point of view, merely identifying populations “at risk” using single assessments (trait-like measures) of ERI is not enough to fully understand the effects ERI on the individual. More information about an individual’s state is needed to unravel probable underlying mechanisms of ERI.

To date, most studies that assess the short-term effects of ERI are cross-sectional, merely providing a “snap-shot” of an individual’s state. The theory claims that ERI is associated with “emotional distress” and “sustained activation of the autonomic system” (Siegrist, 1996b), but it remains unclear what this means. Physiological measurements in the laboratory (Siegrist 1996a), have shown that ERI is associated with a decreased task elicited blood pressure reactivity. However, these laboratory findings are not necessarily true for everyday life, thus it’s ecological validity remains low. To increase the ecological validity of psychological and physiological data, ongoing measurements throughout the day have to be performed (Reich et al., 1988; Schwartz et al., 1996; Sloan et al., 1994; Stone & Shiffman, 1992 & 1994; Delespaul, 1995; van Eck, 1996 & van Eck et al., 1996; Hockey, 1997; Shaprio et al, 1997; Schwartz & Stone, 1998). The studies described in the current thesis are a further step in this direction.

To explore the short-term effects of ERI, information about an individual’s psychological and biological pattern throughout the day, associated with his or her perceived imbalance is needed. For instance, it is tested whether ERI is associated with an individual’s affective state (e.g. negative mood), increased actual demands at work, or physiological state (e.g. lower vagal tone, or disturbed hypothalamo-pituitary-adrenocortical (HPAC) axis reactivity). This information can be used to increase the psychological usability of ERI, for example by introducing precautions (e.g. prevention, intervention and counselling), to reduce the adverse effects of ERI. Thus, both from a scientific and therapeutic perspective it is useful to unravel what short-term (i.e. daily or within-day) psychological and physiological factors are associated with psychosocial risk factors.

In sum, the present thesis documents the daily effects of ERI by performing within-day psychological and physiological measurements at work. First, to set the stage for this research, the ERI theory supplemented with some psychological and psychological expansions is briefly presented in the remainder of this introduction. Second, an outline of the methodological aspects of the rather complicated within-day measurements is presented. Finally, a summary of the research hypotheses and a thesis outline are given.

1.2 The Effort-Reward Imbalance theory

The importance of individual and organisational factors (and their interaction) with respect to health and disease, has been elaborated in social exchange theories. Basically, this set of theories emphasises the importance of reciprocal relationships (Maus, 1925; Levi-Straus, 1969), feelings of fairness (Stouffer et al., 1949), social interdependence (Thibaut & Kelley, 1959) and equity (Adams, 1963) for the successful functioning and health. Social exchange theories offer an explanation for the prevalence of a situation (person-environment mismatch) that seems non-beneficial to the subject. These theories emphasise that it is the perception and evaluation of social exchange in relationships (i.e. between individual and organisation) that determine successful functioning and health. Inequitable situations lead to distress, which motivates individuals to restore equity (Walster et al., 1973). Individuals will strive to maximise their outcomes and minimise their inputs (Adams, 1965).

A specific social exchange theory, the '*effort-reward imbalance*' theory (Siegrist, 1996a), provides promising integrative modelling of relations between psychosocial characteristics of work and health outcomes. The ERI theory states that a person has a strong drive to achieve a high social status (i.e. self-regulation). If, for any reason, a person is not successful in achieving this status, a situation called "*social crisis*" arises (Siegrist, 1996a). The theory further states that this (social crisis) will lead to “emotional distress” and a “sustained activation of the autonomic system”, and eventually to cardiovascular disease. Imbalance will occur if the *effort* that is exerted during work does not correspond with the *reward* that is obtained. Restoration of the balance by minimising effort at work, is not an option because the potential risks (being laid off or facing downward mobility) outweigh the costs of accepting inadequate benefits. Determining the effects of its key constructs on immediate psychological and physiological processes throughout the day will test the short-term implications of ERI. Because testing these short-term implications was never a major focus of the theory, certain inclarities have to be resolved. For example, the theory does not clearly state what is meant by autonomic activation. In the present thesis a specific part of the autonomic nervous system was chosen to reflect autonomic activation, namely vagal control of the heart. This means that, where necessary, the theory is expanded, enabling the testing of its short-term effects.

In the effort-reward imbalance theory, three major constructs are distinguished: extrinsic effort, need for control and reward (see effort-reward imbalance questionnaire in the appendix). The term ‘extrinsic effort’ (or simply “effort”) refers to perceived working conditions, like working under a high time pressure, or frequently being interrupted during work. Reward refers to *status control* , *esteem reward*, and *monetary gratification* (Matschinger, et al., 1986). ‘Status control’, reflects the opportunity a person has to achieve, or have control over, a desired social status (promotion prospects, job security, status inconsistency). 'Esteem reward' reflects experienced respect and support during work, and 'monetary gratification' reflects the job salary relative to co-workers. "Need for control" refers to need for approval, competitiveness, disproportionate irritability and inability to withdraw from work. This construct is closely related to aspects of the type A behaviour pattern, (e.g. hostility and over commitment) which are linked to enhanced arousal in demanding situations. Subjects with a high 'need for control' also tend to misjudge (i.e. overestimate or underestimate) demanding situations, possibly leading to excessive efforts even in situations that seem non-beneficial to the subject.

1.3 Expansion of the effort-reward imbalance theory

The effort-reward imbalance theory hypothesises a relation between effort, reward, need for control on the one hand, and physiological (i.e. "*autonomic activation*") and psychological ("*emotional distress*") responses on the other hand. As is argued a.o. by Hockey (1997), an adequate assessment of the effects of environmental demands on an individual should include ongoing within-day measurements. To enable the testing of the above-mentioned hypothesis, some preceding specifications should be made. Both "autonomic activation" and "emotional distress" have to be defined more precisely, with special attention to the repeated within-day assessment.

Effort-reward imbalance, distress and psychobiological activation

Ever since first attempted by Cannon (1920) and Selye (1950), much has been learned about the physiological systems involved in an individual's response to "stress" or a chronically demanding environment. In their theories of psychosomatic specificity, Henry and Meehan (1981), Mason (1968) and Fisher (1993) describe a close relationship between behavioural and physiological responses in an individual. They also suggest that the specificity of disease is linked with protracted, differential patterns of behavioral and physiological responses. In general, two major axes of psychophysiological and behavioural responses are distinguished: an effort related sympathetic-adrenomedullary (SAM) axis, and a control related hypothalamo-pituitary-adrenocortical (HPAC) axis. Other authors have shown or proposed similar bio-behavioral relations. The SAM axis is mainly associated with effort and coping (Frankenhaeuser, 1979), whilst the HPAC axis is mainly associated with unsuccessful coping, and loss of control (Ursin, 1979). On the psychological level it is associated with helplessness and eventually depressive states. Each activation of the stress response leads to behavioural and peripheral changes that may be associated with emotion, cognitive function, behaviour, reproduction, growth and immunity (Chrousos & Gold, 1992) and sometimes to psychiatric, endocrine and inflammatory diseases.

At this point it should be emphasised that the definition of *effort* in the stress literature differs from the definition used in theories of energetics and human information processing (Gaillard & Wientjes, 1994). In the ERI-theory, effort reflects enduring perceptions of the demanding work environment and need for control. In contrast, theories of energetics and human information processing, (Pribram & McGuiness, 1975; Hockey, 1986), consider effort an emergent result of state-regulation, depletion of resources, activation or attentional processes. A sharp contrast between the two definitions is that in the latter, activation associated with increases in effort is not necessarily maladaptive.

In the present thesis, perceived effort is also measured throughout the day. This is referred to as *demand*, and reflects time pressure, physical demands and interruptions of work throughout the day. Gaillard & Wientjes (1994), refer to enduring work demands (e.g. effort and reward) as *input*. The short-term psychological and physiological responses are referred to as *output* (see table 1). Examples of short-term output variables are: vagal cardiac control, cortisol secretion, mood, demand and satisfaction. As is described above, effort can be defined as an input variable but also as an output variable. The former definition will be used throughout the remainder of this thesis. Input and output variables can lead to *processes* (e.g. autonomic activation and emotional distress), that may eventually result in *long-term* illness or disease (see table 1). Enduring traits (e.g. need for control, negative affect), can moderate the short-term and long-term effects of work stress.

Table 1. A categorisation of the psychological and physiological variables used in this thesis.

INPUT	**OUTPUT**		
Enduring factors and traits	**Short-term effects**	**processes**	**Long-term effects**
Single measurement of:	**Within-day measurement of:**		
Effort, reward, ERI	Vagal cardiac control	autonomic activation	Health functioning
	Cortisol secretion		
	Negative mood	emotional distress	Cardiovascular disease
	Positive mood		
	Demand		
	Satisfaction		
Moderating traits:	**Intervening concepts:**		
Need for control	Mental effort		
Negative affect			

These considerations can be applied to the physiological concomitants of effort-reward imbalance. Siegrist (1996b) implies that autonomic activation plays a role in the pathogenesis of cardiovascular diseases. To date, effort, reward and need for control have been associated with a decreased laboratory task elicited blood pressure reactivity (Siegrist, 1996a), but not yet with cardiovascular dynamics throughout an actual working day. Berntson and co-workers (1991, 1994 & 1997) discuss the complex mechanisms involved in “autonomic activation” (which they refer to as “cardiac autonomic control”). From these studies, it has become clear that is incorrect to refer to the activation of the autonomic nervous system as a generic process. The two systems involved in cardiac autonomic control: sympathetic and parasympathetic innervation of the heart can act independently, depending on the type of neural input. Other studies have shown the balance between these two systems to change as a result of environmental demands in everyday life (Sloan et al., 1994). A decrease in the power of the high frequency band of heart rate is an index of parasympathetic withdrawal (Berntson et al., 1997), and parasympathetic withdrawal has shown to increase as environmental demands increase (Sloan et al.,1994, Aasman et al., 1987). Therefore, in the present thesis, it is hypothesised that the perception of demands throughout the day will be associated with parasympathetic withdrawal. Low vagal control of heart rate has been shown to be related to coronary artery disease (Martin et al., 1987) cardiac events (Liao et al., 1997), and increased mortality (Kleiger et al., 1987), increasing its relevance for the study of the relation between stress and health.

Workers (chronically) experiencing a high level of imbalance are vulnerable to feelings of loss of control, or at least of control being threatened. Understandably, and as put forward by the effort reward imbalance theory, this goes together with negatively toned emotions. As has been mentioned, this psychological state has been associated with activation of the HPAC system, resulting in an increased cortisol output. Cortisol is an important hormone in the regulation of -a/o- metabolic demands, immune responses, and modulation of catecholaminergic activation of the cardiovascular system (Stratakis & Chrousos, 1995) as well as immune system function (Berk et al., 1997). As such, it is of potential vital importance in connecting work stress and ill health. Caplan (1979) demonstrated that chronic work stress may lead to higher cortisol levels (i.e. a slower decrease of cortisol throughout the day). Effort reward imbalance means chronic work stress, and can therefore also be expected to affect cortisol levels throughout the day. The same goes for negative and positive affect (Buchanan et al., 1999). Thus, a high effort-reward imbalance and / or negative affect is expected to be associated with a slower decrease in cortisol levels and /or elevated levels throughout the day.

1.4 Within-day measurements using Ecological Momentary Assessments (EMA) or the Experience Sampling Method (ESM)

To enable the assessment and analysis of ongoing (real life, ecologically valid) within-day psychological and physiological data, a specific method called “Ecological Momentary Assessment” (EMA) or “Experience Sampling Method” (ESM) was used. In the remainder of this thesis the term EMA will be used to refer to ongoing within-day measurements.

Recent technological and methodological advances in the fields of occupational psychology, behavioural medicine and psychobiological research (Stone & Shiffman, 1994; Delespaul, 1995; Berry, 1997) have enabled the adequate assessment and analysis of *ongoing psychological* and *physiological* processes, including the effects of *personal*, *environmental*, and *psychosocial* factors on these processes.

The EMA and ESM have been advocated by several authors as an ecologically valid and reliable method for collecting psychological and physiological data throughout the day (Csikszentmihalyi et al., 1977; Hormuth, 1986; Csikszentmihalyi & Larson, 1987; Delespaul, 1995; Lousberg et al., 1995; Stone, & Shiffman, 1994; Schwartz & Stone, 1998). In general, the method entails a self-report of a subject’s experiences, thoughts, feelings, activities or whereabouts throughout the day over several days. The self-reports are filled in after an electronic device (palmtop computer, paging device, watch etc.), prompts the subject at pre-selected but randomised intervals (time-sampling), or after an event (event-sampling). The self-reports can be coupled with physiological measurements (e.g. cortisol, blood pressure, heart rate etc.) to gain a more comprehensive view of an individual's psychophysiological state (Stone & Shiffman, 1994; van Eck, 1996).

Together with cross-sectional data, within-day measurements result in a database that may be characterised as typically multilevel. The variables in the database can be characterised according to the frequency of their measurements. In psychobiological research, the most frequently used levels correspond with "time of day", "days", "weeks", "months" etc., but can also refer to subject, group, cohort etc. In multilevel data, lower level variables are nested within higher level variables. For example, if data is collected several times a day over several days, the level "time of day" is nested within the level "day". To analyse multilevel data, several analysis techniques have been developed. The most elaborate of these is the multilevel analysis or "random coefficient model" (Bryk & Raudenbush, 1987; Hox 1994; Goldstein, 1995; Woodhouse et al., 1996; Berry, 1997).
As has been hypothesised earlier, variations in psychological and physiological variables throughout the day are not only influenced by cross-sectional "trait-like" factors or environmental factors but also by ongoing within-day factors. Effort, reward and need for control are usually measured as a trait by means of a questionnaire, implicitly assuming that this psychological characteristic is continuously and evenly present.

Consequently, the present research will include assessment of actual effort and reward measured throughout the day, referred to as "*demand*" and "*satisfaction*", respectively. The "states" of demand and satisfaction are not considered to be equivalent but are conceptually related, and to some extent represent the "traits" of effort and reward. Investigating the relation of demand and satisfaction to within day assessment of negative and positive mood and to actual physiological status is an important extension of the study of the assumed stress – health relations. It is argued (chapter 3) that "*demand*" and "*satisfaction*" measured throughout the day are associated with mood changes throughout the day. This is in accordance with a study performed by Reich (Reich et al., 1988), who showed that not only negative and positive mood but also demand and satisfaction are associated with demanding aspects of the environment. Furthermore, subjects have been shown to differ in their predisposition for negative mood states (Watson & Clark, 1984). However, the relationship between state variables (e.g. demand, satisfaction, and mood) and trait variables (e.g. effort, reward, and trait negative affect) are not well understood, neither are their effects on physiological status throughout the day. This has motivated the study of the combined effects of negative and positive affect (i.e. positive affect) as well as positive and negative mood on the dependant variables. In this thesis, it will also be argued that the constructs from the effort-reward imbalance model are associated with changes in cortisol levels (chapter 4) and heart rate variability throughout the day (chapter 5). In addition to this, the effects of well-known, possibly confounding variables such as sleep (Murawski & Crabbé, 1960; Campbell, 1992)) gender (Kirschbaum et al., 1992), smoking (van Eck, 1996a), food consumption (Follenius et al., 1982), time of day (Malliani et al., 1991), and workload (workday versus day-off; Caplan et al., 1979) will be accounted for.

1.5 Research aims

This thesis aims at thoroughly testing assumptions, based on the effort-reward imbalance theory (effort, reward and need for control), regarding the actual psychological and physiological concomitants of the main constructs described by this theory, rather than the long-term effects of cardiovascular disease. More specifically, the effects of effort, reward, and need for control on mood, cortisol levels and vagal control throughout the day are determined. Additionally, the effects of actual demand and satisfaction on the same dependent variables will be assessed. An ongoing multiple occasion sampling method (within-days, over several days), referred to as EMA is used to collect psychological and physiological data throughout the day. Finally, the implications of combining traditional cross-sectional assessment methods with more dynamic multiple occasion sampling, EMA, are discussed, leading to suggestions for future research.

In order to explore the short-term effects of effort-reward imbalance, a series of studies were performed. First, the ERI questionnaire was translated into Dutch. From a scientific point-of-view, merely translating the questionnaire is not enough. Its reliability and validity also should be established. To achieve this, a large subpopulation (n=775) of workers were asked to fill in the ERI questionnaire. The data served as input for a series of factor analyses to determine the questionnaires psychometric qualities. The first study was followed by three other studies, in a smaller subpopulation using intensive measurements. The goal of these studies was to determine the short-term effects of ERI. To achieve this, 77 subjects were equipped with ambulatory instruments (Kölner Vitaport-I system, Hewlett Packard 100 LX palm-top computers). Each of these studies focused on a different aspect. In the first one, focused on the relationships between single assessments of ERI and its within-day counterparts (demand and satisfaction). The other two focused on explaining within-day variations of cortisol and heart rate variability. In summary, to explore the short-term effects of effort-reward imbalance, the following main questions were asked: (each question is answered in the discussion).

1) Are the basic constructs of the effort-reward imbalance theory (effort, reward and need for control), adequately measured by the Dutch version of the effort-reward imbalance questionnaire?
2) (a) What is the relation between the basic constructs of the effort-reward imbalance theory and its within-day counterparts (demand and satisfaction)?
   (b) Which methodological approach should be used to analyse multiple occasion data (EMA)?
3) What are the effects of effort, reward, need for control and within-day measurements of demand, satisfaction and mood on autonomic nervous system vagal activity throughout the day?
4) What are the effects of effort, reward, need for control and within-day measurements of demand, satisfaction and mood on hypothalamo-pituitary-adrenocortical (HPAC) axis activity throughout the day?

1.5 Thesis outline

In the general introduction (**chapter 1**), support for the choice of the effort-reward imbalance theory as the starting point of this thesis is given. This is followed by a description of the modifications that allow a testing of the short-term implications of this theory. Usually effort-reward imbalance is determined by self-report: the effort-reward imbalance questionnaire. For the assessment in a Dutch population, a Dutch version of this questionnaire was developed, of which the psychometric qualities are described in **chapter 2**. In the following chapter (**chapter 3**) a method for determining the effects of cross-sectional estimates of effort, reward, and need for control on within-day measurements of demand, satisfaction, and mood is illustrated. The chapter justifies the use of within-day psychological measurements in combination with cross-sectional measurements. The next chapter (**chapter 4**) reports the effects of effort, reward and need for control as well as demand, satisfaction, and mood on heart rate variability throughout the day. This provides an insight in the psychological variables that may influence parasympathetic functioning throughout the day. **Chapter 5** focuses on the effects of effort, reward, and need for control as well as demand, satisfaction and mood on within-day measurements of cortisol (reflecting activity of the hypothalamo-pituitary-adrenocortical axis). The final chapter (**chapter 6**) discusses the results of the various studies.

Chapter 2

The validity and reliability of the Dutch Effort-Reward Imbalance Questionnaire

Abstract

The reliability and validity of the Effort-Reward Imbalance Questionnaire was tested in a population of 775 blue and white collar workers in the Netherlands. Half of the population was used for test-construction, whilst the other half was used for test-validation. Cronbach's alpha revealed sufficient internal consistency of all subscales except 'need for control'. By performing exploratory probabilistic scaling (Mokken) analysis, the psychometric qualities of 'need for control' was improved. Using confirmatory factor analysis (CFA), the factorial validity of the 'extrinsic effort' and 'reward' subscales was confirmed. A model with three separate dimensions for reward (i.e. status control, esteem reward and monetary gratification) proved adequate, emphasizing the importance of distinguishing subscales. The congruent validity of the scales was assessed by testing whether all factors loaded on the same second order factor. Congruent validity was confirmed, as well as a hypothesized relationship with an external construct: 'health functioning' (MOS SF-20).

Introduction

The impact of the work environment on (mental) health and well-being has been amply demonstrated (e.g. Hackman & Oldham, 1980; Kahn, 1981; Warr, 1987,1994; Cooper & Payne, 1991; Sauter, Hurrell & Cooper,1989; Karasek & Theorell, 1990; Parkes, 1994; Marmot, 1994; Schnall, Landsbergis & Becker, 1994; Kasl, 1996). Contemporary theories about the adverse effects of the work environment are strongly influenced by three theoretical approaches: the *Social Exchange* theory (Homans, 1961; Adams, 1963), the *Person-Environment Fit* approach (French & Kahn, 1962; French, Caplan & Harrison, 1982; Caplan & Jones, 1975) and the *Demand-Control* approach of Karasek (1979). More recently, the *Effort-Reward Imbalance* theory (Siegrist, 1996a) has been developed, concerning the relationship between the work environment and employee health. The researcher who wants to study the effects of this theory is confronted with the problem of how to measure effort-reward imbalance. Siegrist (1996b) uses both subjective and more objective methods to measure imbalance. Subjective methods (i.e. perceptions assessed by paper and pencil), have been associated with risk of coronary heart disease (Bosma et al., 1998), but also with health functioning (Stansfeld et al., 1998). Based on these encouraging reports, and on the fact that perceptual measures have many advantages (e.g. replication of results in different studies) (see also Zapf et al., 1996) we also chose for this assessment method. In the present paper, the reliability and validity of a questionnaire to assess ‘extrinsic effort’, ‘reward’ and ‘need for control’ (three central constructs in the Effort-Reward Imbalance theory) is investigated. These analyses will increase the psychometric quality of the effort-reward imbalance questionnaire, hence adding to the confidence in this measure. First, as a background for this study, the theory of Effort-Reward Imbalance is introduced.

As mentioned, one of the most influential approaches of organisational stress is the *Person-Environment Fit* approach (French & Kahn, 1962). This approach assumes that a discrepancy between environmental demands and an individuals’ capabilities may lead to mental and physical stress reactions (Lazarus, 1991; Frankenhaeuser, 1979). However, the approach has two main shortcomings: Firstly, it does not specify exactly which of the several objective and subjective aspects of the environment are responsible for the mental and physical stress reactions. Secondly, the approach does not explain why a subject does not adapt to the work environment, when a person-environment misfit is experienced.

The first shortcoming has been addressed by Karasek (1979; Karasek & Theorell, 1990) in the *Demand-Control* approach. Karasek states that a comprehensive analysis of the work environment entails two important elements of work: 1) *Job Demands* or workload and 2) *Decision Latitude* or control over objective task characteristics. According to the approach, stress reactions (distress, sickness absence, depression etc.) and associated physiological states (like increased blood pressure etc.) are caused by an interaction between high job demands and poor decision latitude (Marmot & Theorell, 1988). Since the introduction of the Demand-Control model, it has been extensively tested, and has proven to predict cardiovascular disease (Schnall et al., 1994) in particular. However, the approach has not remained entirely free of critique: First, it focuses on job demands as being the most relevant stress component, underestimating the role played by sociological factors. Second, it does not take individual differences (as buffers or enhancers of the stressor-strain relation) into account.

Social exchange theories (like the *effort-reward* imbalance theory) offer an explanation for the prevalence of a situation (person-environment mismatch) that seems non-beneficial to the subject. These theories emphasize that it is the perception and evaluation of social exchange in relationships (i.e. between individual and organization) that determine successful functioning and health. Inequitable situations lead to distress, which motivates individuals to restore equity (Walster et al., 1973). It is assumed that individuals will strive to maximize their outcomes and minimize their inputs (Adams, 1965). Having a certain personality, (e.g. Type A) may add to this tendency.

One of the most likely places for Effort-Reward Imbalance to occur is in the work environment. Perceived imbalance will occur if the *extrinsic effort* (i.e. time pressure, increasing demands, responsibility) that is spent during work does not correspond with the *reward* that is obtained. As a result, the employee feels that his or her social status is threatened, leading to emotional distress, changes in physiological (re)activity, and eventually to cardiovascular disease. The term ‘extrinsic effort’ refers to the perceived working conditions. For instance, an employee may have the impression that (s)he always works under a high time pressure because of a high workload, or that he or she is frequently interrupted during work.
According to the Effort-Reward Imbalance theory, three types of ‘reward’ are distinguished: 1) *status control* , 2) *esteem reward*, and 3) *monetary gratification* (Matschinger, Siegrist, Siegrist & Dittman, 1986). ‘Status control’, refers to the opportunity a person has to achieve, or have control over, a desired social status (promotion prospects, job security, status inconsistency). In contrast to control in the demand-control approach, status control reflects the influence of fragmented job careers, of job instability, redundancy, and forced occupational downward mobility. Under these conditions, concerns about, or even the benefits of task control may be overridden. ‘Esteem reward’ refers to experienced respect and support during work, and ‘monetary gratification’ refers to the job salary relative to coworkers.

In addition, a construct was introduced to describe the persistence of a situation (person-environment mismatch) that seems non-beneficial to the subject: *need for control* (which consists of need for approval, competitiveness, disproportionate irritability and inability to withdraw from work). This construct is closely related to aspects of the type A behavior pattern, (e.g. hostility) which are linked to enhanced arousal in demanding situations. Subjects with a high ‘need for control’ also tend to misjudge (i.e. overestimate or underestimate) demanding situations. Both enhanced arousal and misjudging the situation are considered instrumental in eliciting excessive efforts (even in situations that seem non-beneficial to the subject). ‘Need for control’ may therefore be considered as a generalized coping strategy, instrumental in eliciting excessive efforts that may last for considerable lengths of time and probably linked with activation of the autonomic nervous system. Research shows that the significance of the relation between of Effort-Reward Imbalance and cardiovascular disease is increased (after controlling for traditional risk factor such as age, body mass index, blood pressure and low density lipoprotein-cholesterol), if individuals respond to the situation with a high ‘need for control’ (Siegrist & Peter, 1994).

The aim of the present study is to assess and if necessary improve the reliability and validity of the Effort-Reward Imbalance Questionnaire. This is achieved by examining the reliability, factorial validity, congruent validity and content validity of ‘extrinsic effort’, ‘reward’ and ‘need for control’ in a Dutch population. Reliability was determined by assessing the internal consistency (i.e. by calculating reliability coefficients or Cronbach’s alpha) for each of the subscales of the questionnaire. Factorial validity was determined by testing whether the items loaded on the factors described in the theory using a first order confirmatory factor analysis. Congruent validity is tested by assessing the fit of a model in which all effort-reward imbalance subscales load on the same second order factor (or latent variable). Finally, content validity was assessed by determining it’s relationship with an external reference: “health functioning”.

“Health functioning” was measured using a questionnaire (the MOS SF-20) that covers three dimensions of health: social, mental and physical (Veit & Ware, 1983). The MOS is the most widely used self-report measure of functioning (Stansfeld et al., 1998), originally developed to assess the outcomes of medical care, and has been found to be a reliable and valid instrument in population studies (Ware, 1990). Basically, it is hypothesized that the scales measuring ‘extrinsic effort’ and ‘need for control’ as well as the latent variable ‘reward’ could be distinguished from the subscales that measure mere self reported health. Therefore, a model is tested in which no covariance between these (sub)scales is allowed. However, in the literature, it has been established that ‘work stress’ was associated with negative health outcomes (Stansfeld et al., 1998). Therefore, a second model was tested in which covariance was allowed between the second order factors ‘work stress’ and ‘health functioning’, but not between the first order factors (extrinsic effort, status control, esteem reward, and need for control on the one hand, with physical functioning, role functioning, social functioning, mental health, health perceptions and pain on the other). Before the MOS SF-20 was used as an external reference, it’s congruent validity was determined.

Method

Subjects

In the present study 775 employees (mean age = 43; sd = 6.62) from four companies returned questionnaires that addressed work and health related issues. The sample consisted of both blue and white collar workers from different work settings: software specialists (60%), national railway personnel (25%), health professionals (9%) and office clerks (6%). Eighty-two percent of the participants were male and 18% female.

Procedure

Before statistical analyses were carried out, the sample was divided into two equally sized subsamples: test-construction (n=367) and validation (n=369). These subsamples were matched according to age, sex, educational background and company. Statistical analyses were performed in two steps. In the first step, the test-construction subsample was used to assess construct validation and to eventually develop new (sub)scales using exploratory statistical techniques. In the second step, the validation subsample was used to confirm the psychometric properties of the (sub)scales previously constructed.

Measures

The German "Effort-Reward Imbalance Questionnaire" ("Zentrale Fragen für die Erfassung von Gratifikationskrisen am Arbeidsplatz" by Siegrist and co-workers) was used to measure the employees "Effort-Reward Imbalance". This 47-item questionnaire was translated into Dutch and the adequacy of the translation checked by a Dutch-German bilingual social scientist. Additionally, the questionnaire was translated back into German by an independent professional translator. Differences that arose after the back-translation into German were compared to the original version and the questionnaire was adapted accordingly.

The questionnaire measures three main constructs: *extrinsic effort*, *reward* and *need for control*. ‘Extrinsic effort’ was measured by six items that refer to demanding aspects of the work environment (e.g. “I have constant time pressure due to a heavy work load”). If the subjects answered the question affirmatively they were then asked to rate the severity of this ranging from *not at all distressed* (1 point) to *very distressed* (4 points). A negative answer to the question (indicating the absence of ‘effort’, or that the question was out of order) also scored 1 point. ‘Reward’ was measured by twelve items that form two subscales: ‘esteem reward’ (5 items, e.g. “I receive the respect I deserve from my colleagues”), and ‘status control’ (6 items, e.g. “My promotion prospects are poor”). The last item is referred to as ‘monetary gratification’ (1 item: “Considering all my efforts and achievements, my salary / income is adequate”). The reward items were scored in the same way as the ‘extrinsic effort’ items, so that a minimum score of 1 point and a maximum score of 4 points per item could be obtained.

The ‘need for control’ scale consists of 29 dichotomous items (disagree = 0 points, agree = 1 point) that form four subscales: ‘need for approval’ (6 items, e.g. “I only feel successful when I perform better than I expected”), ‘competitiveness’ (6 items, e.g. “I don’t let others do my work”), ‘disproportionate irritability’ (8 items, e.g. “Even the slightest interruption bothers me”) and ‘inability to withdraw from work’ (9 items, e.g. “Work is usually still on my mind when I go to bed”). The internal consistency of the original (German) version of the ‘reward’ subscales (‘esteem reward’ and ‘status control’) and ‘need for control’ scale are considered satisfactory (see Siegrist & Peter, 1994; Matschinger et al., 1986; Dittmann & Matschinger, 1982). The same goes for the Dutch translation of the effort, reward and revised need for control (sub)scales (see table 1).

Health functioning was measured by administering the Dutch version (Kempen, 1992a) of the 20-item Medical Outcomes Survey Short Form or MOS SF-20 questionnaire (Stewart et al, 1988) in a subsample consisting of railway personnel, health professionals and office clerks (n = 226). The items of the MOS SF-20 provide information about health functioning and quality of life, clustered in 6 dimensions: physical functioning (6 items, e.g. “The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?"), role functioning (2 items, e.g. “During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?”), social functioning (1 item: During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?”), mental health (5 items, e.g. “Have you felt calm and peaceful”?) health perceptions (5 items, e.g. “In general would you say your health is…”) and pain (1 item: “How much bodily pain have you had during the past 4 weeks”?). Scores were transformed into a 100-point scale, higher scores reflecting better functioning except for the pain dimension in which a higher score means more perceived pain. The internal consistency of all subscales of the Dutch MOS SF-20 is satisfactory (Cronbach’s alpha > 0.80 for each subscale) (Kempen, 1992a and 1992b; Moorer & Suurmeijer, 1993; Kempen, Brilman & Ormel, 1993). Kempen (Kempen et al., 1993) has shown the subscales of the MOS SF-20 to be externally valid, by correlating them with external criteria. A high positive correlation (r =

0.78) was found between the MOS SF-20 subscale ‘mental health’ and ‘positive well-being’ (Well-being Scale; Veit & Ware, 1983), as well as with ‘positive affect’ (r = 0.42, Affect Balance Scale; Bradburn, 1969). Additionally, he also found a positive correlation (r = 0.71) between the MOS SF-20 subscale ‘physical functioning’ and ‘movement restriction’ (Kempen et al., 1993).

Data analysis

In the present study, tests of reliability and validity were performed. To enable comparison of data across scales and subscales, identical methods were used to assess reliability and validity. Reliability (internal consistency) was determined by calculating Cronbach’s α. According to criteria proposed by Nunnaly (1978) an α higher than 0.70 indicates satisfactory internal consistency.

Validity was determined by performing confirmatory factor analyses (CFA) on the subsamples using EQS[i]. To indicate the fit of the (sub)scales to the data, a number of the most common ‘goodness-of-fit’ indices were calculated: the Bentler-Bonnet nonnormed fit index (NFI; Bentler & Bonnet, 1980; Tucker & Lewis, 1973), the comparative fit index (CFI; Bentler, 1990), the LISREL AGFI and the root mean squared residual (RMSR). The Satorra-Bentler scaled chi-square (S-B χ^2 Satorra & Bentler, 1988) and the corrected CFI (CFI*)[ii] were also calculated because a number of kurtotic items were detected. These latter two indices correct distributional abnormality. A fit of over 0.90 for CFI and NFI is considered adequate (Byrne, 1994).

As was described in the procedure, statistical analyses were performed on a test-construction and a validation subsample. In the test-construction subsample, the fit of the most plausible model based on theoretical considerations was tested (confirmatory analysis) and if necessary improved (exploratory analysis). Improvement was achieved by using the Lagrange Multiplier test, which determines whether the specification of certain parameters would lead to a better model in a subsequent EQS run. The goodness-of-fit of the optimal model was then tested in the second population (validation subsample). The model was accepted if the fit in the second subsample was adequate. The achievement of fit in the second model minimised the chance that the fit acquired in the first model (after re-specifications) was due to a capitalisation on chance factors.

For one of the scales (need for control) a revised procedure was used. Because the items of the ‘need for control’ subscales are dichotomous, the revised scale was constructed according to principles of the probabilistic test theory. An example of a statistical test based on the probabilistic test theory[iii] is the Mokken analysis (Mokken, 1971; Niemöller, Schuur & Stokman, 1980), which can be used to evaluate existing scales or to construct new ones. The psychometric qualities of the scale are determined by calculating a goodness-of-fit or scalability coefficient (H) and a reliability coefficient (rho). This coefficient can be used to evaluate a set of items thought to be a scale and/or for constructing a scale from a given pool of items. Mokken and Lewis (1982) propose the following criteria for scalability: H < .30 = no scale; 30 = H <40 = weak scale; 40 = H <.50 = medium scale; H = .50 = strong scale. The scalability of whole scales (H) as well as separate items (H(i)) can be judged by this criterion and a reliability coefficient (rho) can be calculated for a set of items. Values over .70 indicate a reliable scale (Niemöller et al., 1980). The Mokken analysis was carried out using a software program called MSP (Debets & Brouwer, 1989; Sijtsma, Debets & Molenaar, 1990).

Results

Reliability and mean values

As can be seen in table 1, all scales had a Cronbach's α of 0.70 or higher, except the original subscales of 'need for control' (see table 1). Therefore, we decided to construct a revised 'need for control' scale, using a Mokken analysis.

Construction of revised need for control

The results of the Mokken analysis are reported in table 2. Three out of the four subscales had low scalabilities, and only one reliable subscale (inability to withdraw from obligations) was found. The total scale (sum of all the items) may be considered reliable (rho = 0.84), but it has a low scalability (H=0.21). These results confirm the findings of the tests for internal consistency.

Table 1. Descriptive statistics and alpha coefficients for the Effort-Reward Imbalance Questionnaire (original and revised subscales: n=775) and MOS SF-20 subscales (n=226).

(Sub)scale	n items	M	S.D.	α
Extrinsic effort	6	10.9	3.0	0.71
Reward				
Status control	6	19.9	3.6	0.70
Esteem reward	5	17.5	3.1	0.77
Monetary Gratification	1	3.6	0.8	-
Need for control (Intrinsic effort)				
Need for approval	6	3.5	1.4	0.43
Competitiveness	6	1.5	1.5	0.59
Time pressure	8	2.8	1.7	0.54
Inability to withdraw from obligations	9	3.4	2.3	0.68
Total scale (Need for control)	29	10.5	5.4	0.82
Revised need for control	9	2.4	2.5	0.81
Health measures				
MOS SF-20				
Physical functioning	6	73.7	27.9	0.76
Role functioning	2	66.7	43.2	0.81
Social functioning	1	62.0	26.8	-
Mental health	5	70.1	20.6	0.88
Health perceptions	5	71.6	19.3	0.78
Pain	1	32.6	32.5	-

Table 2. Scalability (H) and reliability (rho) of the four original need for control subscales and a total scale score, as is provided by the Mokken test-procedure (test-construction subsample (n=367)).

subscale	(H)	rho
Need for approval (NFA)	0.12	0.39
Competitiveness (COM)	0.31	0.66
Disproportionate irritability (DI)	0.22	0.58
Inability to withdraw from obligations (IWO)	0.28	0.73
Total scale “need for control”	0.21	0.84

The analysis was continued by conducting an explorative procedure to find subscales with acceptable scalabilities and reliabilities. The following criteria were applied to the scales and separate items: H(i) = 0.30; H = 0.40; n items = 3; rho =0.70. This procedure lead to the construction of only one scale (see table 3) with a scalability (H) of 0.45 and a reliability (rho) of 0.84. The quality of this scale was then confirmed by using the validation subsample within which both scalability and reliability were still above the proposed criteria (H = 0.40 and rho = 0.81). Cronbach's $\underline{\alpha}$ calculated over the entire population was 0.81, also indicating a satisfactory internal consistency. For the revised (9 items) version of the scale, we find a Cronbach's $\underline{\alpha}$ of .81 which is slightly lower than the Cronbach's $\underline{\alpha}$ of the 29 item version (.84). This difference is quite acceptable, because based on the Spearman-Brown formula, a reduction from 29 to 9 items should decrease the alpha by .22. We only found a .03 reduction. Thus, the practicality of the scale has been improved at minimal loss of information and reliability.

Table 3. The item numbers, mean scores and scalability (H(i)) of the separate items of the revised *need for control* scale (test-construction subsample (n=367)).

Item	scale	Content	Mean(i	H(i)
3	DI	Even the slightest interruption bothers me	**0.13**	**0.46**
14	DI	I can get furious if someone doesn’t understand me the first time	**0.15**	**0.38**
12	COM	I don’t let others do my work	**0.18**	**0.36**
17	NFA	I only feel successful when I perform better than I expected	**0.26**	**0.38**
29	IWO	If I put off doing something that needs to get done today, I’ll have trouble sleeping at night	**0.27**	**0.39**
24	IWO	Work is usually still on my mind when I go to bed	**0.30**	**0.47**
10	IWO	I start thinking about problems as soon as I get up in the morning	**0.39**	**0.43**
15	IWO	When I get home, I can easily relax and forget all about work	**0.40**	**0.39**
16	IWO	People close to me say I sacrifice too much for my job	**0.41**	**0.40**

DI = Disproportionate Irritability, COM = Competitiveness, NFA = Need for Approval, IWO = Inability to withdraw from obligations.

Factorial validity of extrinsic effort, reward and need for control

The factorial validity was assessed by performing a first order confirmatory factor analysis on the test-construction subsample using EQS[iv]. The fit of the following models was tested (see figure 1 and table 4):

Extrinsic effort: It was tested whether the six items of extrinsic effort all loaded on a single latent variable. This model (M1) achieved acceptable fit (CFI^* = .95), and fitted the data better than the null model ($\Delta\chi^2 < 0.001$).

Reward: The fit of three models was tested: A model (M2) in which all items loaded on a single latent variable, and as hypothesised by Siegrist, a model (M3) with two latent variables: ‘status control’ and ‘esteem reward’ and a third dimension (single item): ‘monetary gratification’. Covariance was allowed between the three dimensions, and a model (M3a) in which three error terms were allowed to correlate. The items that were allowed correlated errors were: item 12: (from the ‘status control’ subscale (“Do you experience or expect an undesirable change in your job situation?), item 13 (from the ‘status control’ subscale: “Has job redundancy recently affected your work colleagues”) and item 14 (also from the ‘status control’ subscale: “Is your own job security poor”). M3a had the best fit (CFI* = .97), and was significantly better than M2 ($\Delta\chi^2 < 0.001$).
Need for control: This model (M4) reflects the nine items of the revised[v] scale ‘need for control’ loading on the same first order latent variable. The model achieved acceptable fit (CFI* = 0.92) after 2 pairs of error terms (E3,E12 and E14,E17, see table 3 for respective items) were allowed to correlate (M4a), and was significantly better than the null model ($\Delta\chi^2 < 0.001$).

Models M1, M3 and M4 were also tested in the test validation subsample. Again, the fit of models M3 and M4 was improved by allowing correlated errors (M3a and M4a). The Lagrange Multiplier test revealed that the same correlated errors should be allowed for M3a (reward) but not for M4a (need for control). The test of model 4a in the test validation subsample achieved adequate fit after three error terms (E24,E10; E24,E15 and E10,E15, see table 3) were allowed to correlate. These items refer to the inability to withdraw from obligations, in contrast to the items of the correlated errors in model 4a.

Summarising, the high values of the ‘goodness-of-fit’ indices, demonstrate adequate factorial validity for ‘extrinsic effort’, ‘reward’ and ‘need for control’. For ‘reward’ and ‘need for control’, fit was reached after allowing correlated errors indicating common variance between the items not reflected by the latent factor. The Lagrange Multiplier test in the validation subsample reveals the same correlated errors for ‘reward’ (M3a) but not for ‘need for control’ (M4a). The results increase the confidence in the error intercorrelations for reward (M3a), but not for revised need for control (M4a).

Table 4. Comparison of factorial models representing extrinsic effort, reward and need for control (see figure 1).

Model	χ^2	*df*	$\Delta\chi^2$	NFI	CFI	AGFI	RMSR	S-B χ^2	CFI*
Test-construction subsample (n=367)									
M0: Null model extrinsic effort	327.85	15	-	-	-	-	-	273.34	-
M1: extrinsic effort (1 latent variable)	26.86	9	<0.001	0.91	0.94	0.94	0.026	21.05	0.95
M0: Null model reward	1095.19	66	-	-	-	-	-	625.90	-
M2: reward (1 latent variable)	440.60	54	<0.001	0.54	0.62	0.75	0.151	281.74	0.59
M3: reward (3 separate factors)	182.11	52	<0.001	0.84	0.87	0.88	0.060	125.37	0.87
M3a: reward with correlated errors	98.45	49	<0.001	0.94	0.95	0.93	0.034	67.53	0.97
M0: Null model need for control	909.69	36	-	-	-	-	-	714.70	-
M4: need for control (1 latent variable)	163.58	27	<0.001	0.79	0.84	0.81	0.013	133.89	0.84
M4a: with correlated errors	96.58	25	<0.001	0.88	0.92	0.89	0.012	82.32	0.92
Validation subsample (n=369)									
M0: Null model extrinsic effort	464.38	15	-	-	-	-	-	343.16	-
M1: extrinsic effort (1 latent variable)	23.83	9	<0.001	0.95	.97	0.95	0.022	20.53	0.97
M0: Null model reward	1385.93	66	-	-	-	-	-	775.65	-
M3: reward (3 separate factors)	336.26	52	<0.001	0.87	0.89	0.88	0.088	267.98	0.81
M3a: reward with correlated errors	130.64	49	<0.001	0.92	0.94	0.91	0.051	91.32	0.94
M0: Null model need for control	841.41	36	-	-	-	-	-	638.17	-
M4: need for control (1 latent variable)	203.21	27	<0.001	0.71	0.78	0.76	0.017	154.45	0.79
M4a: with correlated errors	76.92	24	<0.001	0.90	0.93	0.92	0.015	61.77	0.94

M0 is in each case a test of the null model, **M1** tests the factorial validity of extrinsic effort. **M2** tests the factorial validity of reward, in which all items load on a single factor. **M3** tests the factorial validity of reward with three separate foctors (covariance is allowed between the factors). **M3a** is the same as M3 with correlated errors. **M4** tests the factorial validity of need for control. **M4a** is the same as M4 with correlated errors.
For all χ^2, p < 0.001. The significant change in χ^2 of each new model is tested against the preceding model (sign. $\Delta\chi^2$).

<u>Congruent validity</u>

Congruent validity was tested progressively by CFA in the test-construction subsample: First, a model (M1) was tested in which ‘extrinsic effort’, ‘need for control’, ‘status control’, ‘esteem reward’ and ‘monetary gratification’ formed independent dimensions. The error correlations were derived from previous analyses (see table 4). Second, in M2 all first order factors were allowed to load on a single second order factor that can be conceived as “work stress” (see figure 1). M2a included three new correlations between error terms[vi]. Each new model was expected to have a better fit than the preceding model. For instance, the final model (M2a) was expected to have the best fit, followed by (M2) etc. The goodness-of-fit estimates are shown in table 5. As anticipated the chi-square statistic of the null-model (M0) was very high indicating excessive malfit. The fit of the second model (M1) improved significantly, as indicated by ($\Delta\chi^2$). However, only the fit of M2a was adequate. The final model (M2a) also had an adequate fit in the validation subsample, hence confirming congruent validity (table 5). The Lagrange Multiplier test in the validation subsample reveals the same correlated errors for ‘reward’ (M2a), increasing the confidence in the error intercorrelations.

Table 5. Determining the congruent validity of effort, reward and revised need for control (sub)scales, by performing a second order CFA using the test-construction and validation subsamples (see figure 2).

Model **effort, reward & need for control**	χ^2	*df*	sign $\Delta\chi^2$	NFI	CFI	AGFI	RMSR	S-B χ^2	CFI*
test-construction subsample (n=367)									
M0: Null model	2700.84	351	-	-	-	-	-	2136.3	-
M1: 5 factor CFA	902.94	319	<0.001	0.73	0.75	0.79	0.09	743.62	0.76
M2: 5 1st order factors and 1 2nd order factor	604.73	315	<0.001	0.86	0.88	0.86	0.03	504.86	0.89
M2a (with 3 correlated errors)	558.83	312	<0.001	0.88	0.90	0.86	0.03	467.92	0.91
validation subsample (n=369)									
M0: Null model	2960.61	351	-	-	-	-	-	2314.0	-
M2: 5 1st order factors and 1 2nd order factor	619.42	315	<0.001	0.73	0.75	0.79	0.09	743.62	0.90
M2a (with 3 correlated errors)	321.47	312	<0.001	0.89	0.90	0.88	0.06	237.46	0.91

M0 is in each case a test of the null model. **M1** is a test of the independence of extrinsic effort, status control, esteem reward, monetary gratification and revised need for control (5 factor model). The 5 factors are not allowed to load on each other. **M2** In this model the factors in M1 load on a second order factor. **M2a** is the same as M2, except three error terms were allowed to correlate.
The significant change in χ^2 for each new model is tested against the preceding model (sign. $\Delta\chi^2$). For all χ^2, $p < 0.001$.

Summarizing, the model with the best fit was the model in which the effort, reward and need for control subscales were allowed to load on a single second order factor (work stress), confirming congruence.

In the introduction of this paper it was mentioned that subjectively experienced health was measured in addition to ‘extrinsic effort’, ‘reward’ and ‘need for control’. Subjectively experienced health was used as a second order factor in the final analysis of this paper. Before that final model was tested, an assessment, performed in 3 steps (table 6), was made to determine the factor structure of subjectively experienced health. First, the null-model (M0) was tested. Then, convergence of all factors on one second order factor was assessed (M1). This model obtained an adequate fit after re-specification of the errors[vii] (M1a). All six subscales load on the same second order factor ‘health’, indicating congruent validity (table 6).

Table 6. Determining the congruent validity of the MOS SF-20 subscales by performing a second order CFA on a sub-population that also filled out this questionnaire (n=226).

Model	Chi^2	*df*	sign $\Delta\chi^2$	NFI	CFI	AGFI	RMSR	S-B χ^2	CFI^*
health (MOS SF-20)									
M0: Null model	2073.86	190	-	-	-	-	-	1806.30	-
M1: 2nd order CFA	432.86	166	<0.001	0.84	0.86	0.78	0.09	405.13	0.85
M1a	348.91	164	<0.001	0.89	0.90	0.82	0.09	326.21	0.90

M0 is a test of the null model. **M1** is a test for *one* underlying latent variable (second order CFA model). **M1a** is the same as M1, but it also allows covariance between a number of error terms.
The significant change in Chi-square of each new model is tested against the preceding model (sign. $\Delta\chi^2$). For all χ^2, $p < 0.001$.

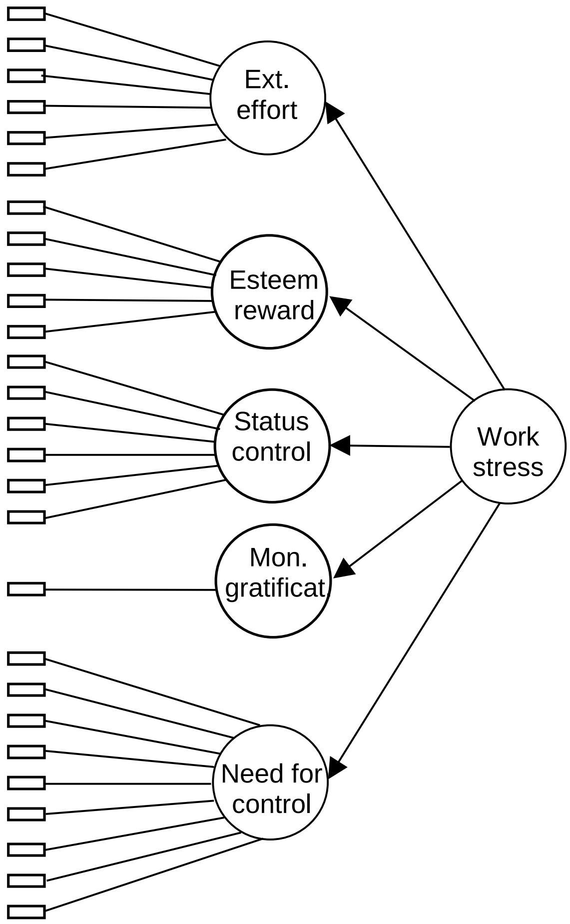


Figure 1. Representation of the model used to test the fit of a model in which extrinsic effort, esteem reward, status control, monetary gratification, and need for control load on the second order factor work stress (see M2 in table 5). Error terms are not shown in the figure. Ext. = extrinitic; Mon. gratificat = monetary gratification.

<u>Content validity</u>

To determine content validity, the (Pearson's -r) intercorrelations between the subscales of the Effort-Reward Imbalance Questionnaire was calculated. The results are given in table 7, and show moderate to high intercorrelations for 'extrinsic effort', 'status control', and 'esteem reward', indicating some overlap (in content) between these scales and subscales. 'Need for control' had a low correlation with the other subscales, which suggests hardly any overlap with the other (sub)scales.

Nearly all subscales of the MOS SF-20 are significantly intercorrelated, except for the correlation between physical functioning and mental health and between mental health and pain. Therefore it can be concluded that most of the MOS SF-20 subscales are conceptually related.

The correlations between the Effort-Reward Imbalance (sub)scales and those of the MOS SF-20 varied between -0.40 and +0.27, indicating a weak to moderate overlap between a number of the subscales (table 7). This is in accordance to what may be theoretically expected. ‘Extrinsic effort’, ‘reward’ and ‘need for control’ and subjectively experienced health were distinguishable, but not totally independent constructs. More specifically, a high ‘extrinsic effort’ was associated with a lower well-being and in general a high ‘reward’ was related to higher well-being.
The original ‘need for control’ subscales and the revised scale were both positively correlated with social functioning and negatively with ‘physical functioning’, ‘mental health’ and ‘health perceptions’. Both the original and revised ‘need for control’ (sub)scales correlated highly positive with each other (r = 0.90).

Table 7. Correlation matrix (Pearson's -r) of the ERI and MOS SF-20 subscales (n=226).

	EE	SC	ER	MG	NfC	R-NfC	PF	RF	SF	MH	HP	P
EE												
SC	-0.36*											
ER	-0.39*	0.56*										
MG	-0.20*	0.39*	0.39*									
NfC	0.10	0.01	-0.12*	-0.04								
R-NfC	0.13*	-0.01	-0.13*	-0.05	0.90*							
PF	-0.15*	0.04	0.10	0.10	-0.39*	-0.40*						
RF	-0.14*	0.10	0.08	-0.05	0.06	0.07	0.51*					
SF	-0.14*	0.16*	0.14*	-0.03	0.20*	0.18*	0.38*	0.53*				
MH	-0.20*	0.24*	0.27*	0.00	-0.14*	-0.13*	0.08	0.21*	0.44*			
HP	-0.27*	0.27	0.24*	0.08	-0.02	-0.06	0.34*	0.22*	0.31*	0.38*		
P	0.15*	0.00	-0.11	-0.03	0.04	0.04	-0.58*	-0.45*	-0.32*	-0.08	-0.35*	

EE = Extrinsic Effort, SC = Status Control, ER = Esteem Reward, MG = Monetary Gratification, NfC = need for control, R-NfC = revised need for control, PF = Physical Functioning, RF = Role Functioning, SF = Social Functioning, MH = Mental Health, HP = Health Perceptions, P = Pain. 2-tailed significance; * = $p < 0.05$

The Pearson's -r correlations show that 'extrinsic effort', 'reward' and 'need for control' are not totally independent.

Finally, the tests of congruent validity were concluded by assessing the fit of two models: 1) a model (M1) with two second order factors 'work stress' and 'health functioning' and no covariance between the two second order factors, and 2) the same as M1 but allowing for covariance between the second order factors (table 8).

The first model did not adequately fit the data. The second model (M2, see figure 2) in which covariance between the second order factors was allowed, shows an improvement in fit (p = 0.039). However the model does not fit the data (goodness of fit indices are below 0.90). Due to the absence of sufficient theoretical support (as to which factors are allowed to cross-load) it did not seem appropriate to re-specify the second model to obtain a better fit. The fit of a model that allows covariance between the second order factors but no covariance between the first order factors was not confirmed, indicating that both instruments were not totally independent.

Table 8. Determining (content) validity by performing a confirmatory factor analysis on effort, reward and revised need for control as well as health functioning (MOS SF-20) (n=226).

Model	χ^2	*df*	sign $\Delta\chi^2$	NFI	CFI	AGFI	RMSR	S-B χ^2	CFI*
effort-reward and health									
M0: Null model	5361.03	1081	-	-	-	-	-	4717.12	-
M1: 2nd order CFA independent	1820.81	1019	<0.001	0.80	0.81	0.71	0.08	1646.03	0.83
M2: 2nd order CFA dependent	1816.56	1018	0.039	0.80	0.81	0.71	0.08	1642.81	0.83

M0 is a test of the null model. **M1** is a model with *two* second order factors ('work stress' and 'health'). No covariance is allowed between the factors of the Effort-Reward Imbalance Questionnaire (extrinsic effort, status control, esteem reward, monetary gratification and need for control) and the MOS SF-20 (physical functioning, role functioning, social functioning, mental health, health perceptions and pain). There is no covariance between the latent factors. Error correlations are the same as in previous models. **M2** is the same as M1, only covariance is allowed between the second order factors. The factors of the Effort-Reward Imbalance Questionnaire and the MOS SF-20 are not allowed to cross-load. For all χ^2, $p < 0.001$.

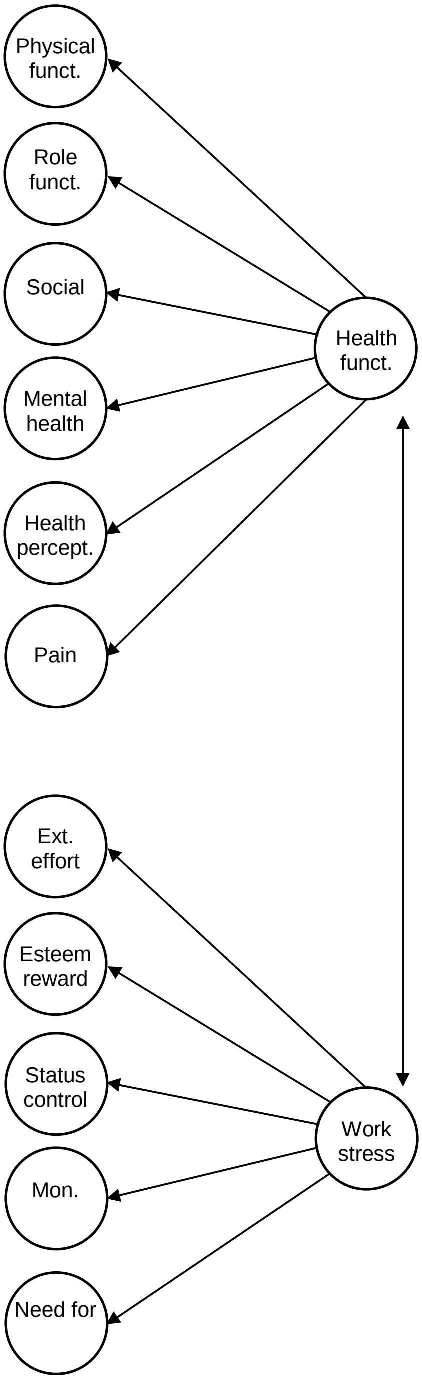


Figure 2. Representation of the model used to determine content validity. Covariance is allowed between the second order factors health functioning and work stress (see M2 in table 8).

On the whole, the effort-reward imbalance questionnaire as well as the MOS SF-20 form coherent clusters as is indicated by congruence (congruent validity, table 5 and 6). A model that tested the independence of the effort-reward imbalance as well as the MOS SF-20 factors, although allowing for covariance between the second order factors, did not fit the data (see table 8). This indicates that more covariance between the factors (other than between the second order factors) is probable.

Discussion

In this paper the reliability, factorial validity, congruent validity and content validity of the Effort-Reward Imbalance Questionnaire was assessed. In accordance with the theory, ‘extrinsic effort’ as well as ‘reward’ (‘status control’, ‘esteem reward’ and ‘monetary gratification’) were both factorially valid (table 4). Yet, a slight weakness was found amongst the items of the ‘status control’ subscale. More specifically, structural equation modelling revealed three items of this scale to have correlated errors. This means that the items have a shared communality that is absent in the factor they load on. Remarkably, the items with shared error variance all refer to job insecurity (e.g. “Do you experience or expect an undesirable change in your work situation?”), whilst the factor they are supposed to load on (‘status control’) entails more than just job security. The importance of these intercorrelations were supported by the test in the validation subsample: The same intercorrelations between error terms improved the fit of the model, which was otherwise inadequate. Therefore, in future studies, it might be fruitful to consider job security as a separate factor of job demands, particularly because future job insecurity has shown to be a major stressor (Hartley et al., 1991).

The original ‘need for control’ subscales revealed low reliabilities and scalabilities. Considering the low reliabilities found in the study reported by Matschinger et al., (1986), these results are not totally surprising. Thus, we concluded that these subscales of ‘need for control’ should not be used in further analyses. Consequently, a revised ‘need for control’ scale was constructed using a Mokken test-procedure for dichotomous items. A single scale with an acceptable reliability and scalability was identified. To enable comparisons with the other scales of the effort reward imbalance scales, a CFA was also performed on the revised ‘need for control’ scale. An acceptable fit was achieved after some error terms were allowed to correlated. The validation subsample revealed other correlated errors than the test-construction subsample. This reduces the confidence in the contribution of these items to the construct ‘need for control’. Future studies should reassess the factor structure of revised ‘need for control’ to increase the confidence in this scale.

The content (or external) validity of ‘need for control’ (e.g. using more objective measures) also has to be determined in future research. Both the 29 item and the revised (9-item) scale for ‘need for control’ are strongly associated with subjectively experienced health. To date, only the 29 item scale has been tested in a longitudinal study to predict future cardiovascular disease. Although we expect the revised scale also to be associated with cardiovascular disease, this link should also be empirically verified. To achieve this, a longitudinal design is needed and until then, no definitive conclusions about external validity can be drawn. In statistical terms it has been determined that the revised ‘need for control’ scale is a one-dimensional construct. We may also conclude that the scale measures the same construct as the original scale, because both have comparable correlations with other variables (table 7) as well as a high intercorrelation. However, the revised subscale has better psychometric characteristics, and is therefore to be preferred. It is strongly recommended that future studies should apply a Mokken analysis to determine the reliability of the dichotomous items, as presented in this paper. This analysis method is superior to other more traditional techniques using Cronbach’s alpha (see the “data analysis” section of the method).

Our assessment of congruent validity and content validity allow a few conclusions. The fit of a model in which the effort-reward imbalance subscales load on one common factor is adequate, indicating congruence (table 6). The results also show that 'reward' and 'extrinsic effort' are slightly correlated (albeit negatively), suggesting that 'extrinsic effort' and 'reward' may have some communality (table 5). A model (see table 8), in which the effort-reward imbalance and MOS SF-20 subscales were only allowed second order covariance did not fit the data. Therefore, we concluded that covariance between the factors should be allowed, if the model were to fit. This suggests that the (sub)scales of the Effort-Reward Imbalance Questionnaire are interrelated and a closer look at the formulation of the items may partly explain this overlap. The subjects were asked to rate 'how distressing' certain effortful and rewarding aspects of their work were, and because in both cases a 'distress' rating was given, it seems plausible that 'effort' and 'reward' do have something in common. It could be argued that what is actually measured is the amount of 'distress' caused by 'effort' and 'reward' rather than perceived 'effort' and 'reward' during work. Future research should focus on this conceptual overlap and also try to identify exactly which dimensions of the model are related with health functioning. Efforts should be made to reformulate the items, avoiding the conceptual overlap with distress. Items should be constructed so that they are less susceptible to individual variation. In this respect, Frese and Zapf (1988) propose formulating items using indices of frequency rather than reflecting subjective feelings. For example, in the present study, subjects had to reply to the effort item "I have constant time pressure due to heavy workload" on a severity scale ranging from "not at all distress" to "very distressed". Instead of rating their perceived level of distress, they could rate how often they experienced time pressure (e.g. everyday, once a week, once a month etc.).

A drawback of the present study is that the content validity of the Effort-Reward Imbalance instrument is best tested by more objective measures like biomedical events (e.g. myocardial infarct and other vascular incidents), physiological changes (autonomic activation) and performance data (measurement of work output etc.), and not solely by psychometric analyses as is the case here. Theoretically, a high 'extrinsic effort' and 'need for control' as well as a low 'reward' should be associated with negative emotions and with an activation of the autonomic nervous system. Although this requires intensive measurement techniques, any future attempts to investigate the construct validity should include them. Because the construction of the revised 'need for control' scale is based solely on psychometric analyses, determining it's relation with external criteria (such as negative emotions and physiological state) might increase the acceptance of the scale. Moreover, this will increase the validity of the scale both nationally and internationally. In spite of these remarks we may conclude that 'effort' and 'reward' are constructs that measure extrinsic factors in the work environment, such as interruptions and disturbances during work, viz. 'reward' (salary, job prospects etc.). Socio-emotional and motivational aspects that determine 'need for control' are also part of the global effor-reward imbalance construct, and measure intrinsic factors. These extrinsic and intrinsic aspects of the work environment have been shown to determine persistence under environmental demands and may also determine an individual's perception of health complaints (Watson & Pennebaker, 1989).

In sum, the following recommendations can be given to increase the instrument's practical use in future studies: a) Job security should be reflected as a separate dimension in future adaptations of the questionnaire. b) The need for control scale has been shortened. Its reliability should be assessed by performing a Mokken analysis. Its predictive validity for cardiovascular disease should be determined in a longitudinal study. c) The items of the effort and reward subscales should be rephrased, in order to decrease the variability caused by differences in subjective perceptions between subjects. Rather than asking subjective rating of work experiences, the items should reflect more quantifiable aspects of the work environment.

Considering the constitution of the population of the present study, it seems reasonable to conclude that Effort-Reward Imbalance is not solely restricted to blue-collar workers, but also to white-collar workers and occupations in the service sector, as has been seen in several international studies using the effort-reward imbalance questionnaire (Peter & Siegrist, 1997; Siegrist et al., 1990; Siegrist et al., 1997). The Dutch translation of the Effort-Reward Imbalance Questionnaire therefore, seems an adequate self-report measure to assess the level of imbalance due to the work environment. Additionally, it may even prove to be relevant for an explanation of self reported health and well being. For example, Stansfeld et al. (1998) have shown aspects of effort and reward at work to be related to health functioning. However, their method to determine effort and reward was not standardised, making a replication of their results difficult. We expect an application of the effort-reward imbalance questionnaire to solve the problems of comparability between studies, and other methodological issues (Zapf et al., 1996). Finally, given it's predictive power for objective health measures, the effort-reward imbalance questionnaire seems a promising instrument for future use in this field.

Footnotes

[i] EQS is statistical software for structural equation modelling (Bentler, 1989)

[ii] Corrected Comparative Fit Index (CFI*) based on Satorra-Bentler χ^2 fit for the null model
= 1- max[(χ^2_0 - df_0), 0] max[(χ^2_k -df_k) , (χ^2_0 -df_0), 0] where df_0 = degrees of freedom for the null model, df_k = degrees of freedom for the hypothesised model, χ^2_0 = chi-square for the null model and χ^2_k = chi-square for the hypothesised model (Hu & Bentler, 1995).

[iii] This model can be viewed as a probabilistic version of GUTTMAN scales analysis for dichotomous items or as a nonparametric approach to item response theory. Another example of an item response model (although parametric) is the Rasch model (Rasch, 1960), often used for the scaling of questionnaires with dichotomous items.

[iv] EQS is statistical software for structural equation modelling (Bentler, 1989)

[v] The factor structure of revised need for control was already been tested by means of Mokken analysis. For reasons of comparability with the other scales, a CFA was also performed.

[vi] The errors that were allowed shared variance belong to items 9 and 10 (from the ‘esteem reward’ subscale), items 4 (from the ‘extrinsic effort’ subscale) and 6 (from the ‘need for control’ scale), and items 5 and 2 (from the ‘extrinsic effort’ subscale).

[vii] The error of items 12 and 10 (mental health) and of items 20 and 13 (social functioning and mental health) were allowed to correlate.

Chapter 3

The short-term effects of Effort, Reward and Affect on related within-day variables: A multilevel analysis of EMA data

Abstract

The main goal of the present study was to justify the use of frequent ongoing within-day measurements of work stress and affect. Cross-sectional assessments of effort, reward, negative affect and positive well being were performed in addition to repeated within-day measurements of demand, satisfaction, negative mood and positive mood. Three levels of data were distinguished: the subject, day and within-day levels. The data was collected according to the principles of Ecological Momentary Assessments (EMA), and analysed using a “random coefficient model” or multilevel analysis.

The results show a significant amount of variance at three levels. Calculating the percentages of variance shows that demand and satisfaction had most variance at the within-day level, rendering these variables more situation-dependent. Negative mood had most variance at the day level indicating large differences on negative mood scores between days of the week. Positive mood had most variance at the subject level, indicating that affect may be relatively more subject and less situation dependent. Further analysis of the data revealed that being at work was associated with higher demand, satisfaction and positive mood. Higher demands and lower positive moods were reported on workdays in comparison to a day-off. The results also show the hypothesised communality between cross-sectionally measured effort, reward, negative affect and positive well-being and repeated assessments of demand, satisfaction, negative mood and positive mood, respectively.

It is discussed that establishing the number of levels is an important first step in analysing EMA data, and therefore should always be performed. Without including relevant levels, unwanted bias may be introduced. It is also demonstrated how multilevel analysis can be used (1) to identify more subject-dependent or more situation-dependent variables, (2) to account for time of day, day of week, workday and being at work, and (3) to determine the communality between related constructs. The analyses help to understand the dynamics of within-day, daily, and between subject variations in psychological variables (work stress and affect). The present paper illustrates how such multiple-occasion data may be collected and analysed, and therefore contributes to this growing field of behavioral medicine.

INTRODUCTION

A considerable amount of studies have shown that health problems can be caused by psychosocial stress (Holmes & Rahe, 1967; Dohrenwend & Dohrenwend, 1974; Henry & Stephens, 1977; Glass, 1977; Fisher, 1993) and by work stress (French & Kahn, 1962; Karasek, 1979; Marmot & Theorell, 1988; Kasl 1991, 1996; Marmot, 1994; Theorell & Karasek, 1996; Siegrist, 1996a; Bosma et al., 1998). In a search for the underlying mechanisms of the relationship, it has been established that health problems are associated with frequently assessed minor, daily stressors (Kanner, et al., 1981; Delongis et al., 1988; Zautra et al., 1988; Reich et al., 1988) and emotional or affective responses to stress (Watson & Clark, 1984; van Eck et al., 1998). The latter two types of variables are also related, and are considered precursors of negative health (Bolger et al., 1989). Such within-day measurements provide information not obtainable from single measurements derived from the application of questionnaires or interviews (Wagner, 1990; Stone & Neale, 1982; Stone & Shiffman, 1994; Hockey, 1997; Berry, 1997).

As is indicated above, there is an increasing interest in the literature to perform multiple within-day measurements of psychological and physiological variables. The main argument for performing these measurements is to obtain information about a subject's actual environment (real-life), increasing the ecological validity of the measurements. Although there is some empirical evidence that data aggregation may be a satisfactory for specific research questions (Pruessner et al., 1997). It has also been argued that a different analysis method should be used that takes full advantage of the richness of the data (Jaccard & Wan, 1993; Schwartz & Stone, 1998). An example of such a method is multilevel analysis (Bock, 1983) also referred to as random coefficient model (Bryk & Raudenbusch, 1992; Goldstein, 1995). The main goal of the present paper is to justify the use of frequent ongoing within-day measurements for the analysis of ambulatory data. This is done in a working population by measuring work stress and affect. A number of issues not adequately addressed in multilevel studies so far, will also be addressed. The present study will first describe a method that can be used to perform ongoing within-day measurements. Then the theory of work stress used here is introduced. Finally three issues not always adequately addressed in the literature a described: (1) establishing the number of levels, (2) determining the distribution of variance across the levels, and (3) determining communality between related constructs.

The most elaborate technique for collecting multiple-occasion data has been named *Experience Sampling Method* (ESM) (Csikszentmihalyi et al., 1977; Hormuth, 1986; Csikszentmihalyi & Larson, 1987; Delespaul, 1995; Lousberg et al., 1995) or *Ecological Momentary Assessment* (EMA) (Stone & Shiffman, 1994). These methods generally entail a self-report of a subject's experiences throughout the day for several days. Usually, the subject has to answer questions after being prompted by an electronic device (palmtop computer, paging device, watch etc.) at pre-selected but randomised intervals (time-sampling), or after an event (event-sampling). The most common questions are about the subject's location, activities, thoughts, mood and perceived stress. In addition to this, psychobiological variables (e.g. cortisol, blood pressure and heart rate) may also be measured. To date, ESM and EMA are used in a wide range of studies, see Delespaul (1995), and Stone and Shiffman (1994) for extensive reviews.

As was mentioned above, understanding the within-day dynamics of work stress and affect may help clarify the assumed complex relationship between stress, affect and health. The Effort-Reward Imbalance (ERI) theory (Siegrist, 1996a) provides a model for enduring work stress, resulting from low reward considering the demanded efforts. The work stress theory states that conditions of high effort and low reward induce adverse emotional consequences. However, psychological (and physiological) state variables have not yet been specified by the effort-reward imbalance theory. In the present study, within day assessments of demand, satisfaction, were used to measure effort and reward throughout the day, at work and at home. It can be argued that perceived demand and satisfaction throughout the day represent the situation dependent or state-like counterparts of effort and reward, respectively. Using demand and satisfaction in daily life to reflect stressful aspects of the environment was also performed by Reich and co-workers (Reich & Zautra, 1983; Reich et al., 1988). These authors refer to demand and satisfaction as “environment initiated” (i.e. situation dependent), and vary strongly throughout the day (Taub & Berger, 1974; Watts et al., 1983), and between days (Rossi & Rossi, 1977; Stone et al., 1985). In other words, to accept demand and satisfaction as valid state representations of effort and reward, we expect a large within-day and daily variance, and some overlap with related variables at the subject level.

Furthermore, as the ERI theory states that a high imbalance will cause psychological distress, we may expect that this will be reflected in negative and positive mood as measured during the day (see also Reich et al, 1988). Negative mood should also be predicted by the trait negative affect (van Eck, 1996), whilst within-day measurements of positive mood should be related to positive well-being (Reich et al., 1988). Reich et al., argue that emotional responses (e.g. desires) are “self-initiated” (i.e. subject dependent) and vary less across multiple measurements. Finally, Egloff (Egloff et al., 1995) have shown negative mood to peak during the week and positive mood to peak during weekends. This effect was attributed to the absence of unwanted events and situations during weekends. These authors distinguished two components of positive mood: an activation and a pleasantness component. The activation component of positive mood peaked in the afternoon, whilst the pleasantness component peaked in the evening. Considering the above, it is hypothesised that the day of the week but also time of day, may have a significant effect on these within-day and daily measurements of mood. The mood variables are therefore expected to be situation dependent.

As was mentioned in the beginning of this introduction, analysing EMA data means addressing some specific issues. The first issue, establishing the number of levels in the data, is common to all studies using ongoing within-day measurements (Hedeker et al., 1994). If data is collected from a number of subjects throughout the day over several days, three ‘levels’ of analysis are distinguished. The levels are: the *subject* level, referring to data collected only once (questionnaires), the *day* level, referring to data collected over several days, and the *within-day* level, referring to frequent measurements within days. The repeated within-day measurement is the dependent variable. If there is not enough variance in the dependent variable at a specific level, it makes no sense distinguishing it as a separate level. For example, little or no variance at the day level means that there are (very little or) no differences between days. On the contrary, if there is enough variance at a particular level, it needs to be distinguished as a separate level. If not, as has been done is some studies (Hedeker et al., 1996; van Eck et al., 1996; Smyth et al., 1998) certain information may remain covered.

Including all levels increases the value of the results because the characteristics of the data set are adequately accounted for. For example, it is probable that the self-reports made by the same subject at two adjacent moments are similar (dependency). In a multilevel analysis, such dependency within subjects (or days) is accounted for. This reduces the risk of Type I error (i.e. bias toward rejecting the null hypothesis) (Schwartz & Stone, 1998). Distinguishing all hypothesised levels enables determining at which level (i.e. subject, day or within-days) an effect occurs, when explanatory variables were introduced. Omitting a specific level means that it will remain uncertain where a particular effect lies.

A second related issue is to determine how the variance is distributed across the levels. This issue refers to the characteristics of a dependent variable. If most variance is at the subject level, explaining variance at this level indicates differences between subjects, suggesting more stable characteristics for that variable. Variance at the other two levels indicates differences between days or within days, suggesting less subject dependent and more situation dependent characteristics.

A third issue is the introduction of independent (explanatory) variables. By including explanatory variables to the analysis, variance at each level can be explained. Of specific interest could be determining the communality between variables that are related at a conceptual level (e.g. single (cross-sectional) assessments of work stress and affect versus their within-day counterparts). Although the higher level variable should explain variance of the dependent variable (expressing communality), variance at the lowest level remains unexplained. This would justify the use of within-day measurements in addition to single (cross-sectional) measurements of the same construct.

In conclusion, the following hypotheses will be answered:

1) The variance of the repeatedly measured dependent variables demand, satisfaction, negative and positive mood is distributed over three levels: the subject, day and within-day levels; each level accounting for a significant proportion of the total variance.
2) The variables demand, satisfaction, negative mood and positive mood are situational dependent.
3) The variables demand, satisfaction, negative mood and positive mood are affected by time of the day.

4) The variables demand, satisfaction, negative mood and positive mood are affected by workdays, being at work, and day of the week.
5) Effort, reward, negative affect and positive well-being are related to demand, satisfaction, negative mood and positive mood respectively.

METHOD

Subjects

Seventy-seven subjects agreed to participate in the present study. Thirty-six of which were health professionals (mean age = 39.8, s.d = 4.7; 20 male, 16 female) and 41 were office clerks (mean age = 32.9, s.d. = 9.8; 23 male, 18 female).

Instruments

Diary measurements of demand, satisfaction, negative mood, positive mood, time of day and presence at work

Within-day measurements of demand, satisfaction and mood were carried out according to the ESM or EMA (Csiksentmihalyi & Larson, 1987; Van Eck, 1996; Delespaul, 1995; Stone & Shiffman, 1994; Smyth et al., 1998), using a diary. The diary questions were presented to the subjects via a palm-top computer (HP-100 LX) that beeped at semi-random intervals throughout the day over several day. The diary contained three questions about the perceived demands (e.g. *"Since the last beep I was interrupted a lot": yes / no*). An affirmative answer scored 1 point and denial scored 0 points. If they answered the question affirmatively, the subjects were then asked to rate how distressing this was on a scale running from 0-3 (*"Not at all distressed"* scored 0 points and *"very distressed"* scored 3 points). A score for a single item was obtained by adding the scale score (0-3) to the score obtained by answering the first question. Per question a maximum of 4 points and a minimum of 0 points could be obtained. The scores for the total demand scale were obtained by summing the answers of the three items together with the scores on the yes/no items, leading to a minimum of 0 points and a maximum of 12. To enable comparison with the mood scales, the demand scores were multiplied by 2, making the ranges of the scales equal (range = 24).
The ESM diary contained two questions that referred to perceived satisfaction (e.g. *"Since the last beep my actions have been rewarding": yes / no*). Scores were obtained the same way as was done for the demand scale. The scores for the total satisfaction scale were obtained by adding the answers of the two items together, leading to a minimum of 0 points and a maximum of 8. To enable comparison with the mood scales, the demand scores were multiplied by 3, making the ranges of the scales equal (range = 24).

Negative and positive mood (e.g.*" I feel happy"*) were also obtained using a numerical scale (ranging from 1 *"not at all"* to 7 *"very much"*). The subjects were asked to rate their mood using eight mood adjectives. Four for negative mood and four for positive mood. Thus the minimum score for each mood scale was 4 and the maximum score was 28 (range = 24). The items used to rate negative mood are: sad, angry, unhappy and worried. Positive mood was rated using the items: happy, playful, energetic and pleased.

Negative mood, positive mood, demand and satisfaction are referred to as variables measured at the within-day level. A specific variable also observed at the within-day level is "time of day". When each state variable was measured, the time of day was also recorded. The first assessment was after 8.00 a.m. and the last beep was not later than

10.30 p.m. By including a separate question in the diary, it was also determined whether subjects were at work (code = 0) or not at work (code = 1).

Diary measurements of workday and type of day

The diary measurements continued over several days, possibly leading to different scores each day, and between workdays and days off. . The variable 'day' is considered a separate level in the analysis. Within the day level, both workdays (vs. day-off) and days of the week were distinguished as separate variables. These variables were transformed into dummy variables (0=workday, 1=day-off; days of week: 1= Monday, Tuesday etc., 0=Sunday). In most cases Saturday and Sunday were days off, although a few health professionals did have to work on one of these days. Weekdays were also usually working days, although occasionally a few subjects took a day-off during the week.

Questionnaire assessments of Effort and reward.

A subjects' perception of effort and reward was measured using the 47-item Dutch Effort-Reward Imbalance Questionnaire (Hanson et al., 1999). Effort was measured by six items that refer to demanding aspects of the work environment (e.g. "I have constant time pressure due to a heavy work load"). If the subjects answered the question affirmatively they were then asked to rate the severity of this ranging from *not at all distressed* (1 point) to *very distressed* (4 points). No affirming the question (indicating the absence of 'effort', or that the question was out of order) also scored 1 point. The score of the effort scale was determined by summing the scores of the separate items (min. score=6 max. score=24). Reward was measured by twelve items that form two subscales: 'esteem reward' (5 items, e.g. "I receive the respect I deserve from my colleagues"), and 'status control' (6 items, e.g. "My promotion prospects are poor"). The last item is referred to as 'monetary gratification' (1 item: "Considering all my efforts and achievements, my salary / income is adequate"). The reward items were scored in the same way as the effort items, so that a minimum score of 1 point and a maximum score of 4 points per item could be obtained. The score of the reward scale was determined by summing the scores of the separate items (min. score=12 max. score=48). A psychometric analysis performed on the scales revealed a good internal consistency (Cronbach's alpha > 0.70, see Hanson et al., 1999).

Questionnaire assessments of negative affect and positive well-being

Negative affect was measured using a Dutch translation of the (22 item) well-being questionnaire (Bradley & Lewis, 1990). The negative affect scale consisted of 7 statements (e.g. "*I have crying spells or feel like it*"). Subjects indicated the extent to which the statements applied to them (0=never applies, 3=always applies). The range of the subscale was 21. A psychometric analysis performed on the scale revealed a satisfactory validity and reliability (Cronbach's alpha = .86) for the negative affect scale (Doosje & Godaert, 1994). The positive well-being scale consisted of 6 statements (e.g. "*I have the kind of life I wanted*"). Subjects indicated the extent to which the statements applied to them (0=never applies, 3=always applies). The range of the scale was 18. Positive well-being, also had a high alpha (Cronbach's alpha = .83) indicating a good reliability.

Procedure

On the day before the measurements started, subjects were asked to fill out questionnaires in order to measure effort, reward, positive well-being and negative affectivity. After this, the use of the portable diaries (implemented in a palm top computer, see Sorbi et al., 1996) was explained. The diary was used to collect ratings of perceived demand, satisfaction, positive and negative mood throughout the day.

The diary of the office clerks enabled 10 variable ratings per day, and the diary of the health professionals enabled 6 ratings per day. After the one-week assessment period, the devices were returned to the investigator. In both groups, diary measurements started at 8.00 a.m. and continued till 10.30 p.m. (see within-day measurements). At the end of all measurements subjects were debriefed in order to determine any confounding factors during measurement.

Some precautions were taken to assure subject compliance:

Device reactivity- In order to reduce non-compliance mainly caused by the device used to collect data (device reactivity), a palm-top computer was used to prompt the subjects. The EMA-questions were presented on the screen of the palm-top computer, and subjects typed their responses into the computer. Palm-top computers are becoming quite popular and these devices are specifically designed as portable instruments. Most subjects were familiar with the device, and were not reluctant (or over-concerned) to carry it around or to use it. The maximal number of beeps that could be generated in a seven day period is 4382 ((41 subjects * 10 beeps * 7 days) + (36 subjects * 6 beeps *7 days)).

Stereotypical responses- The tendency to give stereotypical responses was reduced by alternating positively and negatively formulated questions and by varying the fonts and spacing between the fonts (see Sorbi et al., 1996; Delespaul, 1995; Hedges et al., 1990; Stone et al., 1991). The cursor also appeared at random locations on the screen when subjects had to respond by typing in a number on a numerical scale. For example, when subjects had to rate their mood on a scale from 1 - 7, the cursor did not always appear at the left of the screen (on number 1). It was randomly allocated to one of the scores on the screen after each mood items was presented. This strategy forces subjects to think a bit longer about the desired answer, because moving the cursor required conscious information processing. This is expected to reduce the risk of stereotypical answers, more likely to occur if subjects merely press the buttons on the palm-top computer automatically in response to the questions. Subjects were also prompted at unexpected random intervals in order to prevent anticipation of their answers.

Situational selectivity- A ‘fail-safe’ was built into the palm-top computer to avoid subjects skipping questions at inconvenient moments. For instance, if the subjects did not respond the first time, the palm-top computer prompted them again after 15 minutes. This was expected to decrease the number of missing values. Subjects were also given a certain amount of control over the device. If they really did not want to be prompted at a certain moment, they could make the computer skip a beep (sampling moment). This could only be done once a day, and the reason for skipping beeps was checked during an interview (debriefing). Giving subjects this possibility, they could avoid distress at unwanted moments. Therefore, by giving the subjects more control, it was expected to be more likely that the subjects took the device with them everywhere they went, and thus avoiding unwanted situational selectivity. Finally, all items that were asked were short and unambiguously formulated, which is expected to reduce the time required to fill out the questionnaire. This too was expected to improve compliance (Sorbi et al., 1996).

Statistical analysis

Data analysis was performed as follows. First, a model was tested in which no explanatory variables were entered. Only the variance of the dependent variables was determined (see table 1). From this model the amount of variance (percentages) at each level could be determined, as well as the differences between the dependent variables. Second, the effect of time of day on demand, satisfaction, negative mood and positive mood was assessed (table 2). It was also tested whether the effect of time differed between days and between subjects (this is referred to as testing the 'random effects' of a certain variable). Thus, it was tested if the effects of time of day (within-day level) differed between days (day level) and between subjects (subject level). Third, explanatory variables at the day and subject levels were introduced (table 3). Non-significant variables were dropped from the models. Finally, in table 4 some descriptive statistics are provided to allow comparisons with more familiar data (mean, standard error of mean and correlations).

All estimates of the regression coefficients were obtained using the program MLn (Woodhouse et al., 1996). The significance of the fixed effects was determined by dividing the estimate by its standard error, and the significance of the covariances and variances were determined by the likelihood ratio test (Bryk & Raudenbusch, 1992).

RESULTS

Distribution of variance over the levels

The distribution of the variance of demand, satisfaction, negative mood and positive mood, over three levels (subject, day and beep levels) was determined (see table 1). The analysis justifies the distinction of three levels of analysis.

Situation dependency and subject dependency

The relative percentages indicate the amount of variance that can be explained at each level. For demand and satisfaction most variance was at the beep level (44.1 % and 54.9 % respectively), indication relatively more situation dependency. For negative mood most variance was at the day level (38.5%), but nearly as much variance was at the subject level (37.0%). For positive mood, most variance was at the subject level (46.7 %), indicating relatively more subject dependency in comparison to demand and satisfaction.

Table 1. The variance of demand, satisfaction, negative and positive mood at the subject, day and within-day levels.

Fixed Effects	**Demand** var (percentage)	**Satisfaction** var (percentage)	**Negative mood** var (percentage)	**Positive mood** var (percentage)
Subject level	3.80 (33.8 %)	2.30 (31.0 %)	5.12 (37.0 %)	11.72 (46.7 %)
Day level	2.48 (22.1 %)	1.05 (14.1 %)	5.33 (38.5 %)	7.97 (31.7 %)
Within-day level	4.97 (44.1 %)	4.09 (54.9 %)	3.40 (24.5 %)	5.43 (21.6 %)

n cases = 2816, 77 subjects. Values within parenthesis indicate percentages (%) relative to total variance for each dependent variable.

Time of day effects

To determine the effects of time of day on demand, satisfaction, negative mood and positive mood, four time variables were calculated: time, $time^2$, $time^3$, and $time^4$. $Time^4$ had no significant effect on any dependent variable, and no significant random effects were found for any time variable. No other higher order time variable was calculated. The results show that time of day has significant effects on demand and satisfaction, but not on negative or positive mood (see table 2 and figures 1 & 2). In both figures the observed values for demand and satisfaction slowly increased till about 17.00 in the afternoon, and then declined again towards the evening. The demand values decreased sharply in the evening (when subjects were usually not at work) to a value lower than in the morning.

Table 2. The effect of time of day on demand, satisfaction, negative and positive mood.

Fixed Effects	**Demand** var (s.e.)	**Satisfaction** var (s.e.)	**Negative mood** var (s.e.)	**Positive mood** var (s.e.)
Intercept	1.50 (0.21)*	21.21 (0.28)*	6.51 (0.08)*	18.67 (0.12)*
Time	0.31 (0.05)*	0.64 (0.16)*		
$Time^2$		-0.08 (0.03)*		
$Time^3$	-0.002 (0.0002)*	0.002 (0.001)*		
Random effects	var	var	var	var
Subject level				
Var (intercept)	3.29	2.16	5.12	11.72
Day level				
Var (intercept)	2.68	1.07	5.33	7.97
Within-day level				
Var (intercept)	4.83	4.09	3.40	5.43

Model 1: Tests the fixed and random time effects on demand, satisfaction, negative and positive mood. For all *: $p<0.05$ (n cases = 2816, 77 subjects). Non-significant effects were removed from the models. Values within parenthesis indicate standard errors (s.e.). Significance is reached if variances are larger than s.e. multiplied by 2.

The effects of workdays, being at work and weekdays

The results show (table 3) that not being at work, decreases the perception of demand, satisfaction, negative mood and positive mood. On days off work, demands were higher and positive mood lower.

The results also that in comparison to Sundays, subjects experienced higher demand and satisfaction, there were no differences in negative mood, and positive mood was lower.

Explanatory effects of effort, reward, negative affect and positive well-being after controlling for workday and day of week

The results illustrate the effects of explanatory variables on demand, satisfaction, negative mood and positive mood (see table 3). Effort, reward, negative affect and positive well-being are positively related to demand, satisfaction, negative mood and positive mood respectively. The data also show that negative mood is positively related to effort and negatively to reward. Positive mood is inversely related to negative affect, and satisfaction is positively associated with positive well-being and negative affect. The decrease in variance (in percentages of the variance in the first model, see table 1) after including all explanatory variables, is shown at the bottom of table 3 (explained variance).

The explanatory variables introduced in table 3 largely decrease variance at the subject level for demand and satisfaction. The within-day variables used in the present study hardly explain any variance at the within-day level for demand (2.7 %) and satisfaction (0%). Most variance of negative mood is explained at the day level, whilst most variance of positive mood is explained at the subject level. Interestingly, the within-day variables explain a considerable amount of variance for negative mood (14.3%) and positive mood (11.8%). Thus, although the first model (table 1) showed that the mood variables may be characterised as rather stable (or subject dependent) some variance throughout the day could be explained. This does not hold for demand and satisfaction. Using the present explanatory variables, rather little variance is explained within the days for these variables.

Descriptive statistics

To increase the comprehensibility of the data some descriptive statistical analyses have been performed: mean, standard error mean (S.E. Mean) and correlations (see table 4). The results show positive correlations for effort, reward, negative affect and positive well-being with demand, satisfaction, negative and positive mood respectively. This analysis also supports the last hypothesis in the introduction. Mean and standard error means were calculated for each beep within the day, but aggregated over individuals and days. Due to technical problems and because some subjects did not complete the seven day program, a total 3969 beeps were generated 3623 of which were answered (compliance rate = 91,3%).

The means and standard error mean calculated within-days for demand, satisfaction, negative mood and positive mood are given in figures 1-3. As could be expected based on the results of the multilevel analysis, the mood variables showed hardly any variation thought the day, in contrast to demand and satisfaction. These figures illustrate the effects of time on day.

Table 3. The effect of explanatory variables on, satisfaction, negative and positive mood, respectively.

Fixed Effects	**Demand** var (s.e.)	**Satisfaction** var (s.e.)	**Negative mood** var (s.e.)	**Positive mood** var (s.e.)
Intercept	-2.37 (0.64)*	17.11 (0.67)*	12.50 (0.98)*	16.12 (0.90)*
Time	0.31 (0.04)*	0.55 (0.15)*		
Time^2		-0.06 (0.02)*		
Time^3	-0.002 (0.0002)*	0.002 (0.001)*		
Demand		0.06(0.02)*	0.12 (0.02)*	
Satisfaction	0.08 (0.02)*		-0.10 (0.02)*	0.28 (0.03)*
Negative mood	0.12 (0.02)*	-0.07 (0.02)*		-0.42 (0.02)*
Positive mood		0.13 (0.01)*	-0.25 (0.02)*	
(not) at work	-1.53 (0.18)*	-0.55 (0.15)*	-0.55 (0.16)*	-0.53 (0.24)*
Workday	0.45 (0.19)*			-0.65 (0.27)*
Monday	1.38 (0.24)*	0.46 (0.19)*		-0.77 (0.32)*
Tuesday	1.36 (0.24)*	0.57 (0.19)*		-0.84 (0.32)*
Wednesday	1.30 (0.24)*	0.56 (0.19)*		-1.31 (0.32)*
Thursday	1.09 (0.24)*	1.19 (0.19)*		-1.51 (0.32)*
Friday	1.49 (0.24)*	0.77 (0.19)*		-0.79 (0.29)*
Saturday	0.26 (0.22)	0.32 (0.17)		-0.03 (0.29)
Effort	0.09 (0.03)*		0.28 (0.03)*	
Reward		0.03 (0.01)*	-0.05 (0.02)*	
Negative affect		0.07 (0.03)*	0.18 (0.03)*	-0.36 (0.05)*
Positive well-being		0.05 (0.02)*		0.11 (0.04)*
Random effects	Var	var	Var	var
Subject level				
Var (intercept)	2.17	1.46	4.00	8.08
Day level				
Var (intercept)	2.35	0.80	3.90	5.86
Within-day level				
Var (intercept)	4.83	4.10	2.92	4.80
Explained variance	percentage	percentage	percentage	percentage
Subject level	42.8%	36.5%	21.9%	31.1%
Day level	5.4%	24.3%	27.0%	26.4%
Within-day level	2.7%	0.0%	14.3%	11.8%

Model 2 The table shows the fixed effects of explanatory variables on demand, satisfaction, negative and positive mood. The variances (var) at each level, and explained variance (as percentage of variance at each level in null-model) are also given. For all *: $p<0.05$ (n cases = 2816, 77 subjects). Non-significant effects were removed from the models.

Table 4. Descriptives (mean, S.E. mean and correlations) of demand, satisfaction, negative mood, positive mood, effort, reward, negative affectivity and positive well-being, averaged over all measurement points. * Correlation is significant at the 0.01 level (2-tailed).

		Demand	**Satisfaction**	**Neg. Mood**	**Pos. Mood**
	Mean, S.E Mean	correlation	correlation	correlation	correlation
Demand	2.3 (0.06)		0.10*	0.18*	-0.06*
Satisfaction	22.5 (0.05)			-.014*	0.27*
Neg. Mood	6.5 (0.07)				0.37*
Pos. Mood	18.7 (0.09)				
Effort	10.1 (0.04)	0.08*	0.00	0.15*	0.04
Reward	42.5 (0.10)	0.01	0.09*	-0.15*	0.07*
Negative affect	2.9 (0.05)	0.01	-0.05*	0.20*	-0.32*
Positive well-being	12.2 (0.06)	-0.06*	0.27*	-0.17*	0.26*

Insert fig 1-3 about here

DISCUSSION

Levels of analysis

The hypothesis that a significant amount of variance in the repeatedly assessed data was found at three levels (i.e. measurements of several subjects throughout the day over several days), was confirmed. This means that variations in these variables are due to differences within the days, between the days and between the subjects. By distinguishing three levels of analysis, we also acknowledge that dependency may exist between certain variables within a subject or within a day. This means that scores on a variable (e.g. mood) within a subject (or day for a particular subject) are likely to be similar (i.e. not independent). Ignoring this means that the results will be biased towards rejecting the null hypothesis (Gibbons et al., 1993; Schwartz & Stone, 1998). Thus, by distinguishing all levels of analysis present in the data, the chances of bias are reduced.

Stability versus situation dependency

The amount of variance at each level, (derived from the null-model) can also be used to provide insight in the characteristics of the dependent variables. In the present study, the distribution of the variance over the levels was compared for demand, satisfaction, negative mood and positive mood. It was hypothesised that the variables demand and satisfaction are more situational dependent whilst the mood variables are more stable or subject dependent.

The results showed that variables reflecting an individual's affective state (negative mood and positive mood) had most variance at the subject level, attributing more stable characteristics to these variables. The opposite was found for the variables reflecting perceptions of the work environment (demand and satisfaction). These variables have more within-day variations, and may be considered more situation dependent.

In the literature of personality psychology, there is an ongoing discussion about the effect of personality traits on state-like variables. This is referred to as the "invariance of personality structure". In short, the construct of personality rests on the assumption that individuals are characterised by distinctive qualities that are relatively invariant across situations over time (Mischel & Shoda, 1995). The assumption of invariance, however, has been questioned, because of the lack of sufficient empirical evidence. Under specific circumstances, people may act in contrast to what may be predicted on the basis of their personality. Without adequate measurement and analysis techniques, it may be difficult to gather the necessary empirical evidence. With the analysis method described above, it is possible to determine situation, or subject-dependency of the dependent variables. EMA and multilevel analysis of ongoing within-day measurements data as is illustrated in the present study, may help gather the empirical evidence needed in the search for support for the theory of personality invariance.

Time of day effects

To further describe the data, the effects of time of day were determined. It was established that time of day had a significant effect on perceptions of the work environment (demand

and satisfaction), but not on affective variables (negative and positive mood). The latter finding is in contrast to Taub & Berger (1974) and Watts et al. (1983). More research is needed for conclusive results. The present results, however, support the hypothesis that affective variables have more stable characteristics than self-initiated variables like demand and satisfaction (Reich et al., 1988).

In certain studies (van Eck et al., 1996), time is explicitly included to the analyses as an explanatory variable. The effect of time of day on specific psychobiological variables, like cortisol and adrenaline, has been well established. In line with the studies performed by Smyth et al., (1998) and van Eck et al., (1998), the present study illustrates an adequate method that can be used to account for time of day effects in EMA data.

Work and weekday effects

Assuming that the work environment is a potential source of stress, it may be expected that being at work and workdays will be associated with higher demands and negative mood, as well as lower satisfaction and positive mood (Csikszentmihalyi and Graef, 1980; Reich & Zautra, 1983). In contrast, being at work was associated with higher satisfaction and positive mood. This is conceivable from the perspective of an unemployed person, in which being at home does not always lead to satisfaction and pleasure (positive mood) (Ockenfels et al., 1995). Reich et al. (1988) also reported similar findings. They found that subjects felt more positively as they responded to more demands. It must however be noted that the results reflect the characteristics of the population at hand. Its generalisability still has to be determined. Future studies should focus on this issue, for instance, by studying the unemployed in relation to employment, involving assessments of demand and satisfaction.

Within-day assessments of work stress and affect

It was hypothesised that effort will be positively related to demand, reward to satisfaction, negative affect to negative mood and positive well-being to positive mood. The analyses confirmed these findings, justifying the use of demand and satisfaction as within-day indices of work stress. The same goes for negative and positive mood, which may be considered within-day indices of positive-well being and negative affect. The results also show a positive relation between effort and negative mood, and a negative relation between reward and negative mood. This is in line with the ideas of Watson & Pennebaker (1989), who hypothesise a large communality between stress and affect. Although not conclusive, the results of the present study support the hypothesis (Buchanan et al., 1999) that environmental demands and affect (although partly related) are distinguishable constructs that play an important role in the stress-health continuum. Future studies should further determine the role of these variables in EMA studies.

The analyses also showed that, in comparison to demand and satisfaction, a larger proportion of within-day variance of negative mood and positive mood was explained. Although negative mood and positive mood were attributed more stable (trait-like or subject dependent) characteristics, enough unexplained variance remained to be explained at the within-day level. Studies including psychobiological variables (e.g. cortisol) have explained some of this within-day variance (van Eck et al., 1996), still only a small portion of the variance was explained. Again, the characteristics of the population at hand may be responsible for these small effects. In these studies, healthy working populations were assessed. Human beings have the capability and flexibility (defense and coping mechanisms etc.) to adapt to the changing and increasing demands of the environment. Within-day variations in psychological and physiological variables may merely be part of the adaptive functioning of an individual, not of a maladaptive functioning. Studying stress-affect-health relations in a clinical population may provide larger effects.

Future studies

To enable comparison with traditional analyses, some descriptive statistics were performed (means, standard errors of the mean, and Pearsons-r correlations). To calculate persons-r correlations, the scores on the dependent variable were aggregated. It is important to note that analysing aggregated data ignores within-day and daily differences, leading to unreliable outcomes. This is illustrated by the correlation between satisfaction and negative affect. The aggregated data show a negative correlation between these two variables, suggesting that subjects with higher negative affect will have lower satisfaction scores. This is not necessarily the case. The multilevel analysis shows a positive relation, furthermore, the effects of negative affect on satisfaction may be random (i.e. the effect may differ between days or between subjects). This example illustrates the dangers that can be caused by the analysis and interpretation of aggregated data. If possible, analysis of aggregated data should be avoided in the future. Testing random effects fall beyond the scope of the present paper, however if hypothesised, multilevel analysis should included a test for random effects.

In the present study a palm-top computer was used for data collection. Today, an increased use of mobile devices (GSM, organisers, beepers etc.) makes the integration of EMA (using palm top computers) into everyday life quite easy. The use of palm top computers was considered quite normal, subjects became quite familiar and involved with the devices. We suggest, it is mainly this enthusiasm that led to the rather good compliance rate (91,3%), comparable to the compliance rate van Eck et al. (1996), and Smyth et al. (1998) who used also performed EMA assessments. Although the use of computerised devices for EMA is a great advantage, performing an EMA study can be rather time consuming for both the subject and the researcher. By using the wrong statistical analyses, all benefits of EMA may disappear (Jaccard and Wan, 1993). The present paper illustrates how such multiple-occasion data may be collected and analysed, and therefore contributes to the literature in this growing field of behavioral medicine.

Figure captions

Figure 1. Estimated and observed demand throughout the day

Figure 2. Estimated and observed satisfaction throughout the day

Figure 3. Observed negative and positive mood throughout the day

Figure 1

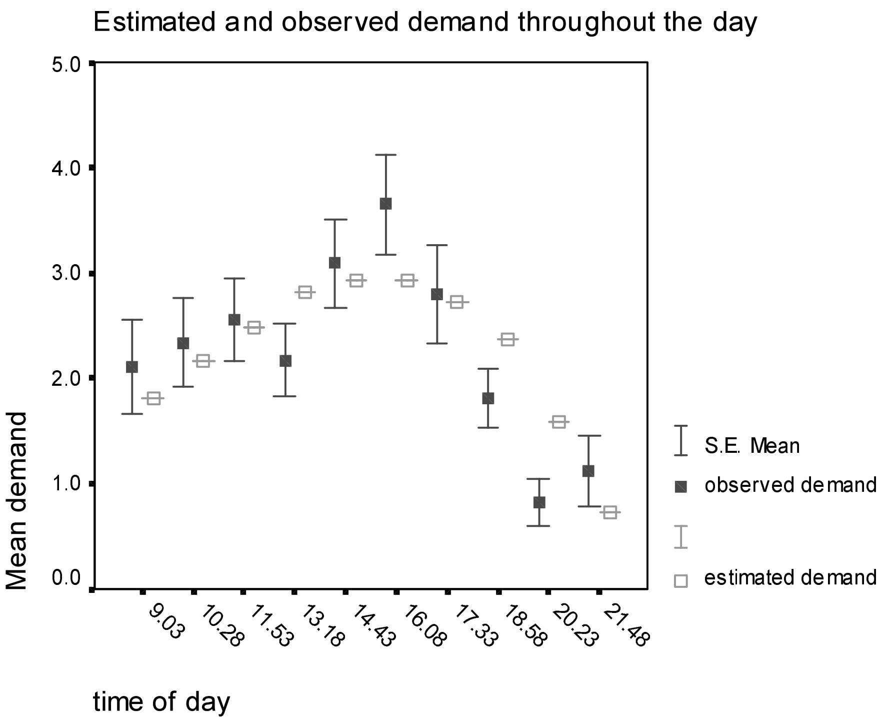

Estimated and observed demand throughout the day
Mean demand
5.0
4.0
3.0
2.0
1.0
0.0
9.03
10.28
11.53
13.18
14.43
16.08
17.33
18.58
20.23
21.48
time of day
S.E. Mean
observed demand
estimated demand

Figure 2

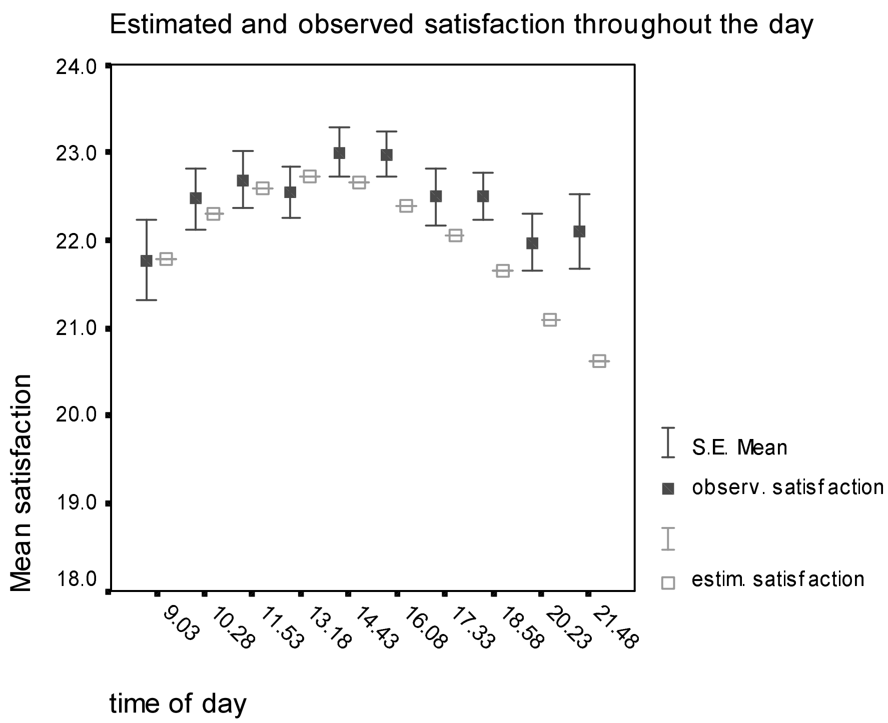
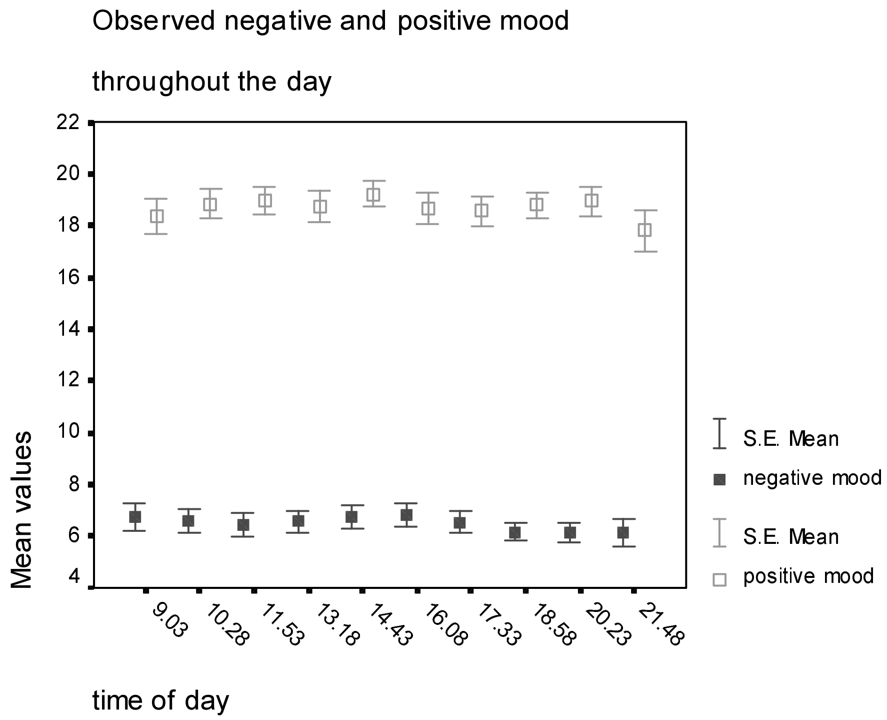

Estimated and observed satisfaction throughout the day
24.0
23.0
22.0
21.0
20.0
19.0
18.0
Mean satisfaction
9.03
10.28
11.53
13.18
14.43
16.08
17.33
18.58
20.23
21.48
time of day
S.E. Mean
observ. satisfaction
estim. satisfaction

Figure 3


Observed negative and positive mood
throughout the day
22
20
18
16
14
12
10
8
6
4
Mean values
9.03
10.28
11.53
13.18
14.43
16.08
17.33
18.58
20.23
21.48
time of day
S.E. Mean
negative mood
S.E. Mean
positive mood

Chapter 4

Vagal cardiac control throughout the day: The relative importance of effort-reward imbalance and within-day measurements of mood, demand and satisfaction

Abstract

The effects of variables derived from a work stress theory (the effort-reward imbalance theory) on the power in the high frequency (HF_HRV) band of heart rate (0.14 - 0.40 Hz) throughout a work day, were determined using multilevel analysis. Explanatory variables were analysed at two levels: At the lowest level (within-day level), the effects of positive mood, negative mood, demand, satisfaction, demand-satisfaction ratio, and time of day were assessed. At the highest level (the subject level), the effects of sleep quality, effort, reward, effort-reward imbalance, need for control, type of work (profession), negative affectivity, gender and smoking on HF_HRV were assessed.

Need for control has a negative effect on HF_HRV after controlling for time of day effects, i.e. subjects with a high need for control have a lower vagal control of the heart. In the long run, these subjects may be considered to be at increased health risk, because they have less of the health protective effects of vagal tone. The interaction between effort-reward imbalance and time of day has a positive effect on HF_HRV, i.e. the cardiac vagal control of subjects with a high effort-reward imbalance increases as the day progresses. It is discussed that this probably reflects reduced effort allocation, ensuing from disengagement from the work demands.

Introduction

The relation of psychosocial factors in work, either objectively assessed or measured by subjective judgements, with cardiovascular reactions and complaints has been amply demonstrated (Karasek, 1979; Hackman & Oldham, 1980; Cooper & Payne, 1991; Marmot, 1994; Siegrist, 1996a). However, less is known about the physiological mechanisms allegedly responsible for this relationship. A theory that may explain certain aspects of these mechanisms has been proposed by Siegrist (1996b). This theory, known as the effort-reward imbalance theory, suggests that a high effort, a low reward and a high need for control first lead to changes in physiological and psychological responses and eventually to the development of cardiovascular disease. However, sufficient evidence, especially for the relation with physiology, is still needed. The present paper will focus on this issue, by assessing the effects of effort-reward imbalance (ERI) -both as a trait and as a state-, as well as need for control on vagal autonomic control (as is indicated by high frequency heart rate variability (HF_HRV)). Furthermore, the effects of within-day measurements of negative mood, positive mood, time of day and other potential determinants (sleep quality, negative affectivity, smoking, gender and profession) on HF_HRV are assessed.

The effort-reward imbalance theory is based on the principle that an imbalance between effort and reward leads to psychophysiological changes referred to as “emotional distress” and an “activation of the autonomic nervous system”. Furthermore, the consequences of effort-reward imbalance are amplified by a high need for control (i.e. a strong tendency to engage in work activities). Thus, three major constructs are distinguished in the effort-reward imbalance theory that may codetermine psychological and physiological responses: the invested effort, reward received and an individual’s need for control. Siegrist and Peter (1994) argue that the risk for cardiovascular disease increases (after controlling for traditional risk factors) if individuals respond to effort-reward imbalance with a high need for control, mainly due to a chronic activation of the autonomic nervous system.

To date, effort, reward and need for control have been associated with a decreased laboratory task elicited blood pressure reactivity (Siegrist, 1996a) but not yet with cardiovascular dynamics throughout an actual working day. Hypotheses about the relation between effort, reward, need for control and cardiovascular changes have to be based on an extension of the theoretical framework. Increased mental effort induces a decrease in vagal tone (Aasman et al., 1987). Low vagal control of heart rate has been shown to be related to coronary artery disease (Martin et al., 1987) and increased mortality (Kleiger et al., 1987). In a recent consensus paper it is confirmed that HF_HRV clearly represents vagal influence: a low HF_HRV is associated with a low vagal cardiac control (Berntson et al., 1997). The meaning of the low frequency (LF) heart rate variability ($< .14$ Hz) is more debated, most probably reflecting a mix of sympathetic and parasympathetic influences. According to Sloan et al., (1994) a high LF/HF_HRV ratio is also associated with the relative dominance of sympathetic nervous system activity.

Putting these elements together, we expect subjects high on effort or on need for control (involving expenditure of mental effort) to have a lower vagal tone. The status of reward relative to autonomic drive is unclear; its effects will be tested as well. Imbalance of effort and reward may lead to either decrease or increase in vagal tone. The former response is expected in individuals, that perceive the environmental demands as a challenge, and still engage in work related activities. The latter response is expected in individuals that cope with the demands by disengagement from work related activities and/or switch to less effort demanding strategies. These responses are in line with the hypothesis that the motivational drive of individuals interacts with environmental demands, and co-determines the psychological and physiological responses (Hockey, 1997). In the effort-reward imbalance theory, need for control reflects the motivational aspects of an individual. Consequently, an individual with a high need for control and a high effort-reward imbalance is expected to have a lower parasympathetic drive than an individual with a high need for control, an interaction that is tested in the present paper.

According to the effort-reward imbalance theory, effort, reward and need for control are stable trait-like constructs, implicitly assuming that these psychological characteristics are continuously and evenly present over longer periods of time. Expanding on the theoretical framework, it may also be argued that ongoing within-day assessments of these variables (referred to as “demand”, and “satisfaction”) also should affect heart rate variability throughout the work day. In line with the effort-reward imbalance theory, in which an imbalance ratio was expected to have a stronger predictive value, the ratio between demand and satisfaction (“the actual demand-satisfaction ratio”) was also determined, anticipating an effect on heart rate variability. By testing all three variables (demand, satisfaction and the demand-satisfaction ratio) simultaneously, it was aimed to determine which of the effects was the strongest.

Other factors than the ones derived from the ERI theory have been shown to affect physiological functioning: the psychological trait of negative affectivity (Parkes, 1994), but also sleep quality, smoking, profession, gender (Egloff et al., 1995; Shapiro et al., 1997; Grossman & Kollai, 1993; Meijman, 1997), and negative and positive mood (Shapiro et al., 1997, Gellman et al., 1990; Schwartz et al., 1994) have been shown to have an effect on physiological changes throughout the day. The relative contribution of these factors to HF_HRV will be estimated as well.

Finally, some studies have also shown that time of day may interact with aspects of work (e.g. night shifts, long working hours) (Akerstedt, 1988, 1991), thereby influencing performance but also physiological state (Campbell, 1992). Another study has shown time of day to affect heart rate variability (Malliani et al., 1991). Therefore, it is hypothesised that time of day will interact with the constructs for the effort-reward imbalance theory, and have an effect on heart rate variability. Specifically, it was explored whether subjects differing in ERI show another HF_HRV pattern over the day, and whether this is affected by need for control

Method

Subjects

From an initial sample of 104 subjects, 77 agreed to participate in the study. Four subjects were removed from the analysis of heart rate data, because they used anti-hypertensive medication, and another three were removed due to equipment failure. The final sample consisted of 70 workers from two different professions: health professionals (mean age = 40.0, s.d. = 4.6; 18 male, 15 female) and office clerks (mean age = 33.1, s.d. = 9.3; 21 male 16 female). The age and proportion of male subjects did not differ significantly between the professions. The work tasks of both professions were usually performed in a seated position. A large part of the day was spent answering telephone calls, communicating with clients or typing data into a computer. Based on the similarities between the groups it may be concluded that the entire sample is homogeneous. However, to ensure this, the variable “profession” was added to the analysis.

Procedure

Two days before the ambulatory measurement of heart rate, subjects were asked to fill out questionnaires in order to measure effort, reward, need for control and negative affectivity. Subjects were also questioned on their medical history (hypertension etc.), smoking habits and profession. These variables were measured once in contrast to the variables demand, satisfaction, positive and negative mood that were measured several times a day using a diary implemented in a palm top computer. The diaries were filled in for seven consecutive days. For the present purpose, only the diary ratings on the day of ambulatory measurements were used for analysis. Sleep quality was measured at the beginning of the day, using a special “morning diary” generated by the palm top computer. After the questionnaires were filled in, the use of the portable diaries was explained.

On the day of the ambulatory heart rate measurements, subjects were equipped with the ambulatory apparatus during the first hour of work (8.00 - 9.00 a.m.). Subjects then engaged in normal work activities during the day. At the end of the work day (4.30 p.m.) the ambulatory physiological measurements of the health professionals were concluded. Although the measurements of some health professionals started later than 8.00 and ended later than 4.30 p.m., no physiological measurements were performed at home. This was in contrast to the office clerks who had to continue ambulatory physiological measurements at home till 9.30 p.m. This means that the data obtained after 4.30 p.m. is mainly based on the measurements obtained from the office clerks. They were instructed how to disconnect the measuring device at home. The devices were returned to the investigator the next day. In both groups, diary measurements started at 8.00 a.m. and continued till 10.30 p.m. (see within-day diary measurements).

At the end of all measurements subjects were debriefed in order to determine any confounding factors during measurement.

Measures

Effort, reward and need for control

The revised Dutch Effort-Reward Imbalance Questionnaire (Hanson et al., 2000b) was used to determine effort, reward and need for control. Effort referred to demanding aspects of the work environment, and was determined by six items (e.g. “I have constant time pressure due to a heavy work load”). Reward was measured by items referring to the esteem by colleagues and superiors (esteem reward, 6 items), monetary gratification (1 item), and status control (5 items). Need for control referred to work related behaviour and commitment (e.g. “I don’t let others do my work”) and was measured by 9 items. The reliability (Chronbach’s alpha) of effort, reward and need for control in this study was respectively .67, .78 and .92.

Negative affectivity

A Dutch translation of the well-being questionnaire (Bradley & Lewis, 1990) was used to measure negative affectivity. A Chronbach’s alpha of .82 was determined, indicating a good reliability of the scale.

Within-day diary measurements

Demand, satisfaction, positive and negative mood

Items of the demand, satisfaction and mood scales were programmed in a portable Hewlett Packard 100 LX computer. The palmtop computer was implemented with software to conduct measurements according to the Experience Sampling Method (ESM) (Csikszentmihalyi & Larson, 1987; Delespaul, 1995). ESM is a method used to assess fluctuating psychological states such as mood, location, activities, thoughts and perceived stress in a subjects natural environment, contingent on an auditive signal (beep). The occurrence of the beep is programmed by the investigator. In the present study, the palm top computer was programmed to beep several times a day at semi-random intervals throughout the day. This method of data collection has several advantages of which the reduction of retrospective bias and the detection of small fluctuations of a subjects state are the most important (see Delespaul, 1995; Hanson et al., 2000a for an extensive review).

The diaries of the subjects from each profession had slightly different beep intervals and number of beeps. The diaries of the health professionals beeped six times a day and the diaries of the office clerks beeped ten times a day. For both professions the first beep could be expected after 8.00 a.m. and the last beep before 10.30 p.m.

The subjects were instructed to complete the diary immediately after each beep by pressing an event maker button on the EGC-recorder. If the diary was not filled in directly after the beep, the subjects were prompted again after 15 minutes. Subjects were also given the possibility to skip 1 beep per day at their own convenience (sometimes beeps are inconvenient, e.g. during an important meeting). This option was expected to enhance compliance. Theoretically, a maximum of 568 beeps ((6 beeps * 33 subjects) + (10 beeps * 37 subjects)) could have been generated, however less beeps were generated, due to mechanical failures (software and hardware) and the exclusion of beeps that occurred during equipment installation and recovery. Eventually, a total of 472 beeps were generated, of which 428 were answered (8 diaries were skipped by the user, 27 were forgotten, and 9 were invalid), leading to a compliance rate of 90.7 %.

The ESM diary contained three questions about the perceived demands: 1) “Since the last beep I have been under time pressure” (yes = 1 / no = 0 points); 2) “Since the last beep I was interrupted a lot” (yes = 1 / no = 0 points); and 3) “Since the last beep I have been physically active” (yes = 1 / no = 0 point); and two questions that referred to perceived satisfaction: 1) “Since the last beep my actions have been rewarding” (yes = 0 / no = 1 points); 2) “Since the last beep my contributions have been acknowledged” (yes = 0 / no = 1 point);. These questions were followed by a scale enabling the rating of the demands or absence of rewards, on a distress scale running from 1-7. The score per item was calculated by combining the score on this distress scale with the score on the preceeding (“yes/no”) questions, hence a maximum score of 8 and a minimum score of 0 could be obtained per item.

Negative mood was determined using a numerical scale (ranging from 1 “not at all” to 7 “very much”). The items used to rate negative mood were: sad, angry, unhappy and worried. The internal consistency for negative mood is 0.78. Positive mood was also determined by a numeric scale (1-7). The items were: happy, playful, energetic and pleased (internal consistency = 0.87).

Continuous ambulatory measurements
Ambulatory data consisting of ECG R-top interval times (or “inter-beat-intervals” (IBIs)) and an index of the subjects body movement, was collected using two recording devices. The VITAPORT-I system was used to collect data from the health professionals, and the VU-AMD was used to collect data from the office clerks.

VITAPORT-I

The VITAPORT-I is a portable event data recorder (8*13*3.2 cm and 300 g) capable of registering several external analogue signals at varying sampling frequencies (see Jain (1995) for an extensive description). For the present purpose only ECG R-top intervals (IBIs), vertical acceleration (movement) and an external marker signal were registered. Each signal is read through a separate channel, pre-processed and stored on a 1 Mb RAM card. Data pre-processing enables efficient storage of data.

IBIs were determined using a built-in R-top detection algorithm based on a principle described by Vary (1980). First the raw ECG was scanned at a frequency of 400 Hz, then after R-top detection, the inter-beat-interval times were stored at a frequency of 4 Hz. To measure ECG, three Ag/AgCl electrodes (AMI type 1650-005 Medtronic) were placed as follows: one electrode was placed 4 cm above the jugular notch of the sternum, the other was placed at the apex of the heart over the ninth rib, and the ground electrode placed above the right iliac crest.

Body movement was derived from a IC-3031 uni-axial 3g Piezo-resistive accelerometer placed on the subjects leg (outer thigh). Vertical accelerations caused by a subject’s walking were registered and identified as body movement. Null-acceleration (0g, caused by a quiet leg in horizontal position) was identified as a subject sitting down. Vertical accelerations were scanned at 50 Hz and stored at a frequency of 2 Hz.

A subject was instructed to press an event marker button after palm top diary beeps. Events were scanned at 4 Hz and stored at 2 Hz.

VU-AMD

The VU-AMD (Free University - Ambulatory Monitoring Device) is a device (3.2*6.5*12 cm and 225 g) specifically designed to measure ECG, respiration, impedance cardiograms (ICG) and vertical acceleration allowing for R-top detection, derivation of pre-ejection periods and body movement (de Geus & van Doornen, 1996). In the present study the device was used to determine IBIs, body movement and occurrences of external events (palm top beeps).
To obtain R-top interval times, the bipolar ECG signal (see VITAPORT-I for electrode placement) was relayed into a differential amplifier with 1 Mohm impedance and through a band pass filter of 17 Hz. R-tops were detected using a level detector with automatic adjustment (Thakor et al., 1983). To store R-top interval times, the device was switched to “beat-to-beat” registration mode by pressing the event marker button. The temporal distance between all successive R-peaks (in miliseconds) are then stored as IBIs in the internal RAM memory.
Body movement was derived from a built-in vertical accelerometer. The output of the accelerometer is amplified, rectified sampled and reset each 5 seconds. Motility values are determined by averaging these samples over periods of 30 seconds.

Data processing

Selection of beep periods

At each palm top beep, subjects had to fill in a diary from which positive mood, negative mood, demand and satisfaction was determined. The time of the beep (time of day) was automatically registered by the palm-top computer. Beeps are introduced as an event, around which a period was selected for the calculation of high frequency (HF_HRV) power of the spectral analysis of IBIs. The periods were determined based on the following criteria: 1) A minimum period length of 3.5 minutes was selected (to enable fast Fourier transform (spectral analysis), and decrease the risks of non-stationary signals, 2) these periods were maximally 15 minutes before or after the diary beep (at longer intervals, the relation of demand, satisfaction, mood and the cardiovascular variables, are expected to weaken, possibly leading to a bias), 3) Subjects should be seated during the selected period. Pilot testing had shown that subjects sitting quietly in a chair had a vertical acceleration lower than 30 gsec (according to the VU-AMS) or between -0.05 g and +0.05 g (according to VITAPORT-I). Short bursts of 30-50 gsec were allowed, since testing showed that slight shocks of an arm against the VU-AMD could cause a sudden short increase in motility values.
Finally, the selected periods were double checked with diary information (“Since the last beep I didn’t walk and was seated (1)10, (2) 20, (3) 30, (4) 40, or (5) 50 minutes before diary entry”) to ensure that subjects were sitting down.
A total of 294 out of 428 periods (= 68.7 %) met the above mentioned criteria. Most missing data was due to body movement or because they fell outside the 15 minute interval before and after the beep.

Artefact correction

Incorrect R-top detection due to supraventricular extra systoles or extra triggers, may lead to too long or too short interval times. Using a software program, (CARSPAN, Mulder et al., 1993) these artefacts were detected and corrected. Artefact detection was carried out using a 50 sec time window that was moved stepwise through the time series of IBI’s.

The detection algorithm was set to classify an IBI as a long or short interval if the IBI fell outside a range of mean IBI (over 50 sec) ± 4 sd. The detected artefacts were then visually inspected, and artefact type was confirmed. Where possible, long artefacts were automatically corrected by linear interpolation. Short artefacts were automatically corrected by adding them to the next IBI. Artefacts not corrected by the software program were manually corrected. Long intervals that fell within the range of mean IBI (over 50 sec) ± 150 msec were not corrected because deviations this size may be considered local trend effects and as such will have no appreciable effect on the frequency spectrum (Mulder, 1988).

<u>Calculation of HF_HRV</u>

After artefact detection and correction, the R-top interval times were fed into the spectral analysis module of the CARSPAN software. This program uses a sparse discrete Fourier transformation (Rompelman, 1985) that can calculate a power frequency spectrum from 0.01 to 0.50 Hz. This method may be seen as a direct Fourier transform of heart rate data in the frequency domain, based on the so called Integral Pulse Frequency Modulator Model (IPFM; Hyndman & Mohn, 1975). According to this model, fluctuations in heart rate are caused by the continuous modulation of the sinus arrhythmic node. In this concept the modulation signal can be seen as a pulse frequency generator, rather than an interval generator. Thus, HF_HRV is seen as a frequency modulated signal rather than an interval modulated signal. The spectral values calculated by CARSPAN are normalised at the mean and expressed in dimensionless “squared modulation index”-units (van Dellen et al., 1985). Because of this transformation, the dependency between the spectral values and mean IBI is resolved (Mulder, 1988). For further analysis, the integrated power density spectra in the high frequency band (HF_HRV, 0.14 - 0.40 Hz) of each selected period was calculated. The resulting data is considered an index of variability as well as vagal autonomic control of the heart (Berntson et al., 1997).

Statistical analysis: random coefficient model

As has been described earlier, the variables effort, reward, need for control, and negative affectivity were measured only once, whilst the variables demand, satisfaction, positive and negative mood as well as the selected IBI periods were measured several times a day. The variables that were measured several times a day are said to be nested within the units (subjects) at a higher level, and are referred to as the lowest level of measurement (beep level). The variables at the highest level (subject level) are sleep quality, effort, reward, effort-reward imbalance, need for control and negative affectivity (see table 1). The data is also related to the time of day, and the moment of data collection differs between individuals (e.g in one subject the first beep may be at 8.30 a.m. whilst the first beep in an other subject may be at 9.10 a.m., leading to varying time points). To adequately assess the effect of higher level variables on lower level variables, and varying time points, a statistical method based on a random coefficient model (Bryk & Raudenbush, 1992; Goldstein, 1995) was employed, rather than a traditional method (such as analysis of variance or regression analysis). Furthermore, due to the characteristics of the measured variables, missing values are not uncommon. Again, traditional analysis techniques need complete data sets. Missing values usually result in the omission of an entire subject. Using a random coefficient model these two problems (varying time points in time and missing cases) are adequately addressed.

Table 1. Measurement levels and variables.

variable	beep level (within-days)	subject level (between subjects)
time	*	
negative mood	*	
positive mood	*	
demand-satisfaction ratio (ADSR)	*	
demand	*	
satisfaction	*	
high frequency heart rate variability (HF_HRV)	*	
sleep quality		*
smoking		*
gender		*
profession		*
negative affectivity		*
effort		*
reward		*
effort-reward imbalance (ERI)		*
need for control		*

In the present study, we set out to assess the variance at the beep and subject level, the random and fixed effects of beep level variables and the fixed effects of subject level variables on HF_HRV. To achieve this, a number of models were created, each testing a specific effect.
To assess the amount of variance at each level, an empty model was tested (intercept only: model 1). Then, the effect of time of day on HF_HRV was assessed (time of day: model 2). After this, the effects of explanatory variables at the lowest level (respectively negative mood, positive mood, actual demand-satisfaction ratio, demand, and satisfaction), and the subject level (respectively sleep quality, gender, smoking, profession, effort, reward, effort-reward imbalance, need for control and negative affectivity) on HF_HRV were tested (model 3). It was also tested whether the effect of each beep level variable differed between individuals (i.e. had a random effect). Finally, possible interaction effects were tested (model 4). The following interactions were of interest: ERI * need for control, effort * time[1], reward * time, and ERI * time. For reasons of simplicity, only the significant effects are shown in the table (table 2)

All estimates of the regression coefficients were obtained using the program MLn (Woodhouse et al., 1996). The significance of the fixed effects was determined by dividing the estimate by its standard error, and the significance of the covariances and variances were determined by the likelihood ratio test (Bryk & Raudenbusch, 1992).

[1] The interactions with $time^2$ and $time^3$ were also determined (see results).

RESULTS

Fixed and random effects on HF_HRV

Before the analyses, a logarithmic transformation was performed on HF_HRV (Ln HF_HRV) data to correct for skewness. This transformation resulted in a normally distributed HF_HRV curve throughout the day (skewness = -0.37, min. = 9.50 max. = 15.99). Then, the amount of variance at each level (the beep level and subject level) was assessed, by constructing an intercept only model (model 1). The intra-level-2 correlation (Goldstein, 1995) shows that 60% (0.876 / (0.583 + 0.876)) of the variance is at the subject level and 40% (0.583 / (0.583 + 0.876) at the beep level. This means that differences between subjects are larger than the differences within the day (60 : 40 %). However, the variance within-days is still quite large.

Table 2. Fixed and random effects on Ln HF_HRV.

Fixed Effects	Estimate + (s.e.) Model 1	Model 2	Model 3	Model 4
Intercept	12.780 (0.158) *	12.360 (0.367) *	12.860 (0.380) *	13.750 (0.617) *
Time		0.383 (0.189) *	0.419 (0.188) *	0.257 (0.192) .
$Time^2$		-0.074 (0.030) *	-0.079 (0.030) *	-0.071 (0.030) *
$Time^3$		0.004 (0.001) *	0.004 (0.001) *	0.004 (0.001) *
Need for control			-0.163 (0.045) *	-0.161 (0.045) *
ERI				-1.615 (0.948) .
ERI * Time				0.227 (0.080) *
Random effects	variance			
Subject level				
Var (intercept)	0.876	0.937	0.696	0.695
Beep level				
Var (intercept)	0.583	0.543	0.539	0.512
Δ deviance	-	-8.28	-11.69	- 8.01

For all models: n beeps = 294, 70 subjects; * = p<0.05. The deviance of each model with respect to the previous model was calculated (Δ deviance).
Model 1: An intercept only model, for estimating variance at the subject and beep levels.
Model 2: The fixed and random effects of time of day (“time”, “$time^2$” , “$time^3$”) on HF_HRV were assessed. Only the fixed effects were significant.
Model 3: The fixed and random effects of all variables on HF_HRV were tested. Only the fixed effects of “time”, “$time^2$” , “$time^3$” (in hours after 8.00 a.m.) and “need for control” were significant. When tested separately, the effect of “profession” was also significant, this effect disappeared when all variables were tested simultaneously.
Model 4: The fixed effects of two interaction variables on HF_HRV were tested separately: “effort-reward imbalance * need for control”, and “effort-reward imbalance * time” . Only the latter interaction effect was significant.

Second, the effect of the time of day on HF_HRV was assessed (model 2). To adequately control for the effect of the time of day on HF_HRV, a HF_HRV curve was first estimated and plotted against time of day. As is shown in table 2 (model 2), the HF_HRV curve can be described by a third degree polynomial. The time variables in this model were model “time” “$time^2$” and “$time^3$”, all of which had a significant effect on HF_HRV.

The fit of a higher degree polynomials (fourth etc.) was not significantly better than the fit of the third degree polynomial, therefore it was concluded that the HF_HRV curve is best described by a third degree polynomial. Both the observed and the estimated curve are plotted in figure 1. The estimated values closely follow the observed values, although the "after lunch dip" (at ± 1.18 p.m.) in the observed values was not reflected by the estimated values. The decrease in variance (Δ 0.040) shows that the time of day effect explains 7 % of the variance at the beep level (0.040 / 0.583).

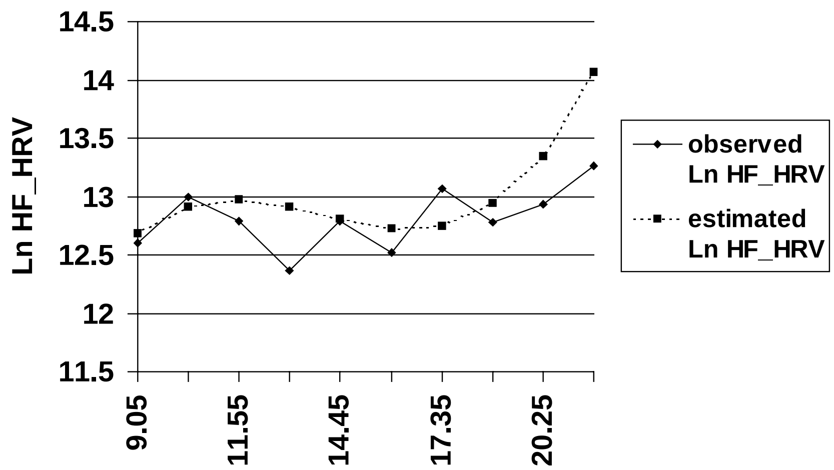


Figure 1. Estimated and observed Ln HF_HRV throughout the day.

A random term for each time variable (time, $time^2$ and $time^3$) was introduced into the model, allowing for individual differences in HF_HRV levels at different times of the day. None of the effects of the random terms were significant, indicating no differences between subjects regarding the effect of time of day.

After assessing time of day effects, the effects of the remaining beep level variables were tested. The fixed and random effects of the following beep level variables on HF_HRV were tested: negative mood, positive mood, the actual demand-satisfaction ratio, demand and satisfaction. Non of these effects were significant.

Next, explanatory subject level variables were introduced: sleep quality, smoking, gender, profession, negative affectivity, effort, reward, need for control, and ERI. When tested separately, both profession and need for control had a significant negative effect on HF_HRV (respectively: estimate = -0.966, s.e. = 0.329; estimate = -0.163, s.e. = 0.045). More specifically, the HF_HRV of the health professionals was 0.966 lower than the HF_HRV of office clerks. An increase in need for control by 1 unit (minimal score = 1 maximal score = 9) is associated with a decrease in HF_HRV of 0.163. When tested simultaneously, only the effect of need for control remained significant (see table 2, model 3).

Finally, the following interaction effects on HF_HRV were tested: 1) between ERI and need for control, 2) between effort and time, 3) between reward and time, and 4) between ERI and time. The interaction between effort and time[1] was significant, indicating that a 1 unit increase in "ERI * time" is associated with a 0.227 HF_HRV increase. Adding the interaction effect to the model, the total model explains 21 % variance at the subject level ((0.876- 0.695) / 0.876) (see table 2 model 4).

Discussion

Most importantly, we found that a higher need for control is associated with lower HF_HRV. According to the effort-reward imbalance theory, a high effort-reward imbalance is associated with vigorous striving and an increased "autonomic activation", an effect supposedly enhanced by need for control. In the present study, we found support for one aspect of this hypothesis: high need for control is associated with vagal withdrawal. As lower heart rate variability (indicating a higher vagal tone) is associated with cardiac events (Liao et al., 1997) and other negative health outcomes (Stansfeld et al., 1998), subjects high in need of control in the long run might be more at risk. The present data indeed show that in these subjects low vagal control is constantly present, at least during waking hours. Extending this type of recordings through the night and more elaborated assessment of cardiac functioning or subclinical cardiac events such as transient ischemia, will further illuminate in how far this pervasive effort spending coping style compromises cardiovascular status.

In contrast to the expectations, effort, reward, ERI, demand, and satisfaction, did not have significant fixed or random effects on HF_HRV. This suggests that the 'simple' effects of perception of the work environment nor the actual experience of demand or satisfaction affect HF_HRV. Neither did the effort reward imbalance, which is a central assumption in the theory of Siegrist. Still, HF_HRV, at specific times of the day, is affected by effort-reward imbalance: subjects high in effort-reward imbalance have a higher vagal tone later in the day. Because a higher vagal tone is associated with lower mental effort, we interpret that later in the day, these subjects spend less mental effort to perform their duties. In the introduction this was referred to as disengagement or change to less effort demanding strategies. In other terms: subjectively experienced effort-reward imbalance seems to be accompanied by less investments in terms of mental effort as the day progresses. Analysing cardiovascular concomitants may clarify (the costs of) the dynamic interaction of motivational drives and environmental demands. Future research should expand on this, introducing more detailed assessment of mental effort, related subjective motivational states and performance measures.

As previously discussed, the imbalance between effort and reward was only reflected in the diurnal curve of HF_HRV, suggesting a disengagement from the work demands later in the day. No main effect of ERI could be shown. The present populations are not excessively stressed. It is conceivable that with progressing age or stress, the mental effort disengagement will not suffice to prevent deleterious effects of perceived disharmony between give and get. Although the interaction “effort-reward imbalance * need for control” was not significant in this study, the combination with a high need of control in the long run may make people especially vulnerable to the negative health effects of a low vagal tone. It is intriguing to link these observations and speculations to the risk factors and the development of burnout: highly striving individuals finally not fulfilling their aspirations (Schaufeli & Buunk, 1996). The similarity of ‘exhaustion’, the primary component of burnout to ‘vital exhaustion’ as related to myocardial infarction (Goodkin & Appels, 1997) may turn out to be less than superficial.

To date, relatively little is known about the relationship between autonomic cardiac control and mood. Sloan et al (Sloan et al., 1994) combined a number of items reflecting negative mood (unhappy, irritable, tense and pressured), and assessed it’s relation with cardiac control. This variable (which they referred to as “stress”) was related to a higher LF/HF_HRV ratio (an index of increased sympathetic predominance in cardiac sympathovagal balance). In contrast to these results, the present study shows that neither negative nor positive mood are related to HF_HRV. A possible explanation for this finding is that in natural settings, HF_HRV may be subject to control by other factors (such as physical activities) that override the influence of mood, although HF_HRV was only determined when the subject was seated for at least five minutes, to minimise the effects of physical activity. However, the influence of previous intensive physical activity (e.g. especially if the effects last longer than five minutes) can not be totally ruled out. Another possible explanation for the absence of a relationship between mood and autonomic activity may be provided by the actual items used to reflect mood. The mood variable used by Sloan et al., did not solely consist of mood items, but also contained items reflecting time pressure and tension. This suggests that the interaction between pressure, tension and negative mood items may affect autonomic activity rather than mood per se. Future studies should continue these efforts to identify the exact items related to autonomic cardiac function. This can be achieved by assessing the effects of a wider range of variables. For example, a study performed by Schwartz et al., (1994) has shown that anger increases ambulatory blood pressure and that feelings of being rushed increases ambulatory heart rate. It should be tested if these variables also affect HF_HRV.

This study has focused on effects of effort and reward on the HF_HRV band, for reasons explained in the introduction. Findings with other work related variables and a different choice of dependent measures should be attended to as well. For instance Meijman (1997) has shown that the power in the middle frequency range of heart rate (0.07 - 0.14 Hz) is associated with mental effort as well as fatigue. Future studies, could very well include these variables and, for instance, identify how time of day and fatigue may affect heart rate variability.

The primary aim of this study was the effect of work related factors on HF_HRV. However, interesting spin-off for the general field of psychobiology should be mentioned as well. Confirming and expanding on the findings of Malliani et al., 1991), the ambulatory measurements of HF_HRV in the present study are affected by the time of the day. The graphical representation of HF_HRV (see figure 1) shows that HF_HRV is low in the morning ((9.00 a.m.), and in the afternoon ((1.00 p.m. - 4.00 p.m.) and increases towards the end of the evening ((9.30 p.m.). As HF_HRV reflects parasympathetic cardiac control, we see two peaks in vagal withdrawal throughout the day: in the morning (at the beginning of the workday), and after lunch. The increase in vagal activity towards the end of the evening, may reflect decreasing demands and/or the occurrence of recovery processes. Factors such as gender and smoking did not have a significant effect on ambulatory HF_HRV.

Conclusions

The importance of ongoing psychophysiological measurements is now gaining recognition (Hockey, 1997). The relationships between patterns of work strain and their consequences for the individual are essentially dynamic, requiring dynamic assessments and analyses to reflect these processes. In the present study, the variance in ambulatory HF_HRV could partly be explained by variables at the beep (time of day) and the subject level (need for control) as well as by interaction of time of the day and subjects' characteristics (ERI * time). This strongly points to the necessity to add ambulatory assessments to the more traditional trait like approaches in order to understand the dynamic psychobiological adaptation or maladaptation (vagal cardiac regulation) to the work environment while actually at work. The present study also proved the feasibility of this approach, without noticeable disturbance of the ongoing work assignments or of the work environment.

The amount of explained variance may not be overwhelming (model 4 explains 21 % at beep level i.e. some 12 % of total variance). However, in contrast to other, momentary effects under artificial conditions (e.g. laboratory) reported in the literature, the effects in this study are present during prolonged periods of time and in a natural setting, enhancing potential clinical relevance.

The negative impact of 'need for control' -considered as a generalised coping strategy- invites to envisage the usefulness of interventions. Intervention programs for burnout (see Schaufeli and Enzman, 1998) include an evaluation of, and adaptive changes in the way people cope with job demands. The intended accompanying positive changes in autonomic drive directly affect 'the heart of the matter'.

Finally, the results of this study point to the challenging issue of "chronopsychobiological" effects: changes in biological regulation over the day are influenced by individual psychological differences, in the present case by a perceived imbalance between give and get in the work situation. Taken together, we consider that the present results add to the understanding of mechanisms by which work related factors may contribute to long term cardiovascular health or disease.

Chapter 5

Cortisol secretion throughout the day, perceptions of the work environment and negative affect

Abstract

The effects of explanatory variables derived from a work stress model (the effort-reward imbalance model), on salivary cortisol were assessed. A multilevel analysis was used to distinguish the effects of single occasion and multiple occasion measurements of work stress and affect on cortisol. The single (or cross-sectional) factors include effort-reward imbalance, need for control, negative affect, and other enduring factors (type of occupation, gender and smokers). The multiple occasion measurements, include negative mood, actual demand-satisfaction ratio, sleep quality, workload (workday versus day-off) and lunch. The effect of time of day on cortisol was controlled for before the analyses were performed.

Negative mood rather than negative affectivity was positively associated with ambulatory measured cortisol dynamics. The variables from the work stress model, effort, reward, need for control did not, neither did its state like derivatives demand and satisfaction. Additionally, the results show that the time course of cortisol differs between individuals and that the effect of sleep quality on cortisol can vary from person to person. This points to the necessity of continued efforts to single out sources of individual variability.
The finding that variables derived from the effort-reward imbalance model are not related with cortisol restricts the generalizability of this model to explain psychobiological relations in work related stress. More in general, the present results invite to further qualify the widely claimed association between chronic stress and HPA activity, at least, as far as can be deducted from cortisol measurements.

INTRODUCTION

It has been established that a chronic increase in hypothalamic-pituitary-adrenal (HPA)-axis activity and the subsequent increase in cortisol is associated with negative health outcomes (McEwen et al., 1993). HPA-axis activity and increases in cortisol have been associated with life stress (Selye, 1980; Mason, 1968; Anisman et al., 1982; Endresen et al., 1992)work stress (Ockenfels et al., 1995; Pollard et al., 1996), negative affect (Buchanan et al., 1999; Smyth et al., 1998; Eck et al., 1996), and loss of sleep (Murawski et al., 1960; Henning et al., 1998; Leproult et al., 1997). A number of authors argue that affect is the major cause of cortisol increases (Buchanan et al., 1999), but the evidence for this, in particularly in daily life remains small (Buchanan et al., 1999; Eck et al., 1996). The present study focuses on this issue, and assesses the relative contribution of each of these factors on cortisol throughout the day.

The Effort-Reward Imbalance (ERI) theory (Siegrist, 1996) provides a model for enduring work stress, resulting from low reward considering the demanded efforts. The work stress theory also states that conditions of high effort and low reward induce adverse emotional consequences, and possibly affect the physiological functioning of an individual (Siegrist et al., 1990). Employees with a high ERI have been shown to have a higher risk in developing cardiovascular disease (Siegrist et al., 1997). To date the short-term underlying mechanisms of this process still remain unclear. It has been demonstrated that high chronic work stress has is associated with a slower decrease of cortisol during the day (Caplan et al., 1979). This is of potentially great importance, since the shape of the cortisol curve (lower than normal values in the morning, and higher than normal in the evening) has been related to lower well-being and health (Smyth et al., 1997). The same is hypothesised for ERI. Furthermore, the ERI theory states that individuals with a high need for control are less likely to disengage from stressful experiences caused by high ERI (Siegrist et al., 1994). Therefore, the effect of ERI on cortisol is expected to be moderated by need for control (i.e. an interaction is expected between ERI and need for control).

As was mentioned above, repeated measurements of ongoing situations have also revealed that daily stressors are associated with increased cortisol (Smyth et al., 1998; Eck et al., 1996). In the present study, the ratio of high demand and low satisfaction is considered a momentary assessment of stress throughout the day at work and at home. Thus, a high ADS-R is expected to be associated with a higher cortisol. Evaluations of events throughout the day can be performed using an Ecological Momentary Assessment (EMA) technique (Stone et al., 1994). To our knowledge, this is the first study that measured demand and satisfaction using EMA. Reich and co-workers (Reich et al., 1988; Reich et al., 1983) also measured demand and satisfaction, but the ratings were given at the end of the day. In their studies, subjects had to rate the demand frequency of 30 daily events, and whether he/she had actually responded to the event. The outcome of the activity was then rated on a 5-point dissatisfaction/satisfaction scale. An average demand/satisfaction ratio was obtained by dividing the number of activities reported by the total of all satisfaction ratings. Another difference with the present study, was that an estimate of occurrence frequency was used to reflect demands rather than an appraisal of the distress caused by the demands.

The effect of daily workload on cortisol dynamics has yield equivocal results. Lundberg et al. (1989; 1980) found a higher cortisol on days with a higher workload in comparison to days with a low (or no) workload, but Pollard (1996) did not find cortisol differences between a day of and working days. A possible explanation is the mediating effect of negative affect (Buchanan et al., 1999).

According to the literature increases in cortisol are the result of negative affect involving fear, anxiety, helplessness and loss of control (Levine et al., 1989; Al'Absi et al., 1993; Frankenhaeuser, 1989; Arnetz et al., 1986). Negative affect is the tendency to experience a wide range of negative emotions like trait anxiety, depression and negative mood (McCrae, 1990; Watson et al., 1984). It is described as "…a general dimension of subjective distress and unpleasurable engagement…" (Watson et al., 1988). Popular instruments used to indicate negative affect are the Positive Affectivity/Negative Affectivity Schedule, PANAS (Watson et al., 1988) or the State-Trait Anxiety Inventory, STAI (Watson et al., 1984). In the present study trait negative affect was measured by seven items reflecting anxiety and depression (Bradley et al., 1990). Negative affect can also be measured as negative mood throughout the day (Doosje et al., 1994; Smyth et al., 1998). In the literature, negative affect is considered to cause inflated correlations between stressors and self reported health symptoms (Costa et al., 1987; Watson et al., 1989). Negative affect rather than stress is expected to be associated with increases in cortisol (Buchanan et al., 1999).

Cortisol is said to increase if the amount of sleep in the preceding night was small (Murawski et al., 1960). Subjects with lower durations of and less recovery in sleep showed a reversal in their circadian function (Henning et al., 1998), and a delay in the recovery of the hypothalamo-pituitary-adrenal axis from early morning circadian cortisol stimulation (Leproult et al., 1997). This is interesting, as sleep is important in restoration of biological functioning (Friess et al., 1995), and a delay in recovery may involve an alteration in negative glucocorticoid feedback regulation (Leproult et al., 1997). In this respect, sleep loss can be assigned a role in the stress – health relation.

Other factors like smoking (McCrae, 1990), gender (Kirschbaum et al., 1992) and food consumption during lunch (Follenius et al., 1982; Malozowski et al., 1990; Quigley et al., 1979) also influence cortisol dynamics. These effects are found after the well-known time of day effect (Krieger et al., 1971; McCrae, 1990) has been controlled for and will be taken into account in this study.

Summarising, cortisol patterning throughout the day is expected to vary as a function of negative affect, work stress and sleep quality, superimposed on the effect of time of day. The following hypotheses are tested, after controlling for the well-known effects of lunch consumption, gender, occupation and smoking:

1) *Negative affect (i.e. trait negative affect and negative mood measured throughout the day) is positively associated with cortisol.*

2) *Subjects with a high work stress (i.e. high ERI, a high need for control (and their interaction), a high ADS-R, and workdays) have higher cortisol.*
3) *Cortisol is elevated on workdays, and in subjects that had some difficulty sleeping.*

METHOD

Subjects

A total of 104 subjects in two companies were invited to participate in the study. After a meeting in which the objectives of the study were explained, seventy-seven subjects agreed to participate in the present study. Thirty-six of the participants were health professionals (mean age = 39.8, s.d = 4.7; 20 male, 16 female) and 41 (mean age = 32.9, s.d. = 9.8; 23 male, 18 female) were office clerks. There was no significant difference in age and proportion of male participants between the occupations.

Materials

Effort, reward and need for control.

Effort, reward and need for control were measured using the revised Dutch Effort-Reward Imbalance Questionnaire (Hanson et al., 1999). The questionnaire measures three main subscales: effort, reward and need for control. Effort is measured by six items that refer to demanding aspects of the work environment (e.g. “I have constant time pressure due to a heavy work load”). If the statement is affirmed, the subjects are then asked to rate its severity from “not at all distressed” (1 point) to “very distressed” (4 points). A negative answer to the statement scores 1 point. Reward is measured by twelve items that refer to the three following topics: ‘esteem reward’ (6 items), ‘monetary gratification’ (1 item) and ‘status control’ (5 items) (e.g. “My promotion prospects are poor”). These items are scored in the same way as the effort items, so that a minimum score of 1 point and a maximum score of 4 points per item can be obtained. In this study (n=77) an internal consistency (Cronbach’s alpha) of .67 and .78 was found for respectively extrinsic effort and reward. A score for effort-reward imbalance was calculated by dividing the score on effort by the weighted score on reward: effort / (reward * (0.5)). The reward scale has twice as many items than the effort scale. Multiplying reward by 0.5 corrects for this. The need for control scale consists of 9 dichotomous items (e.g. *I don’t let others do my work. Agree / disagree*). Affirmative answers to the question scored 1 and disagreement 0. The internal consistency of the need for control scale in this study (n = 77) is 0.92.

Trait negative affect

Negative affect was measured using a Dutch translation (Doosje et al., 1994) of the Well-being questionnaire (Bradley et al., 1990). The questionnaire consisted of four subscales: anxiety, depression, energy and positive well being. A factor analysis performed on the anxiety and depression subscales resulted in a new subscale (7 items) called negative affect. The items used to measure negative affect refer to feelings of depression (e.g. *I have crying spells or feel like it*) and anxiety (e.g. *I feel nervous and anxious*). Both depression and anxiety are associated with negative affect (McCrae, 1990; Watson et al., 1984). Each item was rated on a 4-point numeric scale (with the labels “never” and “always” on the extremes). The range of the scores was 21. A psychometric analysis performed on the scale revealed a satisfactory internal consistency (Cronbach's alpha = .86) (Doosje et al., 1994). In the present study an alpha of .82 (n=77) was obtained.

Sleep Quality

The Groningen sleep quality scale (14 items) was used to measure subjective sleep quality of the preceding night (Mulder-Hajonides van der Meulen et al., 1990; Meijman et al., 1990). The scale covers various complaints about sleep such as: sleep quality in the previous night, insufficient sleep, difficulty falling asleep etc. Higher scores on the scale indicate a lower sleep quality. A score between 2-4 is considered normal in a healthy population. The internal consistency (Cronbach's alpha) was .85 on the first day and .87 on the second.

Smoking, lunch and occupation

In a briefing session before the experiment, subjects were asked whether they smoked, at what time they went for lunch, and their occupation (i.e. office clerk or health professional). Their answers were reconfirmed in a debriefing session after the experiment, and added as separate variables to the data.

Demands, satisfaction and negative mood

An EMA diary was used to measure demand, satisfaction and negative mood. The diary contained three questions about the perceived demands: (1) *"Since the last beep I was interrupted a lot": yes / no*), (2) *"Since the last beep I was under time pressure": yes / no*), and (3) *"Since the last beep I experienced physical demands": yes / no*). Two questions referred to perceived satisfaction: (1) *"Since the last beep my actions were worth the trouble": yes / no*), and (2) *"Since the last beep my input was acknowledged": yes / no*). An appraisal was obtained reflecting the level of distress caused by each item. Distress was rated on a scale running from 1 (*"Not at all distressed"*) to 4 (*"very distressed"*). The total scores of each scale was obtained by summing the scores of the items and their appraisals. Finally, a score for the actual demand-satisfaction ratio was obtained by dividing the scores on demand by the scores on satisfaction: ((2/3)*demand)/satisfaction. The demand scale has three items, and the satisfaction scale has two. Multiplying demand by 2/3 corrects for this difference in number of items.

The subjects were asked to rate their negative mood using four mood adjectives. The scores on negative mood (e.g.*" I feel sad"*) were obtained using a numerical scale (ranging from 1 *"not at all"* to 7 *"very much"*). The items used to rate negative mood were a selection of 4 out of 5 variables used by Smyth et al. (1998): sad, angry, unhappy and worried. The fifth item (depressed/blue) was excluded because no satisfactory translation could be made into Dutch. In this study we found an internal consistency (Cronbach's alpha) of .80, .76 and .85 for respectively negative mood, demand and satisfaction.

Cortisol

Cortisol was determined from saliva samples. Salivary cortisol is considered a reliable index of free plasma cortisol (Vining et al., 1983). The secretion of cortisol is episodic and pulsatile (Gallagher, 1973), and the amount of cortisol in saliva increases within

minutes after the occurrence of a stressful experience. The amount of cortisol found in saliva reaches it's peak approximately 20 minutes after the stressor (Kirschbaum et al., 1992).
Cortisol samples were obtained as follows. Subjects were asked to chew on a cotton swab until it was saturated in saliva. This swab was then placed in a plastic tube (called "Salivette" manufactured by Sarstedt), capped and placed in a refrigerator at the subjects home or work place. After the experiment, the salivettes were stored at -20 ^{0}C. In the present study, cortisol collection rate was 85% (956 cortisol samples were collected). Five samples were discarded due to extreme values (>50 nM). Salivary cortisol values were determined by employing a time-resolved immunoassay with fluormetric end point detection (see (Egloff et al., 1995)), and by radio-immunoassay employing a polyclonal anticortisol-antibody (K7348). [1,2-3H(N)]- Hydrocortisone (NET 185,NEN-DUPONT, Dreiech, Germany) was used as a tracer following chromatografic verification of its purity. Mean and average values obtained from both detection methods did not differ significantly as was determined by a t-test. The lower detection limit of both assay is less than 0.43 nM.

Procedure
The data in this study were collected by means of: questionnaires, salivettes (test tubes for saliva collection) and diaries. Two days before the diary data collection started, the subjects were asked to fill in questionnaires about effort, reward, need for control and negative affect. They were also questioned about their medical history (hypertension etc.), work environment (type of occupation, years of experience etc.) and personal characteristics (sex, age etc.).
The diaries were used to obtain within-day measurements of demands, satisfaction and mood. These measurements were carried out according to the Experience Sampling Method (ESM) (Ockenfels et al., 1995; Eck et al., 1996; Csikszentmihalyi et al., 1987; Delespaul, 1995). Subjects were asked to fill out a diary several times a day. The diary questions were presented to the subjects via a palm-top computer (HP-100 LX) that beeped at semi-random intervals throughout the day. In total 1123 beeps were generated (for all subjects), 1014 of which were answered (compliance rate = 90%). The first beep was after 8.00 a.m. and the last beep was not later than 10.30 p.m. In the subsample of health professionals, beeps were generated 6 times a day, at semi-random intervals of approximately 140 minutes. Beeps were clustered 20 minutes before and 20 minutes after these 140 minute intervals. In the subsample of office clerks, beeps were generated 10 times a day at semi-random intervals of approximately 90 minutes. In this subsample beeps were clustered 20 minutes before and 20 minutes after the 90 minute intervals. Saliva was collected on two days, a work day, and a day off (see measurement of cortisol). Subjects were instructed to collect saliva at the moment of the beeps, label and preserve the salivettes.

Statistical analysis
In the present study, cross-sectional data from questionnaires as well as within-day and daily diary data were collected (see table 1). The questionnaires were used to measure effort, reward need for control and negative affect. The diaries were used to collect

information about negative mood, work stress and sleep quality on two days (a workday and a day-off). To determine the relation between the independent variables and cortisol, a series of regression analyses could have been performed. However, this would have lead to a number of problems: omission of entire subjects due to missing values or measurement points, aggregation bias, capitalisation of chance due to multiple testing, unequal timing of assessment, and correlated assessments (Jaccard et al., 1993; Schwartz et al., 1998). As can be understood from the previous sections, a subject was randomly prompted (by a beep) throughout the day. This leads to measurements that vary in time throughout the day (within-day level) as well as between subjects (subject level). A two-level linear model (or random coefficient model) (Bryk et al., 1987; Goldstein, 1995) was used to analyse the data.

At the moment of the beep the subjects had to answer a number of questions and collect saliva samples. Not always did a subject succeed in doing this on time, leading to missing data. Measurements close in time are also somewhat correlated. In conventional statistical analyses, these data characteristics may result in a large amount of missing subjects, (because a whole subject is omitted), and to biased results. Performing a multilevel analysis resolves these problems (Buchanan et al., 1999). In this paper, several models were explored to test the relationships between cortisol and explanatory variables at each level. Model 1 was tested to determine the number of levels in the data, and the distribution of variance over these levels. The effects of time of day were determined in model 2, and the effects of the remaining variables were tested in model 3. All non-significant effects were removed from the model.

Table 1. Measurement levels and variables.

Variable	within-day level	subject level
time	*	
cortisol	*	
negative mood	*	
actual demand-satisfaction ratio (ADS-R)	*	
sleep quality	*	
lunch	*	
work day	*	
effort-reward imbalance (ERI)		*
need for control		*
negative affectivity		*
occupation		*
gender		*
smoking		*
ERI*time	*	*
ERI*need for control		*

All estimates were obtained using the program MLn (Goldstein, 1995). The significance of the fixed effects was determined by comparing it to its standard error. To achieve significance, the fixed effect should be at least twice the standard error. The significance of the random effects were determined by the likelihood ratio test (Bryk et al., 1987). Only significant fixed effects are presented in the tables. Where necessary, explained variance and random effects are reported in the text.

RESULTS

Descriptive statistics

To increase the comprehensibility of the data some descriptive statistical analyses have been performed: mean, Standard Error of Mean (S.E. Mean) and their quartile scores (see table 1). Mean and SE Mean for within-day variables derived by aggregating the scores at each beep over subjects and days. The mean effort-reward Imbalance (ERI) ratio (0.49) shows that the present sample was not highly stressed. According to a definition of the theory, only subjects with an ERI ratio lager than 1 are at risk of developing cardiovascular disease. The average sleep quality is 3.73, which is normal for a healthy working population. The means and SE Mean calculated within-days for the highest and lowest quartile of negative mood are given in figure 1.

Time of day effects on cortisol

Before testing whether the explanatory variables had a significant effect on cortisol, the amount of variance at each level (the within-day level and subject level) was assessed. The amount of variance at each level was derived from an empty model (model 1, figure 2). A simple calculation shows that 16% of the variance is at the subject level and 84% at the beep level (see table 2).

To adequately control for the effect of the time of day on cortisol, a cortisol curve was first estimated and plotted against time of day. Before this curve was estimated, a fifth root transformation was performed on cortisol (cortisol$^{0.2}$) data to correct for skewness. In accordance with (Ockenfels et al., 1995), this transformation resulted in a normally distributed cortisol curve throughout the day (skewness = -0.19, min. = 0.63 max. = 1.91). As is shown in table 2 (model 2), the cortisol curve can be described by a third degree polynomial. The time variables in this model were model 'time' 'time^{2}' and 'time^{3}'. 'Time' and 'time^{3}' have a negative effect on cortisol, whilst 'time^{2}' has a positive effect on cortisol. The fit of higher degree polynomials (fourth etc.) was not significantly better than the fit of the third degree polynomial. Therefore it was concluded that the cortisol curve is best described by a third degree polynomial. Both the observed and the estimated curve are plotted in a figure 1. The estimated values closely follow the observed values, showing an adequate fit.
A random term for 'time' was introduced into the model, and its effects were tested. A random term allows for individual differences in cortisol at different times of the day. The effect of this term was significant. This means that the effect of 'time' differs between subjects. The other time variables ('time^{2}' and 'time^{3}') had no significant random effect.

Table 2. Mean, and Standard Error of mean (SE Mean) for the actual demand-Satisfaction ratio (ADS-R), Effort-Reward Imbalance (ERI), need for control, trait negative affect, negative mood, and sleep quality.

		ADS-R	ERI	Need for Control	Negative affect	Negative mood	Sleep quality
N		850	850	850	850	850	850
Mean		2.03	.49	3.70	2.95	6.45	3.73
Std. Error of Mean		.05	.01	.11	.10	.13	.10
Percentiles	25	.83	.38	1.00	1.00	4.00	1.00
	50	1.50	.46	3.00	2.00	4.00	3.00
	75	2.50	.58	7.00	4.00	8.00	5.00

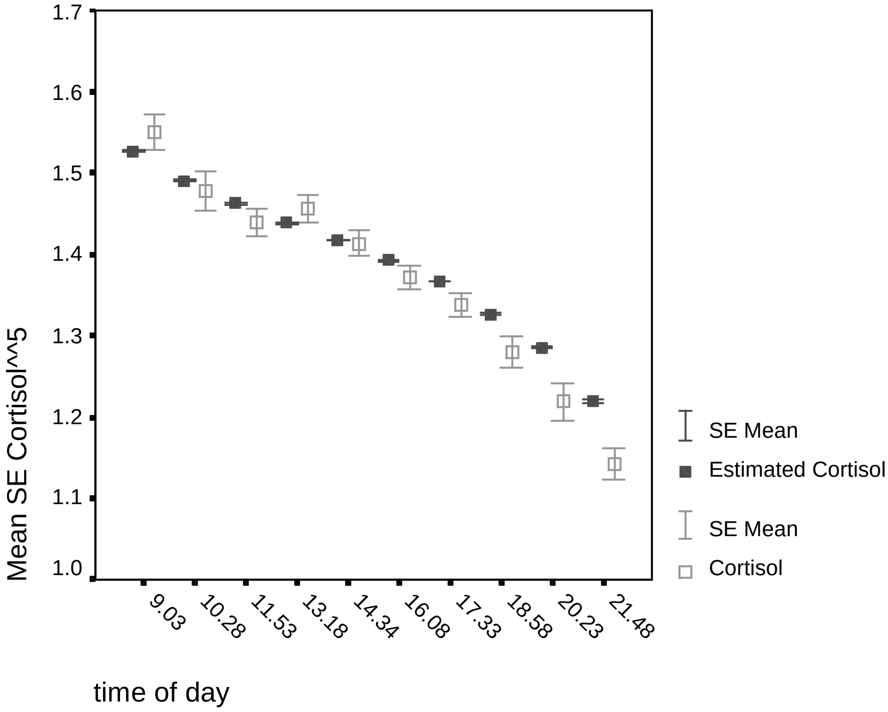


Figure 1. Estimated and observed cortisol throughout the day

Other explanatory variables cortisol

After controlling for time of day, the effects of all other variables on cortisol were tested (table 3, model 3). The results show a significant fixed effect for negative mood, lunch and smoking, and a random effect for ‘sleep quality. This means that the effect of ‘sleep quality’ differs between subjects. All other effects were not significant.

Table 3. The effect of explanatory variables at the beep level on cortisol.

Fixed Effects	Estimate + (s.e.) **Model 1**	**Model 2**	**Model 3**
Intercept	1.365 (0.0118) *	1.555 (0.0269) *	1.509 (0.0342) *
Time		-0.0354 (0.0144) *	-0.0522 (0.0146) *
$Time^2$		0.0034 (0.0023) *	0.0059 (0.0023) *

$Time^3$		-0.0002 (0.0001) *	-0.0003 (0.0001) *
Lunch			0.0504 (0.0168) *
Negative mood			0.0050 (0.0017) *
Sleep quality			-0.0052 (0.0031)
Smoking			0.0324 (0.0105)*
Random effects	variance		
Subject level			
Var (intercept)	0.0068 (16%)	0.0070	0.0038
Var (time)			5.8^{-5}
Var (sleep)			8.7^{-5}
Within-day level			
Var (intercept)	0.0348 (84%)	0.0212	0.0189
Δ deviance	-	395.74	435.71

For all models: n cases = 850, 77 subjects; * = $p<0.05$. The deviance of each model with respect to the null model was calculated (Δ deviance).
Model 1: An intercept only model (empty model), for estimating variance at the subject and within-day levels. The percentage of the total variance is given within parenthesis().
Model 2: The variables ‘time’, ‘$time^2$’ and ‘$time^3$’ (in hours after 8.00 a.m.) were introduced. The random effect of the ‘time’ variable were significant (deviance change Var (time) = 14.70 df = 1, $p<0.001$).
Model 3: Final model including all significant effects. The fixed effects of negative mood and the random effects of sleep quality (deviance change Var (sleep) = 8.39 df = 1, $p<0.001$) are significant.

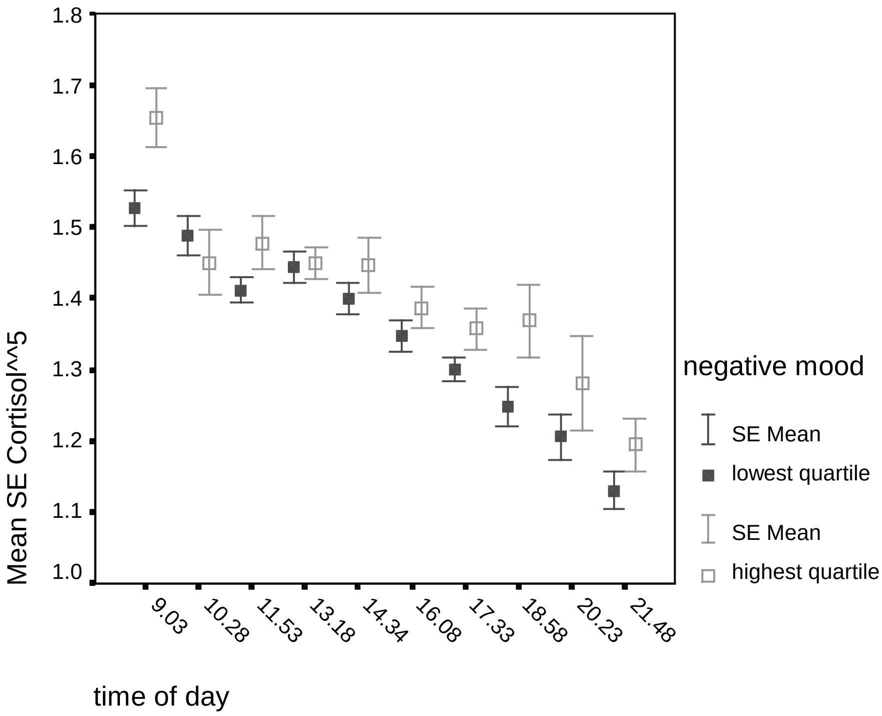


Figure 2. Cortisol throughout the day for the first and fourth quartiles of negative mood.

DISCUSSION

Negative affect

Negative affect was measured at two levels: trait negative affect (measured cross-sectionally) and negative mood (measured throughout the day). The results show that negative mood but not trait negative affect had a significant positive effect on cortisol, after controlling for time of day, food consumption, and smoker effects (see figure 2). The results suggest that the fluctuations in negative mood may be accompanied by changes in cortisol, and that these effects are not the result of a personality trait (i.e. the tendency of subjects to perceive events as negative). These results are in contrast to the results of van Eck et al. (1996).

One explanation for this difference may be the average levels of trait negative affect. Possibly, cortisol is only affected if levels of trait negative affect are high. As can be seen in table 1, the mean average of trait negative affect is 2.95 which is rather low (min. score = 0, max score = 18). Another explanation may be the differences in questionnaires used to measure negative affect. Van Eck used a trait anxiety measure to indicate negative affect. The scale used in the present study also has items referring to both anxiety and depression. Thus, it may be anxiety rather than depression that is related to cortisol.

The average increase in cortisol due to negative mood is 0.085 nmol/L (i.e. 9% increase above mean cortisol levels). The average increase found by Van Eck et al., (1998) and Smyth et al. (1998) are 11% and 12% respectively. These slight differences may again be a result of differences between the studies, concerning the items (adjectives) used to reflect negative mood measured throughout the day. The adjectives used in the present study (sad, angry, unhappy and worried) differ slightly from the items used by Smyth et al (blue, angry, unhappy, worried and frustrated), and by van Eck et al. (depressed, anxious, worried, lonely, tired and miserable). Van Eck et al., also found a relation between agitation (restless, irritated, hurried and nervous) and cortisol (Eck et al., 1996). Given these differences, it remains unclear exactly which items are responsible for the negative mood effect on cortisol. Future studies should address this issue. In conclusion, the effect of negative mood states -as measured in an ecological valid environment- on cortisol proves to be a robust one, found in at least three studies.

The relation between negative affect and cortisol is important, because of hypothesised relations with health (McEwen et al., 1993). In the present study we have seen that even small increases in negative mood throughout the day are related to cortisol increases. This relation is present even though trait negative affect is low, and because of this probably does not lead to cortisol increases. Unfortunately, measures of negative health were not included in the present study. Without such measures, the true importance of within-day cortisol increases on health cannot be determined. We therefore suggest that future studies of cortisol throughout the day should also include indices of somatic symptoms of negative health outcomes.

Work stress

The finding that neither trait ERI nor its within-day counterparts (demand and satisfaction) had a significant effect on cortisol is of particular importance for the ERI theory. In the introduction it was argued that high trait ERI would be associated with higher cortisol characterised by and a slow cortisol decrease towards the end of the day. This relationship with cortisol was suggested because a high ERI is conceptually related to perceived chronic stress, which by some authors has been associated with higher cortisol (Ockenfels et al., 1995). Furthermore, the effects of ERI were expected to be moderated by need for control. This was tested by the interactions given in table 1. None of the hypothesised effects were found. As mentioned in the introduction, the studies relating chronic stress with cortisol have yielded unequivocal results. Pollard et al (1996) found evidence for catecholaminergic effects of high demands in the work situation, but no effects on neither demand nor control on cortisol. In line with this, van Eck (1996) showed that chronically perceived stress did not affect cortisol. This is in contrast with Ockenfels et al. (1995), who did find an effect of perceived stress on cortisol. Summarising, at closer look the evidence for an association of chronic stress with cortisol is not uniform. As outlined by Hellhammer and Kirschbaum (1988) in order to evoke or sustain HPA activation, it is necessary to have extremely stressful situations and / or situations characterised by novelty, taxing social interactions or limited predictability. The present population is selected from normal working population, not extremely stressed. By its very nature, the work situation –even for subjects high in effort reward imbalance- is not novel nor to be considered unpredictable.

It was also hypothesised that the ADS-R measured throughout the day (an index derived from ERI (Siegrist, 1996)), would have a significant effect on cortisol. This was not the case and seems to be in contradiction with (Smyth et al., 1998) and (Eck et al., 1996), both showing an effect of momentary stressors on cortisol. Again it may be argued that the absence of an effect may be due to the characteristics of the perceived situation. Dissatisfying work situations are usually not novel or unpredictable and as such may be different from the kind of stressors assessed in the other studies. Additionally, there is increasing evidence (Buchanan et al., 1999; Eck et al., 1996; Smyth et al., 1997; Al'Absi et al., 1997) that negative mood mediates the effects of stressful events, i.e. only those events that evoke adverse affective changes result in cortisol enhancement. By their very nature, ongoing daily work related stressors probably do not evoke strong enough emotional reactions to affect cortisol.

Alternatively, simultaneous psychological assessments and cortisol measurement, is questionable, because peak cortisol secretion do not occur till 20 minutes after a stressful event. On the other hand, accounting for this by collecting saliva (for cortisol analysis) 20 minutes after being beeped (e.g. (Smyth et al., 1998)) is also debatable. Stressful events do not always occur at the moment of the diary beeps, but may have occurred several minutes before. Collecting saliva 20 minutes after the beep therefore does not guarantee that the time lag between event and saliva collecting is 20 minutes, leaving some uncertainty. This time-lag uncertainty will remain as long as the exact time stressful events occur are unknown. Moreover, in the present study appraisals of mood and saliva were collected simultaneously, indicating that the present set up (i.e. not accounting for the time lag in peak cortisol response) clearly allowed to detect the effects of mood states on cortisol.

Finally, the hypothesis that cortisol values on a work day are higher than on a day off could not be confirmed. While being at variance with (Lundberg et al., 1980), it confirms the results of (Sluiter et al., 1998). A regular working day presumably -and fortunately- is not an extreme stressor, nor is it novel or unpredictable. Future studies should concentrate on assessing these situational characteristics in order to determine their effects on cortisol.

Sleep quality

The relationship between sleep quality and cortisol shows some consistency with the results of (Murawski et al., 1960; Henning et al., 1998; Leproult et al., 1997; Friess et al., 1995) who showed that sleep deprivation resulted in elevated cortisol. Interestingly, our study shows the relationship between sleep quality and cortisol to vary from subject to subject (random effect). Differences between subjects regarding the circadian cortisol rhythm was also demonstrated by Hennig et al (1998). Atypical rhythms were associated with neuroticism. In future research, identification of these subjects will further improve our understanding of cortisol dynamics. From a similar point of view, it is worthwhile mentioning that the cortisol decrease throughout the day, does not hold for all subjects. The effect of time of day on cortisol is also random. Slow unwinding is claimed to contribute to accumulating fatigue, and to health problems (Kuiper et al., 1998). In the present study we could not identify the individual differences accounting for these random effects, although we have determined that effort-reward imbalance, did not help explain them. We expect that clarifying the individual characteristics determining both the decrease during the day and the relationship between sleep quality and cortisol will contribute towards an understanding of the psychobiological concomitants of fatigue or burnout.

Future studies

In conclusion, the present study has provided in insight into cortisol dynamics throughout a working day and a day-off. Data obtained from within-day measurements can be used in addition to other assessment methods, such as repeated exposure and aggregation (Pruessner et al., 1997). The results from the present study can be used to design future experiments in the field. More specifically, if most cortisol variance is explained at the subject level, the effects will be ascribed to differences between subjects on the explanatory variable. In this example, the effects vary with subjects, and are therefore refereed to as “subject-dependent”. If most of the variance is explained at the within-day level, the effects are probably due to differences within a day. Thus, the effects vary from situation to situation, and are referred to as “situation-dependent”. Table 3 shows that 84% of the variance in cortisol is at the within-day level, and 16% at the subjects. This means that even if all the variance is explained, only 16% is due to differences between subjects. The remaining 84% is situation dependent. This variance can only be explained by other within-day variables, which has implications for future research. The largest portion of cortisol variance is at the within-day level. To explain this variance explanatory within-day variables, rather than subject-level variables should be tested.

The present study shows ample leads to future studies that focus on ambulatory measurement of cortisol variations. The impact of a psychological state, negative mood, on cortisol could be confirmed and seems to be a robust one by now. This study confirms the hypothesis that affect rather than work related stress (e.g. ERI or ADS-R) is related to cortisol in a healthy population. On the other hand, it is comforting to realise that experiencing minor stressors in normal daily life does not lead to increased cortisol that on the long run may be connected with negative health outcomes. Furthermore, the Effort-Reward Imbalance model explicitly states that although distress and negative emotions are important, a direct pathway (not via negative affect) to negative health also exists (Siegrist et al., 1997). The present study could not test this hypothesis, but could determine the relative importance between work stress and affect on cortisol throughout the day in a working population. The results show that at least for the present healthy population, affect (negative mood) is related to cortisol responses, not ERI or the demand/satisfaction ratio.

It is interesting to seek whether increases in negative affect may be responsible for other behavioural changes such as sleep deprivation, and if relations with health can be established through such alternative routes. Individual differences in both daily variations and the effect of sleep quality on cortisol offer promising links to understand psychobiological mechanisms for fatigue, burnout or even other health problems.

Chapter 6

General discussion

This thesis set out to test the short-term effects of work stress in the daily environment, using the Effort-Reward Imbalance (ERI) theory as a conceptual framework. Work stress was primarily defined as imbalance between perceived effort and reward in the work environment. According to the ERI theory, the effects should be both in the psychological ("emotional distress") and the physiological ("autonomic activation") domain. Intensive and secure ambulatory measurements were performed to assure reliable and valid measurement of these effects. Advanced multilevel statistical analysis was used to ascertain that information was correctly obtained from these data. This discussion will primarily focus on the research questions as formulated in the introduction, and conclude with a general evaluation.

<u>Question nr. 1</u>

Are the basic constructs of the effort-reward imbalance theory (effort, reward and need for control), adequately measured by the Dutch version of the effort-reward imbalance questionnaire

A first step was to ensure that the Dutch version of the ERI questionnaire was a reliable and valid instrument to assess the intended form of work stress. Adequate reliability and validity was found for the 'effort' and 'reward' subscales. The same goes for the 'need for control' subscale after revision (i.e. some items were dropped). The results also show some overlap between the effort and reward subscales. A closer look at the formulation of the items may partly explain this overlap. The subjects were asked to rate 'how distressing' certain effortful and rewarding aspects of their work were. Because in both cases a 'distress' rating was given, it is plausible that 'effort' and 'reward' indeed have some overlap. It could be argued that what is actually measured is the perceived 'distress' associated with 'effort' and 'reward' rather than the 'effortful' and 'rewarding' aspects of the work environment itself. This suggests that the effort and reward subscales are contaminated. Future efforts should be made to reformulate the items, avoiding the shared conceptual overlap with distress.

In sum, it was established that the basic constructs of the ERI theory (effort, reward and need for control), are adequately measured using the Dutch ERI questionnaire. The need for control scale was revised to increase its reliability. Future studies in this domain should make use of this revised questionnaire (see appendix 1: VIB version 2.0). Despite some critical remarks, the Dutch ERI questionnaire is a valid and reliable instrument to assess work stress in the main research endeavours of this thesis.

Additional conclusions about ERI and its measurement can be drawn from the studies with the ERI questionnaire. First, in the ERI literature, the terms *extrinsic* and *intrinsic* are often used to reflect contrasting aspects of effort (Siegrist, 1996a). Intrinsic effort is strongly linked with an individual's personality or motivational drive. Extrinsic effort is supposed to reflect factors in the environment leading to effort, and it somewhat resembles the construct "job demand" as described by Karasek and Theorell (1990). As argued above, what the ERI questionnaire actually measures is an individual's (intrinsic) perceived "distress" associated with demanding aspects of the work environment. This perception of distress reflects intrinsic qualities of effort rather than extrinsic qualities. Thus both the extrinsic effort and need for control scales may reflect an individual's perception of the work environment, rendering the intrinsic-extrinsic distinction superfluous. To avoid this confusion, the term need for control[1] should be preferred instead of intrinsic effort.

A second consideration concerns the possibility that subjects rate or interpret ERI items differently, leading to unwanted variation. An ambiguous numeric scale used to reflect the severity of "distress" causes this bias. For example, subjects had to reply to the effort item "I have constant time pressure due to heavy workload" on a severity scale ranging from "not at all distressed" to "very distressed". Individuals differ in what they consider "very distressing". Instead of this, a better approach would be to quantify how often a specific event occurred (e.g. everyday, once a week, once a month etc.). This is a more robust form of self-rating, since severity is rated by using indices of frequency rather or fixed anchors than rating subjective feelings (Frese and Zapf, 1988; Zapf et al., 1996). In the future the ERI questionnaire should be made less susceptible to the above-mentioned unwanted variation by introducing more robust forms of self-rating.

A third aspect that has to be considered in future research, is the choice of norm values for ERI. To date, several different methods have been used to determine if an individual or group suffers from ERI. For example Peter et al. (1998) calculated ERI by dividing the effort scores by the reward scores, after correcting for the number of items. Individuals with ratios higher than 1 were considered to be "at risk" for cardiovascular disease. It should be noted that ERI ratios above 1 are rather uncommon in healthy populations. From the population studied in chapter 2 (n=775) 4.9% (i.e. 38 subjects) had an ERI above 1. Of the subpopulation studied in chapter 3, 4 and 5 none had an ERI above 1. This suggests that the subpopulation was not at risk according to this criterion. The criterion however does not take scores on need for control into account, and therefore may be considered incomplete.

Another method to identify subpopulations "at risk" does involve need for control (Siegrist et al., 1992; 1997). In this method, tertile scores were determined for each variable (i.e. effort, reward or need for control). Subjects that had upper tertile scores for at least two variables were considered at risk. Yet another study (Siegrist et al., 1990) suggested that two indicators of high effort (work pressure and immersion (i.e. need for control)) and two indicators of low reward (status inconsistency, job insecurity) can be used to predict new coronary events. Given the above, it may be concluded that it is still not clear what may be understood by being at risk. In this thesis, need for control was considered a separate distinguishable factor, with possible effects on vagal control of the heart. Therefore some importance was given to the interaction between ERI and need for control. Futures studies should test this assumption, and determine a reliable index of being "at risk" that includes need for control.

[1] Recent ideas communicated by Siegrist suggest using another term: "over commitment".

Question nr.2a

What is the relation between the basic constructs of the effort-reward imbalance theory and its within-day counterparts (demand and satisfaction)?

The main goal of the study reported in chapter 3, was to determine the relation between the basic constructs of the ERI theory and its within-day counterparts demand and satisfaction. Hypothesised relations with within-day measurements of negative mood were also tested. The results show that effort and reward are positively associated with their within-day counterparts demand and satisfaction, respectively. This means that these within-day constructs do reflect the subject level variables (single occasion questionnaire assessments) effort and reward, and can be used for testing the short-term affects of work stress in the remainder of this thesis. Effort is associated with a higher negative mood, and reward is associated with a lower negative mood. Thus, the hypothesised link with affect (an index of emotional distress) is confirmed. Still, there is also substantial variance left at the beep level to be explained by other variables. It is also concluded that using a multilevel analysis, the short-term effects of ERI and need for control on within-day psychological and psychobiological variables (like cortisol and heart rate variability) can be determined.

Question nr.2b

Which methodological approach should be used to analyse multiple occasion data (EMA)?

Determining the appropriate approach to analyse the multiple occasion data (i.e. EMA or ESM data) drew strongly from the work of Bryk and Raudenbush (1987, 1992), Jaccard and Wan (1993), Hox (1994), Goldstein (1987, 1995), Woodhouse et al. (1996), Berry (1997), and Schwartz and Stone (1998). These authors propagate a multilevel analysis or "random coefficient model" as the most adequate method to analyse multiple occasion data. Using multilevel analysis, it can be determined *if* and *at which level* a within-day, daily, or subject level independent (or explanatory) variables may have an effect on the dependent variable. This was done for variables used to reflect the short-term effects of ERI and affect, confirming multilevel analysis as a suitable method to analyse multiple occasion data. The results showed that the variance of demand, satisfaction, negative mood and positive mood is divided over three levels (subject level, daily level or within-day level). It is concluded that with this method the short-term effects of ERI (measured at the subject level) on within-day psychological and psychobiological variables (such as cortisol and heart rate variability) can be determined. Moreover, well know biases (Jaccard & Wan, 1993) resulting from aggregating or disaggregating data, listwise deleting subjects are prevented.

From the analyses performed in chapter 3, other information has been gained as well. First, the study illustrates that the distribution of variance across the levels in the data can be used to determine at which level effects are most likely to be found. If most variance is at the subject level, the variable is presumed to be more "subject-dependent" (or stable). Effects at this level are due to differences between subjects on an explanatory variable. If most variance is at the within-day level, the variable is presumed to be more "situation-dependent". Effects at this level are due to differences between measurement points. In the study reported in chapter 3 it was found that the variables demand and satisfaction are predominantly "situation-dependent", and positive mood is more "subject-dependent". Negative mood is in between these two and may be considered predominantly "day-dependent".

Second, determining the amount of variance of a particular variable at different levels may have implications for the future design of EMA or ESM experiments. Finding a lot of variance at the lowest (e.g. within-day) levels legitimates the use of time consuming and costly EMA assessments. This also means that the chances of explaining effects at this level are large. Thus, large variance at the lowest level means that the effort put into performing the within-day measurements was not in vein. Little (or no) variance at the within-day level suggests that effects should be sought at a higher level. If this is the case, performing more stable (e.g. daily or single/cross-sectional) measurements may suffice. However, such conclusions should be drawn with some caution. Little variance at the within-day level does not mean that no effects will be found at this level. On the other hand a large variance at the within-day level does not guarantee that independent variables measured within the days will always have a significant effect at that level. It may be concluded that the amount of variance at a particular level indicates, but does not guarantee where (i.e. at which level) potential independent (or explanatory) variables may have an effect. Large variance at the within-day level warrants EMA assessment, in contrast to little variance. Such information is useful for the design of future EMA studies.

In conclusion, it was established that EMA data can best be analysed by multilevel analysis. With this method the potential richness of the data (e.g. time of day variations, or differences between days) can be explored without introducing biases sometimes associated with other forms of analysis (e.g. aggregating or disaggregating data).

Question nr.3

What are the effects of effort, reward, need for control and within-day measurements of demand, satisfaction and mood on autonomic nervous system vagal activity throughout the day?

A high need for control, but not high effort or low reward was associated with low vagal control. According to the effort-reward imbalance theory, a high effort-reward imbalance is associated with vigorous striving and an increased "autonomic activation". In the present study, we specified and found no support for this hypothesis when the associations with vagal activation throughout the day were studied. Instead, a third construct from the ERI theory, need for control, was positively associated with vagal withdrawal.

The calculation of an interaction of vagal tone with time of the day shows that vagal tone, at specific times of the day, is affected by effort-reward imbalance: subjects high in effort-reward imbalance have a higher vagal tone later in the day. Because a higher vagal tone has been linked with lower mental effort, this could mean that later in the day, these subjects spend less mental effort to perform their duties. In chapter 4 this was referred to as disengagement. In other terms: subjectively experienced effort-reward imbalance seems to be accompanied by fewer investments in terms of mental effort, towards the end of the day.

It is challenging to interpret these results in the light of risk factors for the development of burnout and vital exhaustion (Appels et al., 1982; Appels & Mulder 1988; Appels 1990): highly striving individuals whose aspirations are not fulfilled may finally give up. Thus, in line with (Nelissen-de Vos, 1994) a relation is suggested between need for control, vital exhaustion and myocardial infarction. In addition to this, it is hypothesised that lower vagal control has a mediating role in this relationship. This hypothesis is supported by Liao et al., (1997) who showed that a lower vagal control is associated with cardiac events. The primary component of burnout (Schaufeli & Buunk, 1996) is strongly related to vital exhaustion. Future studies have to determine whether this concept is also mediated by need for control and eventually to negative health outcomes such as cardiovascular disease.

Question nr.4

What are the effects of effort, reward, need for control and within-day measurements of demand, satisfaction and mood on hypothalamo-pituitary-adrenocortical (HPAC) axis activity throughout the day?

The study in chapter 5 shows that ERI or within-day measurements of these constructs (ADSR) do not have an effect on cortisol levels throughout the day. Only within-day measurements of negative mood were related to cortisol. According to Kirschbaum and Hellhammer (1989, 1994), cortisol levels are elevated as a result of novelty, social pressure or loss of control. Van Eck et al., (1996) and Smyth et al., (1998) have linked cortisol levels throughout the day to the appraisal of within-day stresssors. Importantly they found the effects to be mediated by negative affect. Buchanan et al. (1999), Frankenhaeuser et al. (1980), and Lundberg & Frankenhaeuser (1980) also reported the hypothesised mediating effects of negative affect. Others have suggested that not negative affect but emotional arousal is responsible for the increase in cortisol (Pollard et al., 1996; Pollard, 1995). The results of chapter 5 emphasise the importance of negative affect. More specifically, within-day measurements of negative mood may affect cortisol whilst trait negative affect does not. This emphasises the importance of within-day assessments and the benefits it may have in clarifying the stress-cortisol relationship.

The finding that the actual demand-satisfaction ratio was not related to cortisol is somewhat in contradiction to the results obtained by Frankenhaeuser et al. (1980). Interestingly, Smyth et al. (1998) and van Eck et al. (1996) found that the relation between daily stresssors and cortisol disappeared if negative affect was controlled for. These authors also argue that the frequency and duration of stressful events is related to the increase in cortisol. Thus cortisol increases might not be found if the stressful event occurred a long time before cortisol was measured (i.e. 1-2 hours), or if it did not last long. Future studies of stressful events and cortisol should take this timing effect into account.

Final evaluation: Implications for future research

Although the population involved in this study was selected because high work stress was anticipated (reorganisation, complaints about the work environment, etc.). The perceived levels of stress as indicated by the effort-reward imbalance ratio (ERI), showed few relations with physiological variables. Possibly, before effects become visible, some threshold should be exceeded, after which changes in physiological activity throughout the day become visible. As was discussed earlier, of the subpopulation of 77 subjects studied in chapters 3-5, none had an ERI higher that 1. This suggests that the subjects may not be "at risk" according to the ERI theory. However, the focus of the present thesis was not to identify subjects at risk. From a psychological point of view (i.e. intervention or prevention) it makes more sense to identify psychological and physiological changes at an earlier stage. This means involving all subjects in the analysis, even though they may not be at risk according to the definition of ERI of Siegrist (1996b).

Recent theorising, modern equipment for ambulatory measurements and advanced statistical methods were applied to thoroughly test assumptions concerning the short-term effects of work stress in the daily environment. Intensive measurements were performed throughout the day enabling the construction of within-day measurements of effort and reward: demand and satisfaction (also referred to as the Actual Demand-Satisfaction Ratio ADSR). It was hypothesised that relatively high levels of ERI and ADSR would be associated with changes in cortisol secretion and heart rate variability throughout the day. Subjects showed the expected relations with time of day, smoking and food consumption, but not with ERI or ADSR. Even with this close scrutiny, no support could be found for the short-term explanatory value of ERI and ADSR on the chosen physiological variables.

A review of the literature shows that a large portion of contemporary psychological research is based on the assumption that individual differences in psychological make-up are robust. This means that individuals may be categorised according to cross-sectional (single occasion) assessments of their perceived work stress. Extremes in these measurements (i.e. exceeding norm values) are considered abnormal, and are sometimes associated with negative health outcomes. Such relationships are supported by empirical evidence in the form of cross-sectional studies and longitudinal studies that use only one (single occasion) assessment of work stress (Kasl, 1991). This view of stable environmental influences has been challenged, emphasising the role played by the objective environment.

In the present thesis, evidence has been sought to support the above-mentioned assumption (allowing categorisation based on psychological make-up) by assessing the short-term effects of ERI. Although quite interesting with respect to new developments in the field (i.e. EMA provides information not accessible with traditional single occasion assessments), the study reveals only one new relation with physiological variables measured throughout the day. Only need for control was positively related to vagal withdrawal, and negative mood was related to an increase in cortisol secretion throughout the day, confirming other findings (van Eck et al., 1996; Smyth et al., 1998). Based on face validity, need for control and negative mood are related to the type A construct and negative affect, respectively, constructs that hardly reflect work stress alone. Thus, based on the evidence from the present thesis, it may be concluded that the widely held assumption - that work stress is associated with physiological changes in an individual, does not hold for a normal working population, - at least for the physiology as measured in the present study. This doubt has also been expressed by House et al., (1986), and Kasl (1991), and will probably remain till a different approach is used. For instance, more attempts should be made to assess objective environmental demands, or using physiological changes in subjects to identify subjects “at risk” instead of trait-like perceptions of an individual.

This means that it may be worthwhile reversing the assumed causality in traditional research. Instead of identifying subpopulations “at risk” based on psychological trait or psychosocial perceptions of the work environment, these subpopulations can be identified based on physiological characteristics known to affect health. Then, it can be determined whether physiology is related to psychological or psychosocial concomitants such as ERI, ADSR and affect. In addition to this, the prospective character of the psychological constructs should be emphasised. For example, rather than measuring ERI at a single point in time, multiple prospective assessments should be performed. This will ensure that the assessment of ERI reflects a prevailing condition rather than a temporary state of high work stress captured by chance. An attempt to achieve this has been initiated by repeating the EMA measurements on a cross-section of the population at hand. The results are yet to be analysed and will be reported as part of the Netherlands Organisation for Scientific Research (NWO) ‘Fatigue at Work’ programme.

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Summary

In this thesis, a relatively new approach is presented that is used to study changes in psychological and physiological variables resulting from a demanding work environment. Rather than solely focusing on the traditional cross-sectional measurements used to indicate psychosocial indices of work stress, daily and within-day measurements are also performed. With this approach, some relevant issues are identified, and methodological solutions provided to what is considered one of the most promising areas in behavioral medicine: "ongoing-psychophysiological measurements" or "ecological momentary assessments" (EMA).

The aim of the thesis is to determine the short-term effects of work stress on the psychology and physiology of individuals. This entails studying psychological and physiological changes throughout the day associated as well as a single assessment of work stress (i.e. a cross-sectional assessment using a questionnaire). To achieve this, four studies are performed, each of which are shortly described below. An introduction of the work stress theory and a formulation of the main questions precede the description of the separate studies. The thesis ends with a general evaluation of the results.

The operationalisation of work stress is based on a theory called the Effort-Reward Imbalance (ERI) theory, introduced in the first chapter. The theory emphasises that it is the perception and evaluation of social exchange in relationships that determine successful functioning and health. The ERI theory states that "imbalance" occurs if the *effort* that is exerted during work does not correspond with the *reward* that is obtained. This situation is associated with "emotional distress" and a "sustained activation of the autonomic system", and eventually with the incidence of cardiovascular disease. The theory also states that the risk for cardiovascular disease is increased if individuals have a high need for control.

To enable an assessment of the short-term effects of ERI, the terms "autonomic activation" and "emotional distress" are defined more precisely, and measured throughout the day. To determine short-term physiological effects of ERI, indices of two important processes are measured: vagal cardiac control and hypothalamo-pituitary-adrenocortical (HPAC) axis activation. According to the literature, vagal control decreases as environmental demands increase. Vagal withdrawal is associated with the development of cardiovascular disease, which is of relevance to the ERI theory. Because of this, heart rate variability, an index of vagal cardiac control is used in the present thesis. The other major psychophysiological process, HPAC axis activity is indicated by cortisol secretion. Cortisol increases have also been associated with increases in work stress, and is therefore also measured.

To determine the short-term psychological effects of work stress, within-day measurements of demand, satisfaction and mood are performed. The variables demand and satisfaction are considered the within-day counterparts of effort and reward. Carrying out within-day measurements necessitates the use of a specific data collection method: Ecological Momentary Assessment (EMA). The method entails a self-report of a

subject's experiences, thoughts, feelings, activities or whereabouts throughout the day over several days. The self-reports are filled in after a palmtop computer prompts the subjects at random moments throughout the day. The self-reports are coupled with the cortisol and heart rate variability measurements.

The main questions asked in this thesis are:
1 Are the basic constructs of the effort-reward imbalance theory (effort, reward and need for control), adequately measured by the Dutch version of the effort-reward imbalance questionnaire?
2 (a) What is the relation between the basic constructs of the effort-reward imbalance theory and its within-day counterparts (demand and satisfaction)?
2 (b) Which methodological approach should be used to analyse multiple occasion data (EMA)?
3 What are the effects of effort, reward, need for control and within-day measurements of demand, satisfaction and mood on autonomic nervous system vagal activity throughout the day?
4 What are the effects of effort, reward, need for control and within-day measurements of demand, satisfaction and mood on hypothalamo-pituitary-adrenocortical (HPAC) axis activity throughout the day?

The first main question is addressed in chapter 2. The reliability and validity of the Effort-Reward Imbalance Questionnaire is tested in a population of 775 blue and white collar workers in the Netherlands. The study leads to the following conclusions: The basic constructs of the ERI theory (effort, reward and need for control), are adequately measured using the Dutch ERI questionnaire. Some items were dropped from the need for control scale to increase its reliability. Future studies in this domain should make use of this revised questionnaire. Despite some critical remarks, the Dutch ERI questionnaire is a valid and reliable instrument to assess work stress in the main research endeavours of this thesis.

The second main question is addressed in chapter 3. The main goal is to determine the relation between the basic constructs of the ERI theory and its within-day counterparts demand and satisfaction. Hypothesised relations with within-day measurements of mood are also tested. In addition to this, a method is described for analysing multiple occasion data: "random coefficient model or multilevel analysis". This study was performed in a subpopulation of 77 male and female workers, using an electronic diary that was kept for a week. The results show that effort and reward are positively associated with their within-day counterparts demand and satisfaction, respectively. This means that these within-day constructs do reflect the subject level variables (single occasion questionnaire assessments) effort and reward, and can be used for testing the short-term effects of work stress in the remainder of this thesis. A high effort is associated with a high negative mood, and a high reward is associated with a lower negative mood. Thus, the hypothesised link between work stress and affect (or emotional distress) is confirmed. Still, there is also substantial variance left at beep level to be explained by other beep level variables. It is also concluded that using a multilevel analysis, the short-term effects of ERI and need for control on within-day psychological and psychobiological variables (like cortisol and heart rate variability) can be determined.

The third main question is addressed in chapter 4. In this study the short-term effects of effort, reward and need for control on vagal cardiac control are determined. Vagal cardiac control is indicated by the power in the high frequency (0.14 - 0.40 Hz) band of the inter-beat-interval of ECG R-tops (HF_HRV). A multilevel analysis is used to distinguish the effects of single occasion and multiple occasion measurements of work stress and affect on HF_HRV throughout the day. The single (or cross-sectional) occasion assessments include effort-reward imbalance, need for control, negative affect, and other enduring factors (type of occupation, gender and smokers). The multiple occasion measurements, include negative mood, actual demand-satisfaction ratio (ADSR), sleep quality, workload (workday versus day-off) and lunch. The effect of time of day on HF_HRV was controlled for before the remaining relationships were determined. A high need for control, but not high effort or low reward is associated with low vagal control. Thus, no support is found for the hypothesis that a high ERI is associated with vigorous striving, and an increased "autonomic activation". Instead, a third construct from the ERI theory, need for control, is positively associated with vagal withdrawal. An interesting interaction was found between ERI and time of day. As the day progressed, vagal cardiac control increased. A higher vagal tone has been linked with lower mental effort as the day progresses. This suggests that later in the day, these subjects spend less mental effort to perform their duties.

The fourth main question is addressed in chapter 5. In this chapter, the effects of variables from the ERI model on salivary cortisol secretion throughout the day are assessed. The analyses were performed using the same method as described in chapter 4. The results show that ERI or within-day measurements of these constructs (ADSR) do not have an effect on cortisol secretion throughout the day. Only within-day measurements of negative mood are positively related to cortisol.

In conclusion, in the present thesis, the short-term effects of ERI are studied by measuring indices of vagal control, HPAC activity and affect. The studies provide an illustration of recent developments in the field. Primarily, EMA provides information on psychological measurements throughout the day, and reveals information not accessible using traditional single occasion assessments of perceived work related stress. In the present thesis both traditional and EMA measurements were performed. Is spite of the extensive nature of the studies, only limited and indirect empirical support was found for the hypothesised relation between work stress and physiology measured throughout the day. Only need for control is positively related to vagal withdrawal, and negative mood is related to an increase in cortisol secretion throughout the day. These results are of interest to psychobiology in general, but are not of direct importance to the work - stress relation. Based on face validity, it is argued that need for control and negative mood are related to the type A construct and trait negative affect, respectively, constructs that hardly reflect work stress alone. The present thesis uses sophisticated state-of-the art assessment methods and analysis techniques to determine the short-term physiological effects of ERI. Based on the evidence from the present thesis, it may be concluded that the widely held assumption - that work stress is associated with physiological changes in an individual -, does not hold, at least for the normal working population studied here. This questions the pursuit of short-term physiological effects of work stress in a normal working population. Probably, such attempts will remain fruitless till a different approach is used. More attempts should be made to assess objective environmental demands, or to use physiological changes to identify individuals “at risk”, instead of trait-like individual perceptions.

Samenvatting

In dit proefschrift wordt een relatief nieuwe benadering gepresenteerd om veranderingen in psychologische en fysiologische variabelen te bestuderen, die het gevolg zijn van een belastende werkomgeving. Als aanvulling op de traditionele methoden die psychosociale werkstress slechts één keer meten, worden dagelijkse en meervoudige metingen binnen één dag verricht. Met deze benadering is een aantal belangrijke uitkomsten verkregen en methoden ontwikkeld ten behoeve van één van de meest veelbelovende toepassingsgebieden van gedragswetenschappen en geneeskunde: "herhaalde psycho-fysiologische metingen" of "tijdstipgebonden ecologische metingen".

Het doel van dit proefschrift is het bepalen van de korte-termijn effecten van werkstress op de psychologie en fysiologie van mensen. Dit omvat het bestuderen van psychologische en fysiologische veranderingen gedurende de dag en één enkele meting van werkstress. Hiervoor werden vier onderzoeken uitgevoerd. Een introductie van de werkstress theorie en een beschrijving van de hoofdvragen gaan vooraf aan een beschrijving van de verschillende onderzoeken. Het proefschrift eindigt met een algemene evaluatie van de resultaten.

De operationalisatie van werkstress is gestoeld op de zogenaamde *Effort-Reward Imbalance* theorie, (ERI), die in het eerste hoofdstuk wordt behandeld. Deze theorie benadrukt het belang van een evenwicht tussen inspanning en beloning en stelt dat het waarnemen of evalueren van sociale uitwisseling van invloed is op adequaat functioneren en gezondheid. Zij gaat er vanuit dat het evenwicht verloren gaat als de inspanningen tijdens het werk niet in verhouding staan tot de ontvangen beloningen. Een dergelijke onevenwichtige situatie wordt in verband gebracht met een emotionele wantoestand, de zogenaamde *emotional distress*, en een voortdurende activiteit van het autonome zenuwstelsel, de zogenaamde *autonomic activation*. Op den duur kan deze onevenwichtige situatie leiden tot het ontstaan van hart- en vaatziekten. Volgens de theorie hebben personen met een verhoogde behoefte aan regelmogelijkheden een hogere kans op hart- en vaatziekten.

Om de korte-termijn effecten van ERI te kunnen bepalen, zijn de begrippen autonomic activation en emotional distress nader gespecificeerd en gemeten op meerdere tijdstippen gedurende de dag. Om de fysiologische korte-termijn effecten te bepalen zijn de vagale invloeden op het hart en de activiteit van het hypothalamus-bijnierschors systeem (HPAC-as) gemeten. Volgens de literatuur nemen de vagale invloeden op het hart af als de omgevingseisen toenemen. Een afname van vagale activiteit wordt in verband gebracht met de ontwikkeling van hart- en vaatziekten, hetgeen van belang is voor de ERI theorie. Hiervoor wordt de hartslag variabiliteit bepaald die een indirecte maat is van vagale invloeden op het hart. Het tweede belangrijke fysiologische proces, de HPAC-as activiteit, wordt weergegeven door cortisol afscheiding. Een toename in cortisol wordt in verband gebracht met een toename in werkstress. Om de korte-termijn psychologische effecten van werkstress te bepalen worden metingen gedaan van vereisten, tevredenheid en stemming op meerdere tijdstippen van de dag. De variabelen vereisten en tevredenheid zijn afgeleid van de aan eenmalige meting van werkstress gerelateerde begrippen inspanning en beloning. Het uitvoeren van meerdere metingen op één dag vereist het gebruik van nauwgezette methoden om data te verzamelen, de zogenaamde *tijdstipgebonden ecologische metingen* (EMA). Deze methode behelst een zelfrapportage van ervaringen, gevoelens, gedachten, activiteiten en locatie gedurende de dag, over meerdere dagen. De zelfrapportages worden met een Organizer bijgehouden en zijn gekoppeld aan de hartslag variabiliteit en cortisol metingen. De tijdstippen waarop de zelfrapportages worden ingevuld zijn willekeurig en worden aangegeven door de Organizer.

De hoofdvragen van dit proefschrift zijn als volgt:

1) Worden de kernbegrippen van de ERI theorie, inspanning, beloning en behoefte aan regelmogelijkheden op verantwoorde wijze gemeten door de Nederlandse Vragenlijst Inspanning en Beloning (VIB) op het werk?
2a) Wat is het verband tussen de kernbegrippen van de ERI theorie en verwante begrippen die op meerdere tijdstippen gedurende de dag worden gemeten?
2b) Welke methode is het meeste geschikt om data afkomstig uit herhaalde psycho-fysiologische metingen te analyseren?
3) Wat is het effect van inspanning, beloning, behoefte aan regelmogelijkheden en de binnendaags gemeten variabelen vereisten, tevredenheid en stemming op vagale activiteit gedurende de dag?
4) Wat is het effect van inspanning, beloning, behoefte aan regelmogelijkheden en de binnendaags gemeten variabelen vereisten, tevredenheid en stemming op cortisol gedurende de dag?

De eerste hoofdvraag wordt beantwoord in hoofdstuk 2. De betrouwbaarheid en validiteit van de VIB is getest op 775 werknemers in Nederland. De kernbegrippen van de ERI-theorie, inspanning, beloning en behoefte aan regelmogelijkheden, worden op verantwoorde wijze gemeten door de VIB. Om de betrouwbaarheid te verhogen zijn een aantal vragen verwijderd uit de schaal over behoefte aan regelmogelijkheden. Toekomstig onderzoek op dit terrein zal baat hebben bij het gebruik van de herziene vragenlijst (zie appendix 1). Ondanks een aantal kritische opmerkingen, kan gesteld worden dat de VIB een valide en betrouwbaar instrument is om werkstress te meten in de voor dit proefschrift beoogde onderzoeksgebieden.

De tweede hoofdvraag wordt beantwoord in hoofdstuk 3. Het doel is het bepalen van het verband tussen de kernbegrippen van de ERI theorie en de verwante begrippen vereisten en tevredenheid, die op meerdere tijdstippen gedurende de dag worden gemeten. Het veronderstelde verband met binnendaagse metingen van stemming wordt ook getoetst. Bovendien wordt een methode uiteengezet waarmee EMA data kan worden geanalyseerd, het zogenaamde *random coefficient model* ook wel multilevel analyse genoemd. Dit onderzoek werd uitgevoerd bij 77 werkende mannen en vrouwen, die een Organizer gedurende een week hebben bijgehouden. De resultaten laten zien dat inspanning en beloning een positief verband hebben met de gerelateerde begrippen vereisten en tevredenheid. Dit betekent dat de binnendaagse variabelen daadwerkelijk de persoonsgebonden variabelen inspanning en beloning weergeven, en dat deze variabelen tevens korte-termijn effecten van werkstress reflecteren. Een hoge inspanning is gerelateerd aan een hoge negatieve stemming, en hoge beloning is gerelateerd aan een lage negatieve stemming. Hiermee wordt het veronderstelde verband tussen werkstress en de neiging de wereld negatief te aanschouwen, het zogenaamde *trait negative affect*, wordt bevestigd.. Toch blijft voldoende binnendaagse variantie over die verklaard kan worden door andere binnendaagse variabelen. Deze inzichten leiden tot de conclusie dat met behulp van multilevel analyses, de korte termijn effecten van inspanning, beloning en de behoefte aan regelmogelijkheden op binnendaagse metingen van fysiologische variabelen kunnen worden bepaald.

De derde hoofdvraag wordt in hoofdstuk 4 beantwoord. In dat onderzoek worden de korte-termijn effecten van inspanning, beloning, en de behoefte aan regelmogelijkheden op vagale activiteit bepaald. De vagale activiteit is afgeleid uit de energie in het hoge frequentiespectrum (0.14 – 0.40 Hz) van het hartslag interval (HF_HRV). De effecten van éénmalige metingen van werkstress en emoties op HF_HRV gedurende de dag zijn met behulp van een multilevel analyse in kaart gebracht. De éénmalig gemeten variabelen zijn: inspanning, beloning, behoefte aan regelmogelijkheden, beroep, geslacht en roken. De meervoudige metingen omvatten: vereisten, tevredenheid, negatieve stemming, slaapkwaliteit, werklast en het middageten. Het effect van deze variabelen op HF_HRV is bepaald nadat het effect van de tijdstip van de dag is gecontroleerd. Een hoge behoefte aan regelmogelijkheden, maar niet een hoge inspanning of een lage beloning worden in verband gebracht met verminderde vagale invloeden op het hart. De veronderstelling dat een hoge inspanning en een lage beloning leidt tot een toegenomen "autonome activiteit" wordt dus niet ondersteund. Wel wordt een derde begrip dat onderdeel is van het ERI theorie, namelijk de behoefte aan regelmogelijkheden, in verband gebracht met vagale activiteit. Mensen die een hoge behoefte hebben aan regelmogelijkheden blijken een verlaagde vagale invloed te vertonen op het hart. De resultaten laten ook een interessant verband zien tussen ERI en tijdstip van de dag. De vagale invloeden op het hart nemen toe naarmate de dag vordert. Omdat een hoge vagale invloed in verband is gebracht met een lage mentale belasting, kan geconcludeerd worden dat de onderzochten zich mentaal minder inspannen later op de dag.

De vierde hoofdvraag wordt beantwoord in hoofdstuk 5, waarin de effecten van kernbegrippen uit de ERI theorie op cortisol afscheiding gedurende de dag worden behandeld. In dit hoofdstuk worden dezelfde analysemethoden gebruikt als in hoofdstuk 4. De resultaten laten zien dat het evenwicht tussen inspanning en beloning, en de binnendaagse metingen van deze begrippen (de vereisten/tevredenheid ratio) geen effect hebben op de cortisol afscheiding gedurende de dag. Slechts een toename in negatieve stemming blijkt gerelateerd te zijn aan een toename in cortisol afscheiding.

Concluderend, in dit proefschrift zijn de korte-termijn effecten van ERI bepaald door vagale controle, HPAC-as activiteit en stemming te meten. Dit proefschrift sluit aan bij recente ontwikkelingen op het gebied van ambulante psychofyisologische metingen, en laat zien hoe EMA data verzameld en geanalyseerd kan worden, hetgeen niet mogelijk is met traditionele éénmalige (vragenlijst) metingen. Slechts in twee gevallen is empirische ondersteuning gevonden voor de aanname dat werkstress een effect heeft op fysiologie gedurende de dag. De EMA metingen laten wel een negatief verband zien tussen de behoefte aan regelmogelijkheden en vagale invloeden op het hart. Voorts is een positief verband is gevonden tussen negatieve stemming en cortisol afscheiding gedurende de dag. Deze resultaten zijn van belang voor de psychobiologie in het algemeen, maar slechts van beperkte waarde voor de relatie tussen werk en stress. Een validiteitsbeoordeling op inhoudelijke gronden laat zien dat de behoefte aan regelmogelijkheden en negatieve stemming achtereenvolgens sterk lijken op de persoonskenmerken "type A" en een persoonsgebonden neiging de wereld negatief te beschouwen, het zogenaamde "trait negative affect". Dit zijn begrippen die niet per se iets te maken hebben met werkstress. Dit proefschrift gebruikt vernuftige en moderne meetmethoden en analyse technieken om de korte-termijn effecten van ERI te bepalen. De belangrijkste conclusie van dit proefschrift is dat de wijd verspreide aanname dat werkstress in verband kan worden gebracht met fysiologische veranderingen niet opgaat, althans niet voor de in dit proefschrift onderzochte groep normale werkenden. Dit leidt tot de vraag of het nog zin heeft onderzoek te verrichten naar de korte-termijn fysiologische effecten van werkstress bij een normale groep werkenden. Waarschijnlijk zullen dergelijke pogingen zonder resultaat blijven totdat een geheel andere theoretisch paradigma wordt gebruikt. Meer pogingen zullen moeten worden ondernomen om de objectieve omgevingseisen te onderzoeken en tevens zal onderzoek meer gericht moeten zijn op het bepalen van risicogroepen op grond van fysiologische factoren in plaats van persoonsgebonden percepties.

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Vragenlijst over Inspanning en Beloning tijdens het werk

VERSIE 2.0

VIB - Deel 1

Hier volgen enkele uitspraken over mogelijk belastende aspecten van uw huidige werksituatie. Kruis alstublieft het antwoord aan, dat uw werk het beste omschrijft. Als deze situatie niet voorkomt in uw werk, kruis dan "nee" aan:

1. **Er is vaak tijdsdruk door een hoge werkbelasting**
   [] ja
   [] nee
   zo ja: Hoe belastend vindt u dit?

   [] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

2. **Tijdens mijn werk word ik vaak gestoord en onderbroken**
   [] ja
   [] nee
   zo ja: Hoe belastend vindt u dit?

   [] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

3. **Ik draag veel verantwoordelijkheid in mijn werk**
   [] ja
   [] nee
   zo ja: Hoe belastend vindt u dit?

   [] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

4. **Ik moet vaak overuren maken**
   [] ja
   [] nee
   zo ja: Hoe belastend vindt u dit?

   [] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

5. **Mijn werk is lichamelijk inspannend**
   [] ja
   [] nee
   zo ja: Hoe belastend vindt u dit?

   [] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

6. De laatste jaren is mijn werk veeleisender geworden
[] ja
[] nee
zo ja: Hoe belastend vindt u dit?

[] helemaal niet belastend [] matig belastend [] nogal belastend [] zeer belastend

Hier volgen enkele vragen over uw huidige werksituatie. Kruis alstublieft het woord aan, dat uw werk het beste omschrijft.

7. Krijgt u van uw collega's de waardering die u verdient?
[] niet van toepassing
[] ja
[] nee
zo nee: Hoe belastend vindt u dit?

[] helemaal niet belastend [] matig belastend [] nogal belastend [] zeer belastend

8. Ontvangt u van uw meerderen de waardering die u verdient?
[] niet van toepassing
[] ja
[] nee
zo nee: Hoe belastend vindt u dit?

[] helemaal niet belastend [] matig belastend [] nogal belastend [] zeer belastend

9. Krijgt u voldoende ondersteuning in moeilijke situaties?
[] ja
[] nee
zo nee: Hoe belastend vindt u dit?

[] helemaal niet belastend [] matig belastend [] nogal belastend [] zeer belastend

10. Wordt u op het werk onrechtvaardig behandeld?
[] ja
[] nee
zo ja: Hoe belastend vindt u dit?

[] helemaal niet belastend [] matig belastend [] nogal belastend [] zeer belastend

11. Zijn de vooruitzichten op promotie in uw werk slecht
[] niet van toepassing
[] ja
[] nee
zo ja: Hoe belastend vindt u dit?

[] helemaal niet belastend [] matig belastend [] nogal belastend [] zeer belastend

12. Ervaart of verwacht u een ongewenste verandering in uw werksituatie?
[] ja
[] nee
zo ja: Hoe belastend vindt u dit?

[] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

13. Moesten onlangs collega's van u afvloeien?
[] niet van toepassing
[] ja
[] nee
zo ja: Hoe belastend vindt u dit?

[] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

14. Loopt uw baan gevaar?
[] weet niet
[] ja
[] nee
zo ja: Hoe belastend vindt u dit?

[] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

Denk bij de volgende vragen aan alles wat u in uw loopbaan bereikt hebt. Heeft uw inzet resultaat gehad? Heeft u er evenveel voor teruggekregen als u erin gestopt hebt?

15. Vindt u dat uw huidige betrekking in overeenstemming is met uw scholing en opleiding?
[] weet niet
[] ja
[] nee
zo nee: Hoe belastend vindt u dit?

[] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

16. Vindt u dat uw inkomen in overeenstemming is met uw inspanningen en prestaties?
[] weet niet
[] ja
[] nee
zo nee: Hoe belastend vindt u dit?

[] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

17. Vindt u dat de waardering en aanzien die u krijgt in overeenstemming is met uw inspanningen en prestaties?

[] weet niet
[] ja
[] nee
zo nee: Hoe belastend vindt u dit?

[] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

18. Staan uw vooruitzichten op promotie in het werk in verhouding tot al uw inspanningen en prestaties?

[] weet niet
[] ja
[] nee
zo nee: Hoe belastend vindt u dit?

[] helemaal niet belastend []matig belastend [] nogal belastend [] zeer belastend

Vragenlijst over houding ten opzichte van het werk

VERSIE 2.0

VIB - Deel 2

Wilt u bij de volgende zinnen over uw houding ten opzichte van het werk, zonder lang nadenken aankruisen of ze wel of niet kloppen. Als u het moeilijk vindt, een keuze te maken, neem dan het antwoord dat er het dichtst bijkomt. Vul de lijst alstublieft geheel in.

	Klopt	Klopt niet
1. Zelfs de kleinste onderbreking vind ik erg hinderlijk	[]	[]
2. Ik kan echt uit mijn vel springen, wanneer anderen iets niet snel begrijpen	[]	[]
3. Aan mijn werk mag niemand komen	[]	[]
4. Ik heb alleen dan het gevoel succesvol te zijn, wanneer mijn prestaties mijn verwachtingen overtreffen	[]	[]
5. Als ik iets uitstel dat ik eigenlijk vandaag had moeten doen, kan ik ’s nachts niet slapen	[]	[]
6. Het werk laat me zelden los, zelfs ’s avonds spookt het nog door mijn hoofd	[]	[]
7. Het gebeurt me vaak dat ik al bij het wakker worden aan problemen op het werk denk	[]	[]
8. Als ik thuis kom, kan ik mijn werk heel gemakkelijk van me afzetten	[]	[]
9. Mijn partner zegt dat ik me teveel voor mijn werk opoffer	[]	[]

Voorbeeld dagboek voor EMA metingen

VERSIE 1.0 LOVV – Ptt Telecom

1. **Ik zit nu op mijn werk (bij LOVV)**
   [] ja
   [] nee

2. **Ik was met het volgende bezig**

	Standaard 1 & 2	**Administratieve ondersteuning**
1.	Algemene correspondentie / factureren	Probleem oplossen
2.	Oplossen van belemmeringen	Administratieve taken
3.	Orderbehandeling	Algemene informatie verstrekken
4.	Klachtenverwerking	Maken van rapportages
5.	(Andere) rapellijst opdrachten	Uitzetten van orders/aanvragen
6.	Diversen	Diversen
7.	Rustmoment	Rustmoment
8.	Lijn beschikbaar stellen	Vergaderen
9.	Ik zit niet op mijn werk	Ik zit niet op mijn werk

3. **SINDS DE VORIGE PIEP heb ik onder tijdsdruk gestaan**
   [] ja
   [] nee
   zo ja: Dit vind ik belastend

   []niet [] [] [] zeer

4. **SINDS DE VORIGE PIEP werd ik vaak gestoord en onderbroken**
   [] ja
   [] nee
   zo ja: Dit vind ik belastend

   []niet [] [] [] zeer

5. **SINDS DE VORIGE PIEP heb ik me lichamelijk ingespannen**
   [] ja
   [] nee
   zo ja: Dit vind ik belastend

   []niet [] [] [] zeer

6. **SINDS DE VORIGE PIEP zijn mijn bezigheden de moeite waard geweest**
   [] ja
   [] nee
   zo nee: Dit vind ik belastend

   []niet [] [] [] zeer

SINDS DE VORIGE PIEP is mijn inbreng erkend

[] ja
[] nee
zo nee: Dit vind ik belastend

[]niet [] [] [] zeer

7. OP DIT MOMENT VOEL IK ME somber

[]niet [] [] [] [] [] [] zeer

8. OP DIT MOMENT VOEL IK ME vrolijk

[]niet [] [] [] [] [] [] zeer

9. OP DIT MOMENT VOEL IK ME boos

[]niet [] [] [] [] [] [] zeer

10. OP DIT MOMENT VOEL IK ME ongelukkig

[]niet [] [] [] [] [] [] zeer

11. OP DIT MOMENT VOEL IK ME bezorgd

[]niet [] [] [] [] [] [] zeer

12. OP DIT MOMENT VOEL IK ME opgewekt

[]niet [] [] [] [] [] [] zeer

13. OP DIT MOMENT VOEL IK ME energiek

[]niet [] [] [] [] [] [] zeer

14. OP DIT MOMENT VOEL IK ME tevreden

[]niet [] [] [] [] [] [] zeer

Een woord van dank

Ten God, i don don oh! God zij dank 't is klaar!
Uiteraard gaat mijn dank uit naar al diegenen die de optimale randvoorwaarden hebben geschept voor het mogelijk maken van dit proefschrift. Allereerst gaat mijn dank uit naar al diegenen die ik niet met name noem, omdat mijn hersencellen op dit moment kennelijk niet de juiste connecties maken. Dit proefschrift is was zeker niet mogelijk geweest zonder hun hulp, inspiratie, aanmoedigingen en morele steun.

Mr. P.J. Hanson (zoals hij zichzelf noemde), beter bekend als "Prince" of "papa": Your five rules of life have got me this far, and I'm still going strong! Mama: Your sincerity helped me distinguish the good from the bad. Michel, king of Fashion, thanks for your unconditional love. Ik kan natuurlijk zo doorgaan met het noemen van degenen wan wie ik hou, maar dat zal een ongewenste wending geven aan deze dankwoord. Met uitzondering van Harm natuurlijk… you na mi yone bo-boh!

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To you all…. *Nastrovie*!

Curriculum Vitae

Eamonn Hanson was born on April 21st 1966 in Malacca, Malaysia. After spending his youth in Sierra Leone (West Africa), he moved to The Netherlands in 1979 reuniting with Dutch relatives. Primarily driven by his passion for sports and human psychophysiology, he devoted his final years at Groningen University (RUG) towards human performance measurements under extreme circumstances. This resulted in his first international publication in 1993, assessing the effects of noise on task performance and mental effort. After graduation, the assessment of environmental demands on human functioning continued, by studying free-fall lifeboat launches at the NAM (Nederlandse Aardolie Maatschappij). The present thesis is the result of 4 years of extensive research under the inspiring supervision of Guido Godaert at Utrecht University. In these years, the effects of work stress on the human body and mind were explored. This work was completed in parallel to his work at the National Aerospace Laboratory (Nationaal Lucht- en Ruimtevaart Laboratorium, NLR). As a Human Factors Engineer at NLR, Eamonn Hanson continues work in psychophysiology, studying pilot workload in the centrifuge, aircraft, mock-up and flight simulator…