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Perceived fatigue related to work

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To my late grandmother, Hilma Åhsberg,
for encouraging my interest to study.

List of papers. This thesis is based on the following papers, which will be referred to by their Roman numerals.

I Åhsberg, E., Gamberale, F. and Kjellberg, A. (1997) Perceived quality of fatigue during different occupational tasks. Development of a questionnaire, *Int J Ind Ergon*, 20, 121-135.

II Åhsberg, E. and Gamberale, F. (1998) Perceived fatigue during physical work: An experimental evaluation of a fatigue inventory, *Int J Ind Ergon*, 21, 117-131.

III Åhsberg, E., Gamberale, F., and Gustafsson, K.(1998) Perceived fatigue after mental work: An experimental evaluation of a fatigue inventory. Manuscript submitted to journal.
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IV Åhsberg, E., Kecklund, G., Åkerstedt, T., and Gamberale, F. (1998) Shiftwork and different dimensions of fatigue. Manuscript submitted to journal.

V Åhsberg, E. (1998) Dimensions of fatigue in different working populations. Manuscript submitted to journal.
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1. Theoretical and methodological background

In a healthy person fatigue is a normal phenomenon, experienced by everyone and usually easily relieved by rest or sleep (28). Perceived fatigue at work is often regarded as important, because it may interfere with the high efficiency demanded in many occupational settings. Examples of effects of fatigue are poor judgement, omission of details, indifference to essentials, and generally, inadequate performance (162). Fatigue that becomes chronic or excessive may interfere with a person's quality of life (149), and without recovery prolonged fatigue may also lead to work-related disorders (58).

According to a review about fatigue in primary care (122), reports of fatigue are extremely common, particularly in developed countries. For example, 'tiredness and exhaustion' are causing over two million visits to US physicians each year. Another example comes from a Scottish study (81), with 1 344 patients in a health centre, among who 23% felt more 'tired or run down' than usual.

Fatigue is not only a frequently reported symptom in primary care, but also a common public health problem. Most surveys find that, of all somatic symptoms, only headache is more common than fatigue (178, 186). In a Norwegian study with a representative sample of 2 323 persons (normative data), about 11,4% reported substantial fatigue (125). In Sweden, published data about fatigue are relatively scarce. However, concerning work-related fatigue it has recently been shown that of 14 400 employees 41,8% reported to feel 'physically exhausted' every week, and 33,2 employees reported to feel 'tired and listless' every week (171). Another Swedish example is from 522 workers, employed in production and distribution of electricity, where 11% reported themselves to be physically tired and 5% mentally tired after a working day (94).

Managing human fatigue and reducing excessive fatigue are of particular significance in areas such as industry, where fatigue can result in decreased profit, for specific groups such as athletes, where fatigue can affect endurance, and among certain groups of patients, where fatigue is one of the most prevalent symptoms of illness (118, 149, 186). In addition, whenever shift work is required, the workers' performance has to be adequate regardless of time of the day, because this work often affects public safety and involves considerable sums of money (139). Swedish regulations stipulate that unnecessarily fatiguing physical workload should be prevented (58).

1.1. The concept of fatigue

A fundamental but difficult question concerns the meaning of fatigue and how it best can be defined. The problem with the concept of fatigue is that people may be referring to distinctly different states although they are using the same terms, and thereby misunderstandings may arise. For example, a feeling of being tired may be described with the expressions 'weary', 'strained', or 'sleepy'. The concept of fatigue is diffuse in ordinary language, but also important in that it describes a very common phenomenon. Many researchers have, therefore, been tempted to propose their own definitions and classifications. Stringent definitions are also necessary for scientific progress.

Our understanding of the concept of fatigue stems from descriptions of human experiences, which describe both a percept and a physical state (7). However, fatigue has proved difficult to define. As early as 1921 Muscio (143), described fatigue as a variety of unrelated phenomena. He also proposed that the term should be excluded from the scientific discussion, since it was not possible to measure fatigue directly. Interestingly, this proposal is one of the most common citations in the literature about fatigue (e.g. 5, 9, 24, 25, 31, 34, 35, 39, 40, 88, 92, 124, 151, 184, 186, 189). Watson (182) strongly emphasised the same position as Muscio, arguing that fatigue is a confusing concept and that researchers should instead determine operationally the effect of various factors on work output. Somewhat later, in 1934, Bills (14) admitted that the term fatigue was not a single entity but since it was so well established it would be more practical to use the term with a careful definition, rather than to try to eliminate it. Bills emphasise the complex nature of fatigue, and distinguish three aspects: (a) 'physiological fatigue' as a reduction of physical capacity; (b) 'objective fatigue' as work decrement; and (c) 'subjective fatigue' as feelings of weariness. These three types of fatigue are actually defined in the following terms: as what physical capacity the person possesses; as what work achievement the person manages; and as what feelings the person has. This feature triad of fatigue has been widely recognised.

Confining themselves to the subjective aspects of fatigue, Bartley and Chute (8) stated in a classic review that fatigue is at least directly perceived, personal, cumulative, arises from underlying conflicts, and may arise and disappear very suddenly. Furthermore, they tried to comprehend fatigue by defining what is not: it is not synonymous with impairment, it is not entirely a question of energy, it is not the same as being bored, it is not perceived locally, and it cannot be defined only from its source.

Fatigue has been described in many ways, and following Bills approach (14) the operational definitions can be grouped as bodily changes, changes in performance, or perceptual changes (Table 1). The variety of descriptions illustrates clearly that fatigue has various meanings, among which it is sometimes difficult to differentiate. Regardless of selected operational definition, perceived fatigue seems to be more or less related to other concepts, such as pain (135), stress (6), alienation (16), burnout (79), boredom (52), and anxiety (184). Drowsiness or sleepiness are also concepts closely linked to fatigue, and the expressions 'being tired' and 'being sleepy' are often used as synonyms. However, 'being sleepy' is used in a more limited sense, as a desire for sleep (43).

Some authors have pointed out that a feeling of acute fatigue may be pleasant and may serve a beneficiary function in preventing overuse of individual tissues or organs and allowing for restoration (46, 73, 149, 179, 189). It is interesting to note that in medieval writings fatigue was often depicted in positive terms, as 'the point of rest', or 'the spiritual awakening' (153). On the other hand, chronic fatigue may precede or accompany many physical and psychiatric illnesses (142, 149, 185). In addition, a feeling of being tired does not necessarily correlate with physiological impairment, nor with reduced efficiency or other aspects of performance (e.g. 88, 142, 147, 153, 166, 171, 195).

In addition to the specific definitions given above, some *general models of fatigue* have been proposed where the complex nature of fatigue is recognised. Grandjean (73) proposed a neurophysiological model of general fatigue, which comprises a non-specific fatigue excluding muscular fatigue. The nervous mechanisms in different states of perceived fatigue are assumed to be explained by antagonistic activating and inhibitory systems in the reticular

Table 1. Examples of how fatigue has been described in the literature, in terms of bodily changes, performance changes, and perceptual changes.

Variable at focus	Description	Reference
Bodily changes	-it is an expression of reduced latent capacity, that is the physiological potential of a tissue or organ at any given moment	(46)
	-it is any reduction in the force generating capacity of the total neuromuscular system	(12)
	-it is a physical state of disturbed homeostasis due to work	(36)
Performance changes	-it covers all deteriorations traced to continuing exercise	(4)
	-it is expressed as decreasing performance	(27, 71, 85, 183)
	-it denotes a state represented by a loss in efficiency and a general disinclination to work	(136)
Perceptual changes	-it is a feeling of tiredness that is influenced by circadian rhythm, and may vary in pleasantness, intensity and duration	(149)
	-it is a feeling of weariness and inability to mobilise energy to carry on	(23)
	-it is a range of perceptions including exhaustion, lack of motivation and sleepiness	(186)

formation. If the inhibitory system dominates then the person is in a state of fatigue, whereas if the activating system dominates then the person is in a state of wakefulness and ready for activity. Fatigue is described as a state of decreased level of vitality. The level of fatigue may be illustrated by the level of a liquid in a container. Many different sources, such as monotony, noise, manual and mental work, conflicts, or illness, fill this container and lead gradually to a state of fatigue. The recovery is illustrated by an outflow from the container. Each given level of fatigue is to be understood as a defined position along a scale reaching from sleep on one extreme to alertness on the other.

Cameron (31) presented a model where fatigue is regarded as a generalised response to stress over a period of time, and thus also essentially defines fatigue as a personal problem. It is argued that: (a) measuring fatigue in terms of performance is less fruitful, since individual differences and emotional states affect fatigue in unpredictable ways; (b) it is necessary to examine, in fatigue studies, the whole life pattern, and in particular sleep habits; (c) physiological indicators of activation level are unspecific to fatigue and; (d) the time for recovery is the most effective method of quantifying fatigue. In fact, time is regarded as the only variable unique to fatigue, and the degree of fatigue depends primarily on the duration of the stress response.

The few general models of fatigue proposed are interesting in that they seek the underlying mechanisms of fatigue, either in biological (73) or in social/psychological (31) terms. However, these models do not explicitly include physical fatigue, which is one aspect of fatigue that is particular important in working life. Despite the multitude of proposed

definitions and sub-categories, it must be concluded that there is no general agreed-upon definition of fatigue. This means that it is still necessary to define what feature are referred to as fatigue, at the operational level in each specific context.

1.2. Previous studies of fatigue

In the middle of the last century fatigue became a scientific and medical problem, as a result of social and cultural influences as well as of the rise of science and technology (186). One of the first articles about fatigue dates back to 1869 (10), where neurasthenia (chronic fatigue) was described as an exhaustion of the nervous system. Later on, fatigue has become more and more recognised in the literature. However, the focus of interest in studying fatigue has changed over time (30).

During the twenties, the expanding industries were particularly interested in the relation between work schedules, performance and fatigue. The central notion was that the output of a worker was limited in some way by fatigue, and that alleviation of fatigue would enhance productivity (34, 179). During the forties, the allied military air force focused their attention on how skilled performance was affected by fatigue. Performance was still of concern, and perceived fatigue was of no interest in these experiments (3, 42). Performance was observed not only in quantitative, but also in qualitative changes. For example, changes in the rhythm of actions, or disturbances in timing, were suggested as measurable outcomes (4). In the fifties, localised muscle fatigue raised interest among those concerned with guidelines for occupational mechanical exposure (188). From the fifties and on, studies focused on fatigue as a cause of accidents, both among shift work personnel in industries (173) and among motor vehicle drivers (25, 39, 51). Also, the number of physiological studies of fatigue has increased dramatically (e.g. 68, 129), mostly with the focus on avoiding musculoskeletal disorders (78, 105, 117). One example of results from this research is that criteria for defining lifting capacity have been recommended (181).

1.2.1. Conditions contributing to fatigue at work

Perceived fatigue is of course related to the work task being performed, and specific work tasks differ in what kind of demand they impose on a person. Work has generally been distinguished with regard to physical or mental work. However, such a distinction may be regarded as one of degree, where the former involves relatively more use of large muscles, whereas the latter involves relatively more of the nervous system (14). In addition to physical (a) and mental (b) workload, there are other conditions which also affect the general state of the individual. These include sensory load (c), time of day (d), psychological (e) and physical (f) environment, and person-related characteristics (g). These conditions will be explained in the following text.

(a) Physical load can roughly be described as whole body work or local physical work (104). Whole body work, consists of dynamic load on large muscle groups and it makes demands on a person's oxygen uptake capacity. Local physical work, often consists of low steady load on small muscle groups and it makes demands on a person's capacity to develop and maintain muscle force. Compared to whole body work, local physical work is much less understood, although it is known that it may lead to substantial fatigue (180). Studies of physical work and fatigue have often focused on muscular work until exhaustion. Both for static muscular load and dynamic muscular work, endurance is related to the developed force,

and the stronger the muscles, the greater the load they can endure without developing muscular fatigue (204). Even if heavy physical work is not as common in industrialised countries today as in previous decades, much physical work is still performed. Nowadays, in many workplaces physical work exists, but is of a monotonous and repetitive character. Physical fatigue is often regarded as synonymous with muscle fatigue, but, it has also been recognised as a more complex phenomenon influenced by both physiological and psychological factors (130, 136, 204).

(b) Mental load related to strain and fatigue can roughly be described as overload or underload. That is, in qualitative terms overload would refer to too much novelty and complexity, and in quantitative terms it would refer to working too long or doing a work task too often. Underload typically refers to monotonous or otherwise repetitive work tasks (57). A well-known model of work strain has been proposed by Karasek (99). It predicts that mental strain results from the interaction of 'work demands' and 'work decision latitude'. The former concerns the work demands made on the worker, whereas the latter refers to the possibilities of the worker to decide how to meet these demands. Another model worth mentioning proposes that mental workload consists of three factors; 'time load', 'mental effort' and 'psychological stress' (154). However, there is no agreed-upon definition of mental load (140). At least in industrialised countries, there has been a growing trend towards more white collar work, where mental functions such as information processing and decision analyses are important. Such work, performed for sustained periods of time, has resulted in mental fatigue (146). Mental fatigue has been described as a developing process that occurs only after a relatively long time of activity (4), and as a feeling of weariness induced by mental work (75).

The problem of being tired at work, when the work has been of a primarily mental character, has been studied for example among train control operators, where cortical functions were found to vary during a 24-hour shift (116); among bus drivers, where workload resulted in less effective mental performance (1); and among air traffic controllers, where a marked increase in signs of fatigue was found after the 6th hour of work (76).

(c) Sensory load would, for example, refer to conditions where the work requires rapid and precise eye movements which put demands on the visual system (75). Eye strain is recognised as a problem particularly among visual display terminal (VDT) operators, and much of the relevant work has been concerned with visual fatigue (15, 40, 155). Also, reaction time has been known to become irregular with working time, and increasing response irregularity in a complex reaction time test (naming colours seen and substitution of letters with numbers) has been interpreted as a sign of mental fatigue (13).

(d) Other conditions contributing to fatigue are the time of the day when the work is being performed, and the amount of sleep deprivation. It has become evident that circadian rhythms strongly affect both performance (53, 132) and sleepiness (89), as well as that effects of work tasks cannot easily be distinguished from effects of inadequate or disturbed sleep (30). It has been suggested that performance will be sensitive to sleep deprivation if the task is complex, and if there is a lack of interest, incentive or reward (192). In addition, sleep deprivation potentates the dearousing effects of situational variables (110). It has been acknowledged that it is difficult to separate the effects of time of the day from the effects of workload accumulating during a working day (1).

As a consequence of industrialisation, as well as of the economic conditions of the post-World War II period, the amount of shift work has increased in the Western World. Today, shift work occurs in a wide range of occupations and industries, with a large diversity of shift

schedules (115). In a model of performance in shift work (54), it is suggested that the 'on-shift' performance of the shift worker is the product of many interacting factors; the major factors being task demands, the particular shift system, and inter-individual differences. These factors are assumed to influence the circadian effect on performance, affective states, and physiological functions.

(e) Psychological working conditions, such as presence of a goal and probability of success, affect a person's motivation (49), which in turn affects how tired he or she feels.

(f) Also, factors to the physical environment, such as heat (63), cold (47), noise (97), and solvents (61) affect a person's general state of fatigue.

(g) The effects of work on fatigue may be modified by individual characteristics, both physical and psychological. It was early recognised that individuals differ greatly in their susceptibility to feelings of fatigue (141). It is often stated that work performance (49, 157, 184), as well as the level of perceived fatigue (60, 184), are affected by motivation. Examples of other differences between individuals that may affect the tolerance to shift work are (138): age (people over 50 years often have coping difficulties), personality (neurotic extroverts show better adjustment than introverts), level of commitment (a person who structures her or his life around the need to work at unusual hours copes better than a person who, for example, holds a second job during time off), and circadian type (it appears that evening types are more able to cope with shift work than morning types). The effects of gender and age on fatigue have also received attention. As with several other health symptoms, reports of fatigue are more common among women than among men (e.g. 2, 103, 126, 149, 175). However, in an epidemiological study with a US national sample, it was concluded that gender is not a statistically significant predictor of perceived fatigue (35). No consistent variation has been found either between age and fatigue (37, 41, 144), or between age and work productivity (121). It seems reasonable to believe that the effects of the different conditions mentioned above interact. The effects on the individual caused by all these conditions are sometimes called fatigue, but it is obvious that the term then describes states that differ in many respects.

1.2.2. Manifestations of fatigue

In the analysis of fatigue it has seemed natural to seek first the cause of the perceived state, and then categorise its characteristics. For example, as early as 1884 (141) intellectual fatigue was separated from muscular fatigue, in a study of the muscular ability to contract fully when repeatedly stimulated. As mentioned above, another early and persisting classification described the effects of work in terms of physiological (a), objective (b), and subjective (c) fatigue (14).

(a) Physiological manifestations of fatigue can in general be seen as a diminished force-generating capacity. The effects of physical work on humans have been extensively described by Åstrand and Rodahl (204) and, for example, a fall in blood sugar and accumulation of lactic acid in muscles have been considered as signs of fatigue (114, 204). As stated before, studies of physical capacity have often involved muscular work until exhaustion. One main problem still to be solved concerns whether physical endurance is limited by peripheral factors, such as local muscular strength, or by central factors, either as malfunctions of nerve cells (48, 66, 126), or as motivation or pain tolerance (45, 87, 166). In *Study II* maximal endurance time of holding one arm in 90^{o} forward flexion was measured. Interestingly, only about 50% of the variance of the muscular endurance time could be explained by

physiological factors. The rest may be attributed to individual differences in psychological factors, such as pain tolerance, motivation and mood (130).

(b) Objective, or behavioural manifestations of fatigue can be seen as performance deteriorations, or as physical expressions such as yawning. As humans we are affected by circadian rhythms, and as early as in 1905 (132), a circadian effect on performance in an attention-demanding task was demonstrated. Later several performance rhythms have been found, where task demands, in particular the working memory load, appear to be significant in determining the performance trends (55). Also, the circadian effects on sleepiness, hormone excretion and temperature are well-known (137, 201). An example of serious effects of circadian rhythms on fatigue is that the number of road traffic accidents has been found to increase between midnight and morning hours (84, 172). There are many similarities in the problems encountered by a shift working individuals, regardless of shift schedule. These problems include keeping alert, securing sleep time and scheduling private activities (115).

Fatigue has also been studied in relation to skilled performance. For example, in a study among aircraft pilots increased lapses of attention with time were found. In addition, during alertness decline attention was found to be focused on items of central importance (3). The consequences of such changes due to fatigue should, for example, be seen in flying and driving, where increasing lapses of attention sometimes could result in accidents. Attention must be very critical in transport, and it is surprising that lapses of attention do not lead to many more accidents than are reported. However, already in 1915 (170), it was argued that there was no link between fatigue and accidents, and as far as the author knows, no such simple relation has been established (51, 133, 172).

Attitudes towards risk and effort seem to be affected by fatigue (87), for example, an explicit increase in risk-taking with time exists among drivers (26). The consequences of fatigue seem to be highly specific to the type of work being performed. The literature shows contradictory results, and the evidence for transfer of fatigue is very limited (87). For example, light exercise has been found to improve performance in a tapping task, whereas the performance deteriorated with heavy exercise (44). Visual information processing has also been found to deteriorate while running (80).

(c) Subjective manifestations of fatigue can be seen in reports of physical or mental fatigue. Self-reports of fatigue have been treated as a main variable in some studies (e.g. 36, 92, 101, 190) or as a correlate to other variables in other studies (e.g. 43, 108, 137, 159, 161). The reported personal state is meaningful in itself, and constitutes a basic source of information (64). Self-reports are particularly valuable when measuring effects of mental work, as the physiological factors are more elusive in mental work than in physical work. When studying physical work it is possible to demonstrate large and measurable changes in the body, in a way that has not been possible when studying mental work. Examples of self-reported symptoms as signs of mental fatigue are 'poor concentration', 'can't easily make decisions', and 'thoughts are slow' (11); Examples of self-reported symptoms as signs of physical fatigue are 'exertion', 'discomfort', and 'aching' (124, 129, 190); Examples of self-reported symptoms as signs of sleepiness are 'difficulties keeping your eyes open' and 'fighting sleep' (68).

The following points constitute a summary of the knowledge on fatigue:

(a) A person's perceived fatigue is of course dependent on the sum of all internal and external circumstances. Conditions such as the physical and mental work requirements, as well as the time of day when the work is being performed, seem to be the most important conditions contributing to fatigue in occupational settings.

(b) The manifestations of fatigue may be described as reductions in physical capacity, as work decrements, and as feelings of weariness.

(c) It has been common to focus on changes in performance when discussing work and fatigue, where a decrease in performance has been interpreted as a sign of fatigue. However, subjects have an ability to exert extra effort or to make a change in strategy, in order to compensate for any deficit (87). It has also been argued (31) that "It is not legitimate to describe any change in the individual's behaviour as 'due' to fatigue, since the term is no more than a general description of his personal state...." (p.640).

(d) The personal state is important in itself, and data in the form of self-reports are valuable in all types of human studies of work environments as they provide an integrated assessment of the effects of the environment.

1.3. The measurement of fatigue

There is no sharp dividing line between physiological and psychological considerations of fatigue (167), because certain psychological functions are closely related to physiological processes. An example of such psychological functions is wakefulness/sleepiness, which correlates highly with cortical activity (176). As a consequence, many studies have used both perceptual and physiological methods of measurement, with a main emphasis on physiological measures and perceptual measures as correlates, or vice versa. Changes in performance or sensory abilities are also frequently reported as signs of fatigue in relation to work tasks. The choice of measurement method of course depends on the explicit or implicit definition of fatigue and on the purpose of the study.

1.3.1. Physiological methods of measurement

Depending on the research question, different physiological variables have been used as indicators of fatigue. For example, local muscle fatigue has been quantified through disturbances at cell-level, measuring biochemical and ionic changes (180), changes in electromyography (EMG) (77, 93, 127), as well as changes in blood pressure and heart rate (29, 106). Changes in heart rate and oxygen consumption, as indicators of energy consumption, have often been interpreted as general physical fatigue (59, 103, 203). Sleepiness, as a consequence of night work, has been studied with electroencephalography (EEG) and electrooculography (EOG) (176, 202) and urinary melatonin (201). EEG has also been used to measure mental fatigue after simulated mental work (146). Hormone excretion has also been measured, and for example, urinary cortisol has been found to correlate with perceived fatigue among industrial workers exposed to high sound levels of noise (134).

1.3.2. Methods for measuring performance and sensory ability

Other variables, such as work task performance, reaction time, and sensory abilities, have been used as indicators of fatigue. Changes in performance have been studied, for example, in computerised tests as an effect of sleep deprivation (131), and in a data entry task where error rate was studied in relation to rest pauses (86). An increase in reaction time has been registered as a measure of fatigue, for example among aeroplane mechanics after exposure to noise (113) and among industrial concrete block cast workers (163). Changes in critical flicker fusion frequency (CFF) has been used as a measure of fatigue, for example among visual display terminal operators (155), air-traffic (76) and railway-traffic controllers (116).

Some less common methods have been observations of participants, in order to estimate physical exertion by observable cues (124), changes in binocular convergence, in order to relate visual functioning to sleep deprivation (88), and minimum audible pressure, in order to assess fatigue after VDT work where an increase of the threshold value is interpreted as a sign of fatigue (174).

1.3.3. Psychological methods of measurement

Different psychological instruments have been used to measure perceived fatigue. Self-report techniques is a general label for many psychological measures, and self-reports have been called the basic elements of medical examination (50), which indicates their importance in diagnostics. A similar importance of self-reports when measuring fatigue is assumed in this thesis.

Mostly, perceived fatigue has been measured by uni-dimensional scaling, including a single question about how tired the person feels (e.g. 71, 120, 137, 146, 153, 157, 161, 205). However, perceived exertion and fatigue during physical work have also been assessed by psychophysical methods. Psychophysical methods can be divided into *estimation methods*, where the person estimates the relative magnitude of a perceptual attribute, and *production methods*, where the person manipulates physical stimulations to reflect given perceptual relations (60). For example, estimation methods have been applied in studies of fatigue (91) and exertion (63) during dynamic work, and production methods have been applied in studies of maximum acceptable workload for repetitive lifting work (65). In general, however, estimation methods such as magnitude estimation and category scaling have been preferred to production methods. In magnitude estimation, the person is asked to indicate, for example, the perceived magnitude of a comparison stimulus with a number relative to a designated number for a standard stimulus, whereas in category scaling the person is asked to indicate the intensity of a stimulus on a scale with equal intervals. A basic finding in psychophysical research is that the relationship between the perceived magnitude of a perceptual attribute (e.g. exertion) and the physical intensity of a stimulus (e.g. work load), typically, can be described as a power function. For example, a function with an exponent of 1.6 has been found to describe the relationship between workload and perceived exertion while working on a cycle ergometer (18, 59).

Much effort has been devoted to developing rating scales by which perceived exertion and fatigue can be measured. Borg (19, 20) has developed several rating scales which have been correlated with physiological responses and physical load. His RPE (Ratings of Perceived Exertion) and CR10 (Category Ratio) scales have been very successful (22). The development of the RPE scale has been based on studies with aerobic work on a cycle ergometer, and the numerical ratings are approximately linearly related to heart rate and oxygen consumption. The CR10-scale is a general intensity scale which purportedly gives ratings on ratio level using a verbally labelled category scale. The CR10-scale is based on the range model, which assumes that the minimal and maximal perceptual intensities are equal for different individuals, in spite of the fact that the corresponding physical intensities may vary greatly (21). The CR10-scale has, for example, been used for ratings of perceived pain, taste, loudness, and difficulties in manual handling (22). The RPE and the CR10 have in practice been the only instruments available, for ratings of perceived fatigue in relation to occupational work.

However, even if the same intensity of fatigue can be perceived after different work tasks, the perception of fatigue may be of different character. In other words, the perceived quality of fatigue may vary. In uni-dimensional ratings it is typically assumed that perceived quality of fatigue is invariant. With a *multi-dimensional approach* it is possible to simultaneously assess both the quality and the intensity of the perception of fatigue (108), although a few attempts to investigate different aspects of work-related perceived fatigue have been reported (Table 2). The qualitatively different states of fatigue most commonly discussed are physical and mental fatigue (33, 56, 74, 187). Such a duality has face-validity, and the mind-body perspective has attracted much attention (92). Other major states of fatigue that have been studied are sleepiness (69, 198) and discomfort (32). Some studies have demonstrated further aspects of fatigue. For example, two dimensions, "weakened activation" and "weakened motivation" were found in a study among railway men (100). Three dimensions, "drowsiness and dullness", "mental symptoms", and "projection of physical disintegration" were extracted from 30 symptoms of fatigue based on ratings from 9 575 industrial workers (159). These dimensions were later used in an extensive field survey with 17 789 participants, where the first dimension found was common to many types of work, the second dimension dominated among mental workers, and the third dimension dominated mainly among those with physical work (194). Concerning heavy physical work, three dimensions, "fatigue", "task aversion", and "motivation", have been proposed as describing subjective symptomatology while cycling (109).

Some questionnaires are also available for clinical use. In practice, one of the most interesting examples (168, 169) of perceived fatigue among cancer patients is a five-dimensional inventory, the Multidimensional Fatigue Inventory. The validity of this inventory was evaluated through confirmatory factor analysis and the factors were interpreted as "general fatigue", "physical fatigue", "mental fatigue", "reduced motivation" and "reduced activity". Another instrument for patients, the Piper Fatigue self-report Scale (151), primarily developed from clinical experience among radiation therapy patients, proposed seven dimensions; "temporal", "intensity", "affective", "sensory", "evaluative", "associated symptoms", and "relief". The instruments developed for measurements among patients consist of questions or sentences describing symptoms of disease. It is not clear to what extent fatigue as a symptom of sickness differs from fatigue after work, but the construct of fatigue may differ depending on what context is referred to.

Table 2. Examples of results from multi-dimensional approaches to work-related fatigue.

	Dimension						
Reference	"Physical"	"Mental"	"Activation"	"Motivation"	"Drowsiness"	"Fatigue"	"Task aversion"
(33)	X	X					
(56)	X	X					
(74)	X	X					
(187)	X	X					
(159)	X	X			X		
(100)			X	X			
(109)				X		X	X

The following may be concluded regarding the measurement of fatigue:

(a) Fatigue has been treated as a main variable, or a correlate to other variables, in a large number of studies.

(b) Depending on the research question, fatigue has been measured with physiological or psychological methods of measurement, or as changes in performance or sensory abilities. Nevertheless, as far as the author knows, no comprehensive approach towards perceived fatigue related to occupational work has been presented.

(c) An instrument based on relevant work-related aspects of fatigue could be useful in many occupational settings. Several authors have also pointed out the general need for further research about fatigue, as well as for development of measurement methods (e.g. 24, 73, 79, 109, 123, 148, 165).

2. General aim

Despite the above mentioned studies, no systematic attempt has been made in order to reach a general understanding of perceived fatigue in occupational settings. The general aim of this thesis was to further the understanding of perceived fatigue related to work.

More specifically, this thesis was based on the notion of perceived fatigue as being a multidimensional construct, and the aim was: (a) To identify meaningful dimensions of this construct; (b) To develop an instrument for measuring perceived fatigue, based on self-reports; (c) To validate the importance of these dimensions with regard to physical work, mental work, and shift work.

3. An alternative approach to work-related fatigue

As stated above, the idea of perceived fatigue as a multi-dimensional concept is not entirely new, but as far as the author knows, no comprehensive approach towards work-related fatigue has been presented. The studies in this thesis attempted to identify relevant dimensions of perceived fatigue in occupational settings (*Studies I, V*), and to test the identified dimensions in physical work (*Study II*), mental work (*Study II*) and shift work (*Study II*).

3.1. Dimensions of perceived fatigue

The multi-dimensional instruments for perceived fatigue developed in occupational settings have been limited to industrial work (159) and transport service (100). The proposed dimensions can roughly be classified as mental or physical dimensions. Shiftwork has not been included in these models.

As an attempt to study perceived fatigue in relation to some major aspects of demands in occupational work, the structure of fatigue was investigated in an explorative study (*Study I*). A questionnaire was answered by 705 persons, employed in 14 different occupations and including two different groups of students (Table 1, *Study I*). The participants rated their perceived fatigue during a work task, which they regarded as being typical of their occupation. The ratings of fatigue were made with regard to 95 verbal expressions, using a numerical scale. The choice of verbal expressions describing fatigue came from previous research (17, 33, 112, 120), from dictionaries, and from information gathered through

systematic interviews of ten persons who were asked to describe the fatigue they perceived in their job. A total of 172 verbal expressions were collected in this way. The number of expressions was then reduced to 95, according to the judgement of the authors and six additional persons. An expression was excluded if at least two persons considered it to be irrelevant, if it described related concepts such as stress or mood, or if it had a meaning opposite to fatigue (as for instance *energetic*). The ratings were subjected to factor analyses, and the expressions that were less statistically satisfying could be excluded by means of stepwise post-hoc analyses. These reductions led to a model of 25 expressions, evenly distributed on five factors. These factors were named: *Lack of energy*, *Physical exertion*, *Physical discomfort*, *Lack of motivation*, and *Sleepiness.* For clarity, the dimensions of SOFI are always given in italics, whereas other dimensions have been given in quotations marks. The strength of the five factors differed between the occupational groups. The results offered a new qualitative and quantitative description of the physical (*Physical exertion* and *Physical discomfort*) and mental (*Lack of motivation* and *Sleepiness*) dimensions of perceived fatigue. In addition, the factor *Lack of energy* seemed to describe a general underlying quality of fatigue with both physical and mental characteristics. On the basis of these results, a preliminary instrument for assessing fatigue was developed, the Swedish Occupational Fatigue Inventory (SOFI), in which each factor is represented by five expressions (*Study I*).

This proposed structure was later cross-validated with a new sample (*Study V*). Based on the results from three validation studies to be described below (*Studies II, III, IV*), a revised version (two expressions were replaced, and the response alternatives were changed from 11 to 7) of SOFI was constructed. The SOFI was administered to 597 persons, employed in five occupations with very different workloads. The employees rated their perceived fatigue after work, and the ratings were analysed using linear structural equation models (LISREL (98)). The results from this field study suggested a slightly revised model for perceived fatigue, where the five dimensions remained, but the number of variables were reduced from 25 to 20 (see Figure 1, *Study V*). *Lack of energy* is defined as a nested factor, which means that all observed variables load in this factor. Four variables load uniquely in *Lack of energy*. The correlation between the specific factors *Sleepiness* and *Lack of motivation* is high (r=.55), whereas *Physical discomfort* is only slightly related to *Physical exertion* (r=.02), *Sleepiness* (r=.13) and *Lack of motivation* (r=.12). *Physical exertion* is negatively related to *Sleepiness* (r=-.30) and *Lack of motivation* (r=-.22). This new model explained 68,1% of the total variance in the ratings, which indicates that even if the model is statistically acceptable and may have face validity, some amount of the variance is left unexplained. This unexplained variance can either be due to inter- and intra-individual differences in using the rating scales, two error sources unavoidable in perceptual measurement, or due to a dimension of relevance which is not measured. As the unexplained variance is relatively small, it seems reasonable to believe that it should be composed mostly of statistical error variance. The internal consistency in the five factors varies between α-values of 0.80-0.92 (*Study V*). The proposed construct of perceived fatigue is illustrated in Figure 1.

In summary, a five-dimensional model of work-related perceived fatigue is proposed in *Study 1*. The results of the cross-validation (*Study V*) are mainly consistent with the proposed model. On the basis of these results, a revised version of the SOFI was produced (see Appendix).

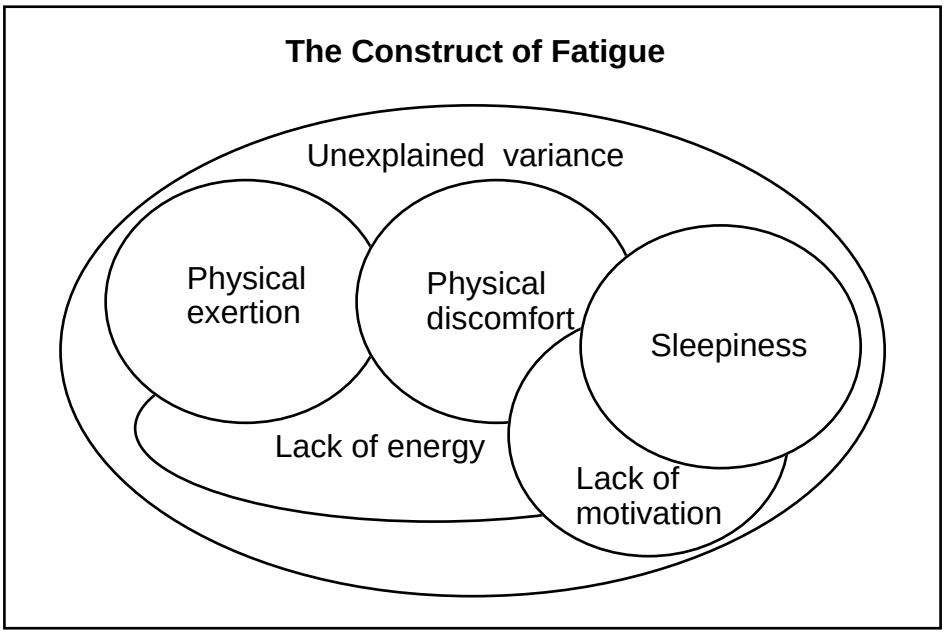

Figure 1. A model for perceived fatigue, with five inter-correlated latent factors. *Lack of energy* is a nested factor, related to four specific factors, which all are positively related to each other, except for *Physical exertion* which is negatively related to *Lack of motivation* and *Sleepiness* (*Study V*).

3.2. Fatigue related to physical work

Some degree of physical activity is required in all kinds of work, but of course, it is most prominent in blue collar work. Modern technology has contributed greatly to the elimination of much heavy work in industrialised countries, but heavy physical work is still necessary in some occupations, such as construction, forestry and many service occupations (204). When questions have been raised about how a person feels when working physically, it has been common to measure the perceived exertion, operationally defined by Borg (22) as the "degree of heaviness and strain experienced in physical work" (p.9). Also, estimates of perceived effort have been of interest in studies of manual handling tasks (62). Physical work implies that not only the muscles are exposed to workload, but also the joints and connective tissue structures (83). Reactions to strain in such passive structures have been called ligament fatigue (193).

In order to test the validity of the proposed five dimensions of SOFI (*Study I*), two experiments (*Studies II, III*) and one field study (*Study IV*) were planned. The first experiment (*Study II*) dealt with two kinds of physical work, heavy dynamic whole body work and low levels of static load on small muscle groups. Three main hypotheses were formulated: First, the scale values were expected to be highest in the factor *Physical exertion* after a workload of a dynamic character on large muscle groups during cycling. Second, the scale values were expected to be highest in the factor *Physical discomfort* after a workload of a static character on small muscle groups in one arm. Third, high scale values were also expected in the factor *Lack of energy* after both work tasks, whereas the values in *Lack of motivation* and *Sleepiness* were expected to be low. Another purpose in *Study II* was to study if there were any gender differences in the perception of fatigue after physical work. The participants were 20 men and 20 women, who exercised on a cycle ergometer, on three different workloads relative to their

individual maximal capacity. Furthermore, they held one arm straight in 90^{o} forward flexion, with three different durations relative to their individual maximal endurance time. After each work session, perceived fatigue was assessed on the SOFI and on the CR10-scale. The trials were conducted during two days for each subject. For dynamic work the highest scale values were obtained on *Physical exertion*, whereas static work mostly influenced the values on *Physical discomfort*. High values were also found on *Lack of energy* and on the CR10-scale after both work tasks. Men and women did not differ significantly with respect to their ratings.

The two physical experimental work tasks (*Study II*) are comparable to the occupational fire-fighting and cash-registering (*Study V*), respectively. The fire-fighting had the same character as the experimental cycling, as it was a physically heavy and dynamic whole body work. The cash-registering had the same character as the experimental local static load on one arm, as it meant small physical loads on specific muscle groups for a relatively long time. The firemen reported the highest values on *Physical exertion* after fire-fighting for at least 20 min, while the cashiers reported the highest values on *Physical discomfort* after a day with cash-registering for at least 2 hours. Both the firemen and the cashiers reported relatively high values on *Lack of energy*.

In summary, the physical dimensions of the SOFI seem to be valid in so far as that the level of perceived fatigue (CR10) was relatively high after both physical work tasks, but the quality differed. The factor *Physical exertion* dominated after primarily dynamic whole body work, while the factor *Physical discomfort* dominated after primarily static or intermittent work with small muscle groups. Further, the results agree with the assumed physical character of the factor *Lack of energy*. No gender differences in perceived fatigue after physical work were found (*Study II*).

3.3. Fatigue related to mental work

The prevalence of white collar work has increased in industrialised countries. It is assumed that work environments requiring information processing and decision analyses produce increased mental activities, that have profound effects on mental fatigue (146). In experiments it has been common to use physiological measures, such as electrocardiogram (ECG), breathing frequency, muscle tension and skin resistance, as correlates for mental workload. The assumption is that there are some measurable psychophysiological effects, but such studied measures have seldom been sensitive to workload variations (96, 177).

The second experiment (*Study III*) dealt with two kinds of mental work, information processing and sustained attention. The subjects were 20 men and 20 women, who worked with proof reading (2x90 min) and a vigilance task (2x60) min). Two main hypotheses were formulated: First, both work tasks were expected to result in relatively high scale values on *Lack of energy* and low values on *Physical exertion* and *Physical discomfort*, in accordance with a previous field study of mental work (196). Second, the factors *Lack of motivation* and *Sleepiness* were expected to be affected primarily by the vigilance task, which was simple, repetitive and demanded continuous attention. The working time was assumed to be an important component in the development of perceived fatigue. An additional purpose was to study if there were any gender differences in the perception of fatigue after mental work. The work tasks were constructed to give a very low level of physical load, and each subject spent an entire work day in the laboratory. After each work session, perceived fatigue was reported

with the SOFI and the CR10-scale. In addition, physiological reactions were registered; blood pressure, heart rate, heart rate variability and muscle activity in corrugator supercilii, as well as measures of performance; reaction time, number of pages read and number of detected proof errors and number of detected signals. The highest scale values were obtained on *Lack of energy*, *Lack of motivation* and *Sleepiness*, particularly after the vigilance task. High values after both work tasks were also obtained on the CR10-scale. No increase in perceived fatigue with working time was found. Men and women did not differ significantly in perceived fatigue. Very small physiological changes were seen, and no correlations between physiological reactions and perceived fatigue were found.

The two mental experimental work tasks (*Study III*) have some analogies with the occupational bus driving and teaching (*Study V*). The bus driving had the same character as the experimental vigilance task, in the sense that it demanded continuous attention for a relatively long time. The teaching had the same character as the experimental proof reading, in the sense that it demanded information processing for a relatively long time. The teachers reported the highest values on *Lack of energy* after teaching for a whole day, while the bus drivers reported the highest values on *Lack of energy*, *Lack of motivation* and *Sleepiness* after a day with city bus driving. It was assumed that the work demand information processing would mainly characterise both the simulated proof reading and the real teaching. In spite of the similar mental work demand, the scaling profiles differed somewhat. The teachers described their perceived fatigue mainly in terms of *Lack of energy*, while the participants after proof reading described their fatigue in terms of both *Lack of energy*, *Lack of motivation* and *Sleepiness.* A possible explanation may be that the experimental situation, with 90-min sessions without a break, increased the demands of continuous attention, and thus increased the feelings of *Lack of motivation* and *Sleepiness.* The teaching, on the other hand, was carried out in a comprehensive school during a whole working day, with at least some freedom for the teachers to structure the working day.

In summary, the mental dimensions of the SOFI-inventory seem to be valid in so far as that the factor *Lack of energy* dominated after work with primarily information processing, while the factors *Lack of motivation* and *Sleepiness*, as well as of *Lack of energy*, dominated after attention-demanding work. The multi-dimensional dominance in the responses after attention-demanding work tasks may be explained by relatively high correlations between *Lack of motivation* and *Sleepiness*. No gender differences in perceived fatigue after mental work were found (*Study III*).

3.4. Fatigue related to shift work

As stated previously, fatigue is not only affected by workload, but also by the circumstances under which the work is to be performed. Of particular importance is the time of the day and the work schedule. Three factors seem to determine the ability to cope with shift work: getting enough sleep, circadian rhythm adaptation, and social adjustment (138). Circadian rhythms and sleep-wake patterns never seem to adjust completely to rotating shift work, whereas the adjustment is better, but not perfect, in permanent night work (197). The problems of adjustment includes falling asleep rapidly in the morning after a night shift, but awakening prematurely due to the circadian rhythm, as well as difficulties in falling asleep as early as needed on the night before a morning shift (199). Irregular work hours increase the

risk for accidents, apparently mediated by sleepiness (90), and a majority of shift workers experience sleepiness in connection with night work (198, 200).

In order to test the validity of SOFI in relation to shift work, the dimensions of perceived fatigue, as well as the development of fatigue over an entire shift cycle, were studied at a paper mill (*Study IV*). Three hypotheses were formulated: First, relatively high scale values of *Sleepiness* were expected to result from night work. Second, perceived fatigue was expected to be higher after night shifts, as compared to morning and afternoon shifts. Third, reported fatigue was expected to accumulate over a shift cycle. In addition, a further purpose was to study if there were any gender differences in perceived fatigue after shift work. The participants were 48 men and 44 women, who worked on a rapidly rotating three shift schedule in a paper-mill. Perceived fatigue was reported at the end of each shift, using the SOFI, the Karolinska Sleepiness Scale (KSS), and one question about the duration of the fatigue. The results showed that perceived fatigue was primarily expressed in terms of *Sleepiness*, and to some extent also in terms of *Lack of energy* and *Lack of motivation.* These qualitative aspects of fatigue also discriminated most between work shifts, where the highest levels of fatigue were reported during the night shifts. Interactions between work shift and work period were found for the factors *Lack of energy* and *Physical exertion*. That is, the reported fatigue was higher during the last work period after the night and morning shifts, as compared to the afternoon shift and the three shifts in the first work period. Some gender differences were found in this field study; the women reported a higher degree of fatigue than the men. Reaction time tests were also carried out at the end of each shift, and longer reaction times coincided with increasing ratings of the mental aspects of fatigue.

In summary, sleepiness is well known in work at night. The results in *Study IV* show that, in addition to *Sleepiness, Lack of energy* and *Lack of motivation* also form part of perceived fatigue after night shifts. In addition, perceived fatigue tends to accumulate during night shifts. Further, women reported a higher degree of fatigue than men

4. General discussion

4.1. The construct of work-related fatigue

This thesis has focused on verbal descriptions of perceived fatigue, and the general aim was to further the understanding of work-related perceived fatigue. The results indicate that the construct of work-related perceived fatigue can be described as being composed of five dimensions. These dimensions are called *Lack of energy*, *Physical exertion*, *Physical discomfort*, *Lack of motivation,* and *Sleepiness* (Figure 1). Contrary to most earlier studies of fatigue, the proposed model of perceived fatigue attempts to simultaneously integrate several aspects of work-related fatigue.

Overall, the results are consistent with previous knowledge of work-related fatigue in the sense that significant aspects of fatigue (physical, mental, and sleepiness) are integrated in the model proposed in this thesis. Fatigue due to physical work may be described by *Lack of energy*, *Physical exertion* and *Physical discomfort* (*Study II*), fatigue due to mental work by *Lack of energy* (*Study III*), *Lack of motivation* and *Sleepiness*, and fatigue due to night work by *Sleepiness* (*Study IV*). The results in *Study IV* also add to previous knowledge by showing that night work is not only associated with *Sleepiness*, but also with *Lack of energy* and *Lack*

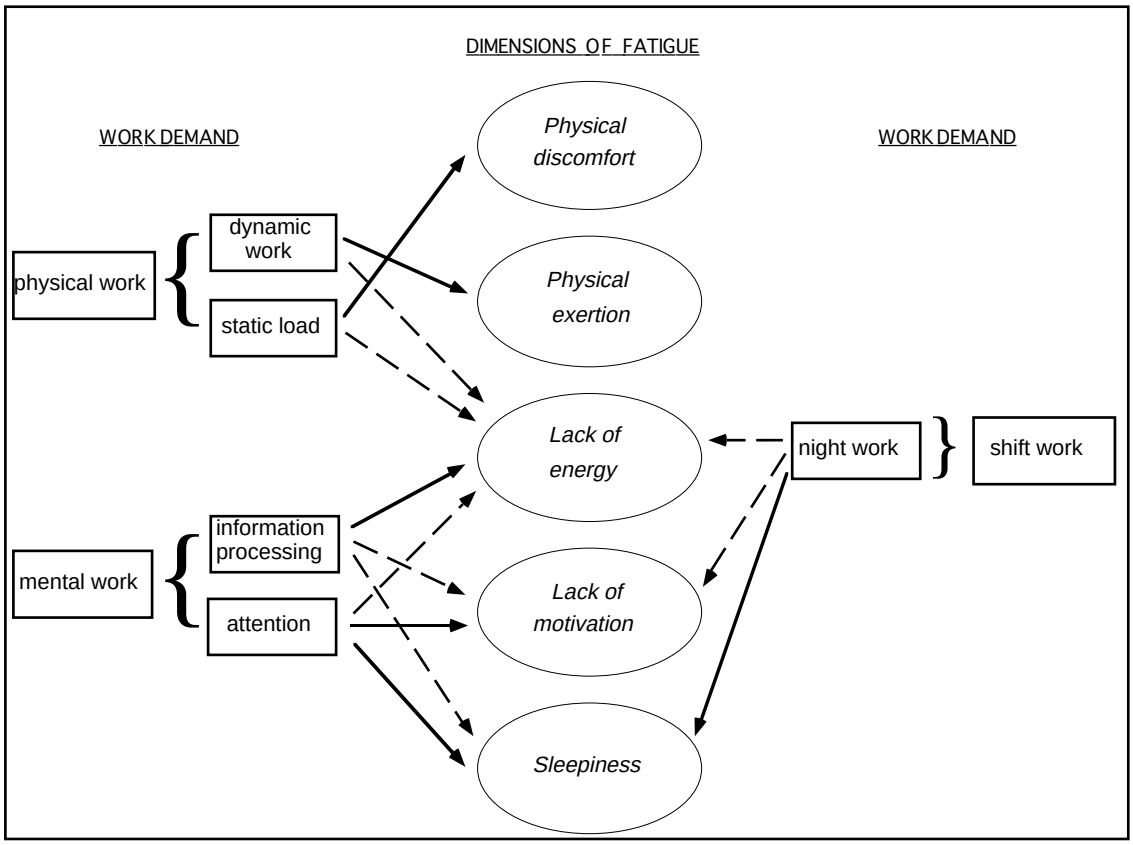

Figure 2. A simplified summary of the empirical relations between workload and perceived fatigue (*Studies II, III, IV, V*). The brackets represent specific aspects of three different occupational demands (physical, mental, and shift work). The arrows represent the relations between work and fatigue, and the full lines represent the strongest relations.

of motivation. The results, in terms of the kind of work load that affects different dimensions of fatigue (*Studies II, III, IV*), is illustrated in Figure 2.

The cross-validation with a new sample (*Study V*) lead to a slightly revised model for perceived fatigue. The five dimensions remained, but the number of variables were reduced from 25 to 20. Already in *Study I* the factor *Lack of energy* was interpreted as a factor of both physical and mental character, due to the strong correlations between *Lack of energy* and the other four factors. In the following studies (*Studies II, III, IV*), it was confirmed that *Lack of energy* was relevant for both physical and mental work tasks, as well as for night work. The LISREL analyses (*Study V*) indicated the best fit for a model where *Lack of energy* was defined as a nested factor, directly related to all manifest variables and uniquely related to the previous variables in *Lack of energy*. Thereby, it seems reasonable to accept the general character of *Lack of energy*. It has previously been suggested that different fatigue states share an essential identity (5). Such an essential identity could be represented by *Lack of energy*.

4.1.1. Gender differences

As stated before, it is recognised that women report higher levels of fatigue than men (e.g. 2, 126, 149). The results in this thesis showed such gender differences for fatigue measured in real life settings (*Study IV*), but not for fatigue measured during simulated experimental work (*Studies II, III*). Thus, when women and men were exposed to exactly the same mental

workload (*Study III*), or to individually adjusted physical workloads (*Study II*), no gender differences in reported fatigue could be found. Therefore, perceived fatigue is influenced by factors other than the only the work task or the time when work is performed, and the impact of the total situation on fatigue has to be recognised.

4.2. Conceptual and methodological discussion

4.2.1. Dimensionality

Latent factors represent a construct, not directly measurable, by which it is possible to identify dimensions of psychological significance from observed variables (101). As fatigue can be described by a large number of different verbal expressions, latent factors describe the common denominator in these expressions. Thus, by conducting a factor analysis of empirical scalings, it is possible to achieve a simpler description of the phenomenon. However, it may be difficult to ascertain the meaningfulness of latent factors. A common criticism of factor analysis is that the outcome is already postulated by the variables included. In *Study I*, where the proposed dimensions were found, the included variables were 95 verbal expressions gathered from literature and interviews with workers in different occupations. As these variables were assessed by 16 very different groups, the range of variables probably covered the major aspects of perceived fatigue in occupational work.

It may also be difficult to pin-point the inherent differences between correlated dimensions, in particular, when the dimensions are highly correlated, as for *Lack of motivation* and *Sleepiness*. However, there seems to be a clear difference between the dimensions, even if they sometimes occur together. *Sleepiness* can be interpreted as an effect of primarily night work and *Lack of motivation* as an effect of primarily monotonous work. For example, driving a car at night in most cases makes a person sleepy, even if the motivation to continue driving is very high. In addition, the defined dimensions actually reach statistical significance in the initial factor analyses (*Study I*) as well as in the last LISREL analyses (*Study V*).

Another problem is that it may be difficult to understand what dimensionality means, both conceptually and statistically. As in this thesis, the results suggest that there are five dimensions of fatigue related to work. This proposition is based on data from very different kinds of work and, therefore, comprises a range of possible aspects of perceived fatigue. But, if only one occupation is studied, probably only one or some of the proposed dimensions will be relevant. If such single-occupation data are subjected to LISREL analyses, then the results probably would indicate a poor model fit. This is shown in *Study V*, where analyses of data from a total of five occupational groups reached an acceptable model fit, whereas no sub-group reached an acceptable level of model fit in terms of a Goodness of Fit Index (*Study V*, Table 2). It seems that the more extreme the work task, as for fire-fighting and working night shift, the lower the model fit. It is possible that the relatively poor model fit may be due to the small sample size in each sub-group, or due to very homogenous sub-groups. A homogenous group may demonstrate a small variation in the ratings, and several dimensions may correlate depending on the specific conditions. In the latter case it is not possible to distinguish the proposed dimensions.

4.2.2. Ratings

The method of collecting data in the form of self-reports is accompanied by several problems. For example, apart from conveying the truth of perceptions, verbal reports may also depend

on what a person is able to report (191). The procedure requires a good linguistic understanding, as well as a good ability to use numbers (22). Other common problems in self-reports are response biases (e.g. a tendency to avoid extreme alternatives, or to agree with statements) and social desirability (e.g. trying to give a positive impression) (64). The results also hinge closely upon the interpretation of particular words by respondents, as well as on cultural and linguistic heritage. This means that the perceived content in verbal expressions may vary between different geographical areas, and may also change with time. Further, individuals may not only differ between each other, but the same person may also vary in certain aspects on different occasions.

It may also be a problem to ascertain to what extent the responses obtained reflect perceptual or cognitive processes (62). That is, when asked to estimate the perceived fatigue, subjects might report what they consider is the right answer in a given situation, instead of reporting the actually experienced sensation. There is also a memory problem in self-reports (111). When asking people to recall how they felt in a certain situation, the longer time elapsed since the event, the lower the credibility.

4.2.3. Validity and reliability

Four of the five studies have assessed the validity of the proposed dimensions of perceived fatigue, as it seemed most important to estimate what actually was measured with the SOFI. Overall, the results indicated a reasonably good validity of the SOFI, in the sense that different work tasks resulted in scaling profiles with emphasis on different dimensions.

One matter which is not discussed in the papers is that the reports in this thesis are mostly made immediately after work, but in *Study I* the participants were asked to refer to an imaginary situation, typical of their work, and to describe their feelings of fatigue. This meant that there was no experimental control over the time between the actual work and the reporting. In the experiments, however, the control over the work situations was typically high, with as few disturbing factors as possible. Still, it may be argued that it is not relevant to test an instrument aimed for occupational settings in a laboratory, as was done in *Study II* and *Study III*, in spite of the scientific advantages of an experiment. Nevertheless, experimental designs were considered necessary when developing the SOFI, in order to estimate the relation between work tasks and fatigue.

Reliability was primarily studied as internal consistency in each sub-scale, but some data about repeated measures (stability) have been obtained. The correlations between scale values after physical work on the two highest (relative) load levels (*Study II*), after mental work in the morning and the afternoon (*Study III*), and after night work in the first and the seventh week (*Study IV*), all indicated a relatively high reliability.

4.2.4. The SOFI

The discriminative ability of SOFI is known in so far that different scaling profiles are found in different occupational groups (*Study V*), and in response to different simulated work tasks (*Studies II, III*). Reports of fatigue are not normally distributed in population studies, but show a positive skew (148). This means that most people report rather low levels of fatigue, but also that there is no obvious cut-off point between the normal and abnormal state of fatigue (186). In one study of fatigue a cut-off score was defined, in order to be able to determine a case of substantial fatigue (33). Such a categorisation can be useful in clinical

contexts, but since the purpose in this thesis was not to make diagnoses, no cut-off score was defined for the SOFI. Therefore, no calculations of the sensitivity/specificity have been made.

Further, no control or comparison group was assigned in any of the studies. This means that it is not possible to determine from the absolute scaling score if a person is suffering from substantial fatigue. Instead, the advantage of using SOFI is to distinguish qualitative aspects of fatigue, and this makes it possible to study how qualitative aspects of fatigue develop over time.

A number of comparisons have been made between the five SOFI-factors in the separate studies in this thesis, but it is essential to stress that direct comparisons between the absolute scale values of each expression may be misleading. Each verbal expression (see Appendix) may in itself have a given intensity, for example, a feeling of 'out of breath' may inherently be conceived as more intense than a feeling of being 'drowsy'. The mean values on each dimension will then be affected also by the intensity of each expression per se.

4.2.5. Physiological correlates

A final question concerns the physiological variables, such as measures of heart rate, blood pressure and EMG, that have been used in this thesis as correlates to perceived fatigue (*Studies II, III*). This approach assumed that psychological events are associated with physiological processes, even if it has previously proved difficult to establish such associations (96, 177). In the experiment with physical work (*Study II*) it was found that there were clear positive correlations between certain dimensions of perceived fatigue and physiological variables. On the other hand, in the experiment with mental work (*Study III*), no correlations were found, as the variations in physiological variables were rather small. *Study III* only showed a tendency towards an inverse relationship between fatigue and blood pressure. Thus, the relation between physiological variables and perceived fatigue depends on the kind of work performed.

An interesting question for further research is; to what extent is it possible to predict physiological changes from reports of fatigue with the SOFI? Probably the most investigated rating scale in relation to physiological variables is the RPE scale. The RPE is linearly related to heart rate in dynamic work on cycling, but it has been reported (161) that RPE ratings are not linearly related to heart rate while dancing, which also is a dynamic whole body work. This again indicates that there is no simple relation between physiological variables and perceived fatigue, and that the very specific kind of work determines the relation.

4.2.6. Other limitations

In the discussion above I focused on the perception of fatigue, although our scientific interest in the dimensionality of fatigue may differ from that of the general population. It seems possible that for laymen it would be more important to know what can be done in order to alleviate fatigue. The scope of this thesis does not go that far, but the recovery must typically depend on the 'cause' (6, 28). In the case of work-related fatigue, recovery must depend on the kind, difficulty and length of work (14).

The time aspect, or the duration of fatigue, is of course of great importance for the individual. This thesis has focused on acute fatigue, which means that not only patients with the Chronic Fatigue Syndrome (186), but also relevant factors in the work environment, such as work with clients, overtime for long periods, threats of downsizing, have been excluded. No evaluation of the importance for acute and chronic fatigue is made in this thesis. It was

simply, on a theoretical basis, not considered possible to cover both areas in the single studies.

The main types of work at focus in this thesis have been physical work, mental work and shift work. Another common type of great importance is emotional work. Emotional labour has been defined as dealing with other peoples feelings (95), which is central in health care, home nursing, child and geriatric care. Higher levels of fatigue have been reported among health care workers, in comparison with figures for the general population in the UK (82). The prevalence and quality of fatigue among 'emotional workers' is an interesting issue for further studies.

4.3. Future possibilities of SOFI

As already stated, so far the SOFI has been limited in application to fatigue related to work. In order to investigate the potential general use of the SOFI, two studies are presently being carried out among cancer patients, by the National Institute for Working Life, Stockholms Sjukhem and the Karolinska Hospital. These involve studies of (a) the effects of radiation therapy on fatigue among curable patients, and (b) the qualitative aspects of fatigue among dying patients. The results will hopefully indicate if the SOFI is relevant for two non-occupational groups that suffer from severe fatigue, as well as describe what kind of fatigue cancer patients experience.

The effects of interacting workloads on fatigue are not well known. It has been found that physical exertion is rated higher on night shifts than on day shifts (206), but it would be interesting, for example, to investigate the combination of high physical and mental load. Employees in rescue services are often exposed to such a combined workload.

4.4. Conclusions

The results in this thesis can be summarised as follows:

(a) The construct of work-related perceived fatigue can be described as composed of five dimensions. These dimensions are *Lack of energy*, *Physical exertion*, *Physical discomfort*, *Lack of motivation*, and *Sleepiness.* The multi-dimensional approach makes it possible to discriminate qualitative differences in perceived fatigue.

(b) A measuring instrument of perceived fatigue (SOFI) has been developed, and tested in laboratory and field conditions. The validity of SOFI is reasonably good, in that it showed a good ability to reflect different fatigue dimensions in different types of work. The reliability of SOFI, in terms of internal consistency in each dimension, is satisfactory.

(c) Perceived fatigue after physical work is primarily described as *Lack of energy*, *Physical exertion* and *Physical discomfort*.

(d) Perceived fatigue after mental work is primarily described as *Lack of energy*, *Lack of motivation* and *Sleepiness*.

(e) Perceived fatigue after shift work is primarily described as *Sleepiness*, *Lack of energy* and *Lack of motivation.*

(f) When women and men are exposed to the same mental work load, or to individually adjusted physical work load, no gender differences in perceived fatigue is found.

5. Summary

Åhsberg, E. Perceived fatigue related to work. *Arbete och Hälsa* 1998:19

Perceived fatigue at work is important because it may be unpleasant for the individual, it may interfere with productivity, and prolonged fatigue without recovery may lead to work-related disorders. This thesis presents a comprehensive approach towards assessment of work-related perceived fatigue. The thesis is based on the notion that perceived fatigue is a multidimensional construct, and the principal aim is to identify these dimensions. The aim is further to develop an instrument for measuring work-related perceived fatigue based on self-reports, and to validate the importance of these fatigue dimensions during different types of work.

An instrument, the Swedish Occupational Fatigue Inventory (SOFI), was developed for measuring fatigue based on self-reports. In a questionnaire survey 705 employees from different occupations described their perceived fatigue by rating 95 verbal expressions. Factor analyses resulted in five dimensions of work-related perceived fatigue. These dimensions were called *Lack of energy*, *Physical exertion*, *Physical discomfort*, *Lack of motivation*, and *Sleepiness*. The SOFI consisted of 25 items, and each of the five dimensions were assessed by five items.

The proposed five-dimensional model of perceived fatigue was evaluated in two laboratory experiments and one field study. The first experiment focused on fatigue after physical work, whereas the second experiment focused on fatigue after mental work. The field study was conducted among industrial three-shift workers, who answered a questionnaire after each shift. The results indicated a reasonably good validity of the instrument, in the sense that it showed an ability to reflect different fatigue dimensions in different types of work. That is, perceived fatigue due to physical work was primarily described by *Lack of energy*, *Physical exertion* and *Physical discomfort*, fatigue due to mental work primarily by *Lack of energy*, *Lack of motivation* and *Sleepiness*, and fatigue due to night work primarily by *Sleepiness*. The results also add to previous knowledge by showing that night work is not only associated with perceived *Sleepiness*, but also with *Lack of energy* and *Lack of motivation.*

The proposed five-dimensional model of perceived fatigue was cross-validated in a new occupational population, using the SOFI to assess fatigue in different work situations. Linear structural equation analyses (LISREL) of the results suggested a slightly revised model for perceived fatigue, still comprising five dimensions, but with a reduced number of variables - 20 instead of 25. *Lack of energy* was defined as a latent factor directly related to all observed variables, indicating its general character.

The results in this thesis also showed common gender differences of perceived fatigue in field settings: women reported more fatigue than men. However, gender did not differ in fatigue during simulated work in the laboratory, irrespective of whether the work consisted of similar mental workload or individually adjusted physical workload. This indicates that work-related perceived fatigue is influenced by factors other than the work task.

In conclusion, work-related perceived fatigue can be described as being composed of five dimensions. An instrument, the SOFI, has been developed. The results indicated a reasonably good validity for the SOFI.

Key words: Perceived fatigue, work, physical, mental, circadian rhythms, scaling, gender.

6. Sammanfattning

Åhsberg, E. Upplevd trötthet i samband med arbete. *Arbete och Hälsa* 1998:19

Upplevd trötthet i arbetslivet är viktigt eftersom: den enskilde individen kan besväras av trötthet; trötthet kan minska produktiviteten; och trötthet över tid, utan möjlighet till återhämtning, kan leda till arbetsrelaterade besvär. Denna avhandling presenterar en övergripande ansats mot mätning av arbets-relaterad trötthet. Avhandlingen utgår från upplevd trötthet som ett flerdimensionellt konstrukt, och det huvudsakliga syftet är att identifiera dessa dimensioner. Dessutom är syftet att utveckla ett mätinstrument för arbets-relaterad upplevd trötthet, och att pröva betydelsen av trötthetsdimensionerna vid olika arbeten.

Ett mätinstrument, Swedish Occupational Fatigue Inventory (SOFI), konstruerades för att mäta trött med hjälp av själv-skattningar. I en frågeformulärsstudie beskrev 705 anställda, från olika yrken, sina trötthetsupplevelser genom att skatta 95 verbala uttryck. Via faktoranalyser erhölls en fem-dimensionell modell om arbetsrelaterad trötthet. Dessa dimensioner kallas *Brist på energi*, *Fysisk ansträngning*, *Fysiskt obehag, Brist på motivation*, och *Sömnighet*. SOFI bestod av 25 uttryck, varav var och en av de fem dimensionerna skattades med hjälp av fem uttryck.

Validiteten i den förslagna fem-dimensionella modellen om upplevd trötthet prövades med två experiment och en fältstudie. Det första experimentet rörde trötthet efter fysiskt arbete, medan det andra experimentet rörde trötthet efter mentalt arbete. Fältstudien utfördes bland tre-skifts arbetande industriarbetare, vilka besvarade ett frågeformulär efter varje skiftpass. Resultaten indikerade en relativt god validitet av mätinstrumentet, så till vida att det kunde urskilja olika trötthetsdimensioner vid olika typer av arbetsuppgifter. Det vill säga: upplevd trötthet efter mentalt arbete beskrevs huvudsakligen som *Brist på energi, Brist på motivation,* och *Sömnighet*; trötthet efter fysiskt arbete beskrevs huvudsakligen som *Brist på energi, Fysisk ansträngning* och *Fysiskt obehag*; och trötthet efter nattarbete beskrevs huvudsakligen som *Sömnighet*. Resultaten visar också att nattarbete inte bara är förknippat med upplevelser av *Sömnighet*, utan också med *Brist på energi* och *Brist på motivation*.

Den förslagna fem-dimensionella modellen om upplevd trötthet kors-validerades med hjälp av en ny undersökningsgrupp. Resultaten tydde på att modellen borde revideras något, till en modell där de fem dimensionerna kvarstod, men där antalet variabler var färre - 20 istället för 25. *Brist på energi* definierades som en latent faktor direkt relaterad till samtliga observerade variabler, vilket talar för den generella karaktären av dimensionen *Brist på energi*.

Resultaten i denna avhandling visar vanliga könsskillnader i fältstudier: kvinnor rapporterar en högre grad av trötthet jämför med män. Däremot kunde inga sådana könskillnader påvisas i experimenten, oavsett om kvinnor och män var utsatta för samma mentala arbetsbelastning, eller individuellt anpassad fysisk arbetsbelastning. Detta indikerar att arbetsrelaterade trötthetsupplevelser även påverkas av andra faktorer än enbart arbetsuppgiften.

Sammanfattningsvis, arbetsrelaterad upplevd trötthet kan beskrivas med hjälp av fem dimensioner. Ett mätinstrument, SOFI, har utvecklats. Resultaten tyder på en relativt god validitet för SOFI.

Nyckelord: Upplevd trötthet, arbete, fysiskt, mentalt, dygnsrytmer, skattningar, kön.

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Think of how it felt when you were most tired. To what extent do the expressions below describe how you felt? For every expression, answer spontaneously, and mark the number that corresponds to how you feel right now. The numbers vary between 0 (not at all) and 6 (to a very high degree).

	not at all						**to a very high degree**
	0	1	2	3	4	5	6
palpitations	0	1	2	3	4	5	6
lack of concern	0	1	2	3	4	5	6
worn out	0	1	2	3	4	5	6
tense muscles	0	1	2	3	4	5	6
falling asleep	0	1	2	3	4	5	6
numbness	0	1	2	3	4	5	6
sweaty	0	1	2	3	4	5	6
spent	0	1	2	3	4	5	6
drowsy	0	1	2	3	4	5	6
passive	0	1	2	3	4	5	6
stiff joints	0	1	2	3	4	5	6
indifferent	0	1	2	3	4	5	6
out of breath	0	1	2	3	4	5	6
yawning	0	1	2	3	4	5	6
drained	0	1	2	3	4	5	6
sleepy	0	1	2	3	4	5	6
overworked	0	1	2	3	4	5	6
aching	0	1	2	3	4	5	6
breathing heavily	0	1	2	3	4	5	6
uninterested	0	1	2	3	4	5	6

Comments

The question is usually formulated according to the purpose of the study. The question may concern; for example, "how you feel right now", how the subject has felt "during the last ten minutes" or "when you were most tired".

The inventory consists of five subscales:

1. Lack of energy. A dimension which describes general feelings of diminishing strength. The expressions *worn out, spent, drained, overworked* belong to this scale.

2. Physical exertion. A dimension which describes whole-body sensations that may be the result of dynamic work and to a certain extent a sign of metabolic exhaustion. The expressions *palpitations, sweaty, out of breath, breathing heavily* belong to this scale.

3. Physical discomfort. A dimension which describes more local bodily sensations that may result from static or isometric work load. The expressions *tense muscles, numbness, stiff joints, aching* belong to this scale.

4. Lack of motivation. A dimension which describes feelings of not being involved or enthusiastic. The expressions *lack of concern, passive, indifferent, uninterested* belong to this scale.

5. Sleepiness. A dimension which describes feelings of sleepiness. The expressions *falling asleep, drowsy, yawning, sleepy* belong to this scale.

To obtain a measure for each subscale, calculate a mean of the four ratings.