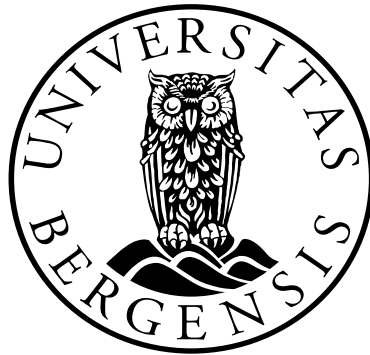


# **Adaptation and health in extreme and isolated environments**

*From 78°N to 75°S*

**Anette Harris**



Dissertation for the degree philosophiae doctor (PhD)  
at the University of Bergen

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## Scientific environment

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## Abstract

The main purpose of this thesis was to explore the variation in health, diurnal cortisol rhythm, and performance related to working and living in extreme and isolated environments. The thesis consists of three papers that all deal with this topic, but the populations and environments differ. The first paper is based on a study of workers on a small oil rig in the North Sea. In the second paper, workers who constructed a tunnel in the Arctic region of Svalbard (78° north) were studied. In the third paper, personnel overwintering in the Antarctic (67° and 75° South) were studied. At regular intervals all participants filled out questionnaires, did performance tests, and sampled saliva for the analysis of cortisol. All participants were able to keep a normal cortisol rhythm, maintained good health, and good performance, independent of the environment they lived in. One exception was that overwintering personnel in the Antarctic complained more about tiredness and sleep problems half way thru their stay, possibly because of boredom in this isolated environment. These highly selected men and women coped very well under extreme isolation and extreme external environments. The oil rig workers were also tested for potential effects of “swing shift”, during the day they shifted from night work to day work. This had no negative effects on health or on performance measured as reaction time. Similar results were found for construction workers in the Arctic. Extended work hours and the extreme change in external light, had no ill effects on diurnal rhythms, performance, or subjectively reported health complaints. The only deviation from normal rhythms was that during the period with 24 hours darkness, employee’s working day had a lower cortisol response to awakening and, accordingly, less decrease during the day.

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*Bergen, May 2011*

*Anette Harris*



## List of publications

- Paper 1      Harris, A, Waage, S, Ursin, H, Hansen ÅM, Bjorvatn, B., Eriksen, HR. 2010. Shift Work, Cortisol and Health among Offshore Workers. *Psychoneuroendocrinology*. Vol 35, p 1339-1347. *Reprinted with permission from Elsevier. All rights reserved.*
- Paper 2      Harris, A, Waage, S, Ursin, H, Eriksen, HR. 2010. Saliva cortisol levels in construction workers in the Arctic (78° N). *International Journal of Circumpolar Health* (submitted). *Reprinted with permission from International Journal of Circumpolar health. All rights reserved.*
- Paper 3      Harris, A, Marquis, P, Eriksen, HR, Grant, I, Corbett, R, Lie SA, Ursin H. Diurnal rhythm in British Antarctic personnel. *Rural and Remote Health* 10: 1351. (Online), 2010. *All rights reserved to the authors.*
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# 1. Introduction and theoretical framework

This thesis is about biological and psychological adaptation to work and living in extreme and isolated environments. This is measured with questionnaires on health, well being, psychological factors, and by following the diurnal cortisol rhythm of the participants. Extreme environments may be defined as "settings that possess extraordinary physical, psychological, and interpersonal demands that require significant human adaptation for survival and performance" (The Society for Human Performance in Extreme Environments (HPEE), 2010). Three such extreme environments were selected for this thesis, an oil rig in the North Sea, construction workers in the Arctic region of Svalbard, and various personnel in the Antarctica. This selection is reasonably representative of the environments studied in this type of research dealing with survival and maintained performance in extreme environments like outer space, underwater environments, underground environments, and open sea. Experience in extreme environments is relevant for many occupations that involve either isolation or potential hostile environments. This may include submarines, offshore work, police work, medical care, and various military personnel.

If we want to minimize the potentially adverse consequences of working in these types of environments, knowledge about adaptation is of importance, since more and more people live and work in extreme and isolated environments. The natural laboratory offered by these isolated and extreme environments gives the researcher an opportunity to perform research in a natural setting and still have many of the same advantages as in a laboratory with control over many possible confounders (Suedfeld, 1998). In this way we can use extreme and isolated environments as an arena to get more knowledge about phenomena that are of importance outside this area as well. The aim of the thesis is to highlight some of the aspects related to adaptation to extreme and isolated environments by measurement of health, performance, and the biological adaptation to these environments by measuring the diurnal cortisol rhythm.

## 1.1 Adaptation and health in extreme and isolated environments

Three extreme environments were selected for this thesis; the Antarctic, the Arctic region of Svalbard, and an oil rig in the North Sea. All environments represent areas where modern society, contemporary science, and working life require that people live and work, even if the environments are isolated and challenging.

As far as we know, the first men to go ashore on the Antarctic continent itself were four Norwegians. In 1895 they participated in one of the first three trial expeditions to establish whaling in the ocean surrounding the Antarctica. One of them, Carsten E. Borchgrevink, came back in 1898, with the ship “Southern Cross”, financed by English sponsors. His expedition became the first to spend the winter on the Antarctic Continent. At the same time, the Belgica Expedition was the first expedition to spend the winter in the Antarctica ice belt (1897-1899). Roald Amundsen was among the crewmembers in the Belgica Expedition. The field of Antarctic or polar psychology did not begin as a scientific enterprise with establishment of permanent research stations on the ice until the middle of the 1950’s (Taylor, 1987). Since then, there has also been an increase in number of people who temporarily live and work in this harsh environment (Palinkas & Suedfeld, 2008).

The other environments may not be as harsh as the Antarctic continent; even so, the work requires facing an environment that is potentially very dangerous. The Svalbard islands have a permanent settlement with regular air transport, hospital, coal mines, scientific laboratories, and tourist trade. The name Svalbard for this group of islands is probably from 1194, according to classical Icelandic books. The Dutch explorer William Barents discover the islands in 1596 and gave the main island the name “Spitsbergen”, a name the main island still carries. The construction workers we studied build a tunnel from the harbour to the coalmine in Svea, Svalbard. Svea is

extremely isolated, accessible by air, sea, or by snow scooters. The Svea coal mine was very active in the years 1917 to 1925; it was ruined by a German attack during the Second World War, rebuilt and is presently an active coal mine.

The Norwegian oil production in the North Sea started in 1969 and is presently a major source for Norwegian wealth. The production requires oil platforms, stationary installations where transport of personnel from the main land, is by helicopters.

Settlements in these environments are necessary for research, industry/business, economy and meteorology. Those living and working in these extreme environments are exposed to environmental stressors, such as extremes of photoperiod, temperature, and in the Antarctic also dry air and high electromagnetic radiation. The geographic and social isolation is a psychological stressor.

Bennett (1976, p.246) has defined behavioural adaptation as “the coping mechanisms that humans display in obtaining their wants and adjusting their lives to the surrounding milieu, or the milieu of their lives and purposes”. In a broad sense, adaptation or the concept of coping could be understood as a moderator of the association between stress (stressor) and illness. Palinkas (2003) has suggested 4 distinct characteristics that should be considered in association to psychosocial behaviour and adaptation to extreme and isolated environments. The first factor concerns the seasonal characteristics that may affect mood and result in depressive symptoms. The phenomenon is associated with the altered diurnal cycle and psychosocial segmentation of the mission. Secondly, adaptation may depend on situational factors. Concurrent measures of personality, coping styles and interpersonal needs may therefore be better predictors of mood than pre-deployment measures. The third characteristic is that social factors and low social coherence are

strong predictors for depression, anxiety and anger. The fourth characteristic is “salutogenic” factors. The concept was first mentioned by Antonovsky (1987) and the idea is that certain stressful conditions may, in some people, have positive beneficial and health promoting outcomes instead of a pathogenic outcome. Successful coping with stress is a source of self-esteem, pride, and greater ability to cope with future stressors. This is a way to understand why so many of the workers in extreme and isolated environments have more positive than negative experiences and also report long term positive after-effects subsequent to their stay (Suedfeld & Steel, 2000).

The opposite of a salutogenic perspective is the more traditional pathogenic model, focusing on potentially negative health outcomes. In offshore workers, sleep problems, reduced sleep quality (Cooper & Sutherland, 1987; Menezes, Pires, Benedito-Silva, & Tufik, 2004; Miles, 2001; Parkes, 1994), higher anxiety levels, but no differences in other somatic symptoms or social dysfunctions, have been reported (Parkes, 1992a). In the more harsh environments in Antarctica, where the workers normally have longer stays than on the oil rigs, health complaints associated to seasonality and situational factors have received a lot of attention (Palinkas & Suedfeld, 2008). The most common complaints include sleep disruption, impaired cognitive performance, negative affect, and interpersonal tension and conflict (Palinkas & Suedfeld, 2008). The phenomenon has been labelled with different names like the “winter over syndrome” (Palinkas, 1992) or the “third quarter phenomenon” (Bechtel & Berning, 1991). The “winter over syndrome” is defined by depressive symptoms and mood disturbances, which are attributed to patterns of exposure to daylight associated with time of year and latitude (Palinkas, Gunderson, Holland, Miller, & Johnson, 2000). The “third quarter phenomenon”, is defined by a decline of mood and an increase in crew conflicts that appears to peak just after mission mid-point, regardless of length of confinement (Bechtel & Berning, 1991). The third quarter phenomenon has been explained by the fact that the workers realize

that they have passed the halfway point of their mission (with separation and isolation from family and friends) at the same time they realize that the second half remains (Bechtel & Berning, 1991). Changes in thyroid function have also been reported, “the polar T3 syndrome”, assumed to be related to exposure to cold (Palinkas et al., 2007; Reed et al., 1990; Xu et al., 2003).

## 1.2 Cognitive Activation Theory of stress (CATS)

When discussing adaptation to extreme and isolated environments, it is of importance to consider that different people have different expectations to an extreme environment. This may again affect the response and the way they adapt to the challenges of such an environment (Levine & Ursin, 1991; Ursin & Eriksen, 2004). Cognitive activation theory of stress (CATS) puts forward that stress is related to both health and illness. The theory offers a formal and constructive way to understand why the same stressor (e.g. working in an extreme and isolated place) in different people will result in different activation (stress response) and health outcomes. CATS argues that when the individual, be that a rat, a cat, or a human being, is exposed to a stimulus implying a possible threat, the brain processes or filters the sensory signals. This filtering process acts to find the answer to the crucial question; what does this stimulus mean and what can I do about it? If the individual expects to cope with the stressor, and feels that his/her response will give a positive result (coping), the stress response will be short lasting and may result in training effects to the body and the brain. If the individual feels that there is no association between response and results (helplessness), or a negative association between response and results (hopelessness), the stress response may lead to sustained physiological activation that may represent a health risk (Ursin, 1988; Ursin & Eriksen, 2004). This outcome expectancy is based on the individual’s learning history with the same or similar stressors (Levine & Ursin, 1991). It is the individual’s own experience and learning history (outcome expectancies) that determines the response to extreme and isolated environments. This determines the way they adapt to possible



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stressors, like separation from regular social network, reduced privacy, the potential threat associated with helicopter flight to the oil rigs, or the fact that there are no possibilities of evacuation from the base station during the Antarctic winter.

### 1.3 The Hypothalamus Pituitary Adrenal (HPA) axis and cortisol

The Hypothalamus Pituitary Adrenal (HPA) axis, together with the sympathetic part of the vegetative nervous system, is the main components of the stress response. Short term activations are necessary and adaptive. However, a sustained activation of this system may be associated with negative health outcomes (McEwen, 1998; Ursin & Eriksen, 2004). Cortisol is accepted as a robust marker of activation of adrenocortical activity (HPA activity) (Clow, Thorn, Evans, & Hucklebridge, 2004; Pruessner, Hellhammer, & Kirschbaum, 1999), with effects on most of the main organ system (Sapolsky, Romero, & Munck, 2000). Different kinds of stimuli, like workload, excitements, exercise etc. serve to activate the HPA axis, resulting in an increase in cortisol (See Figure 1).

Under normal conditions cortisol follows a 24 hour rhythm with the highest levels in the second half of the night, a peak level early in the morning, and a low level in the evening. During the day there are several secretory episodes of short duration and high amplitude, depending on the challenges the individual is faced with on that particular day. The average values show a high level in the morning for most people, and low values towards the night. Cortisol is therefore also viewed as a marker of diurnal rhythm (Born & Fehm, 2000). Repeated salivary cortisol samples during the day appears to be an excellent measure for monitoring circadian rhythm variation in adrenal activity (Shinkai, Watanabe, Kurokawa, & Torii, 1993).

## Hypothalamus Pituitary Adrenal (HPA) axis and the release of cortisol

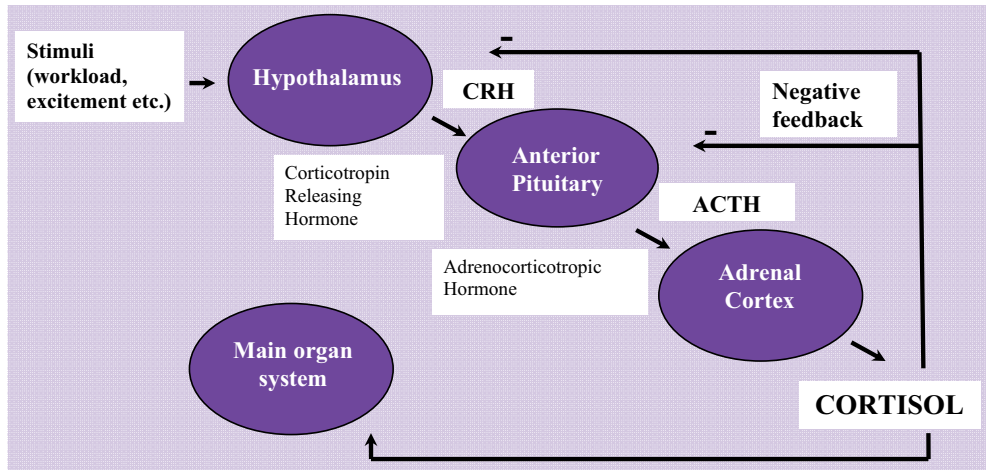


Figure 1. The secretion of corticotrophin-releasing hormone (CRH) by the hypothalamus triggers pituitary secretion of adrenocorticotropic hormone (ACTH) in the pituitary gland. ACTH will then be transported by the blood to the adrenal cortex where it triggers glucocorticoid secretion (cortisol). Cortisol in turn exerts negative feedback on the HPA-axis at the level of the pituitary and hypothalamus (to suppress CRH and ACTH production).

There are a number of different ways to measure the diurnal variation in cortisol. This makes evaluation and comparison between studies difficult. The awakening response (CAR) is measured as the increase from awakening to 30 minutes later, or as the area under the curve (AUC) (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). The decrease from awakening or from the highest level after awakening, to evening, or only the evening samples, is often used. Finally, complex statistical analyses that compute all the different measures in one analysis, or as the area under the curve (AUC), are also frequently reported. The sensitivity of cortisol to the “stress” factors during the day adds to the variance in the measures. During the day, there are a number of short time peaks, with high levels of cortisol. These peaks are, of course, not synchronized with the awakening response. When using average data of the diurnal cortisol curve, these peaks disappear when presenting figures (Figure

2).

## The "smooth" or the "true" diurnal rhythm

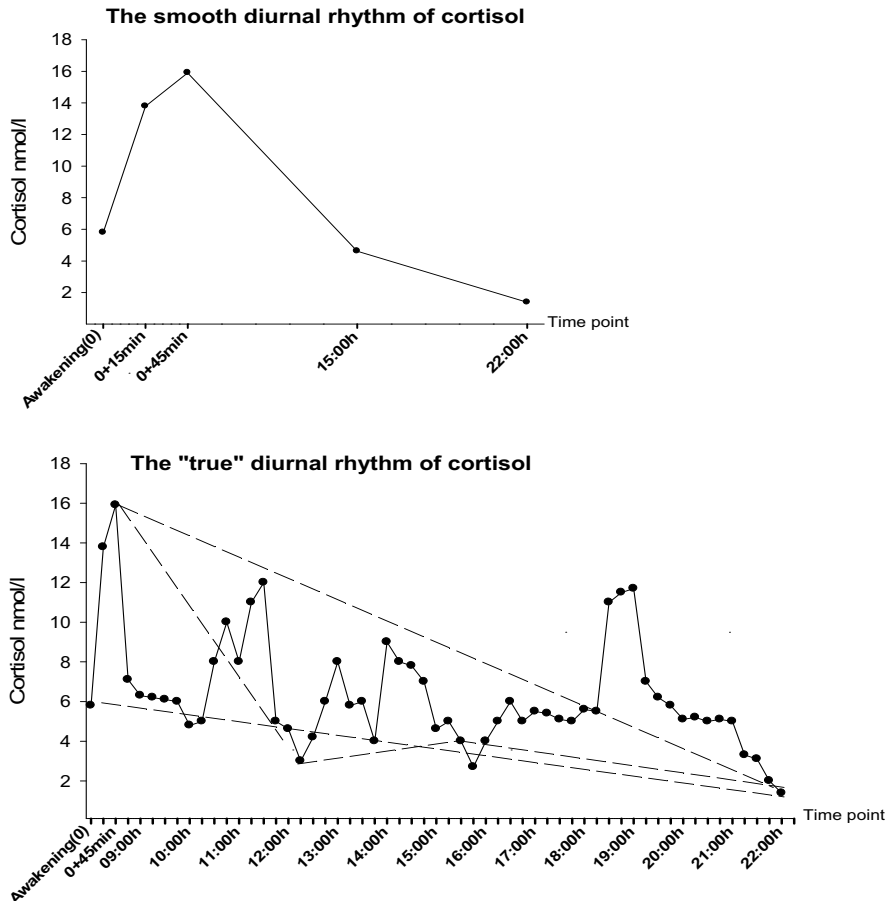


Figure 2. These illustrations shows “the smooth diurnal cortisol rhythm” with the cortisol awakening response and the decrease during the day often presented in papers, and “the true” diurnal cortisol rhythm that include the cortisol awakening response, several secretory episodes during the day, where the amplitude depends on a broad range of psychological factors and how the individual cope with those factors and a low level in the evening. The dotted lines illustrate different ways researchers measure the decrease during the day, either from the first cortisol samples after awakening to evening, or from the highest levels in the morning to evening, or from awakening, or the highest value after awakening through some fixed point during the day.

Changes in this diurnal rhythm have been associated with psychological and somatic complaints as for instance major depression (Yehuda, Teicher, Trestman, Levengood, & Siever, 1996) and cancer (Sephton, Sapolsky, Kraemer, & Spiegel, 2000; Touitou, Bogdan, Levi, Benavides, & Auzéby, 1996). So far even extensive research has not demonstrated whether alterations of the HPA axis play a role in the development of the disease, or whether changes in the cortisol levels, when found, is a consequence of comorbidities associated with different diseases.

In plasma, cortisol exists primarily in three states; unbound, bound to albumin, and bound to corticosteroid-binding globulin. Salivary cortisol represents only the unbound, free cortisol. Cortisol measured in saliva has shown high correlation with total cortisol in plasma (Kirschbaum & Hellhammer, 1994; Pruessner et al., 1997). The non-invasive method of measuring cortisol in saliva has been used increasingly in field studies over the last decades.

The cortisol awakening response (CAR), defined as the period of cortisol secretory activity in the first 30-60 minutes immediately post-awakening, (Pruessner, et al., 1997) is presumed to be determined by circadian influences but will also reflect phasic psychophysiological processes specific to the wakening up process (Wilhelm, Born, Kudielka, Schlotz, & Wust, 2007). The CAR may therefore be viewed as a measure of activation or arousal; waking up is a necessary and healthy response (Thorn, Hucklebridge, Evans, & Clow, 2009; Ursin & Eriksen, 2004). In the last decades the magnitude of the CAR has been associated with a broad range of psychosocial factors and health outcomes, but the results have frequently been inconsistent (Clow, et al., 2004; Fries, Dettenborn, & Kirschbaum, 2009). In a recent meta-analyses of 147 eligible studies, it is indicated that job stress and general life stress are associated with an increased CAR, whereas fatigue, burnout, and exhaustion are characterized by a reduced CAR (Chida & Steptoe, 2009).

### **1.3.1 Cortisol and recovery**

The cognitive activation theory of stress (CATS) is the theoretical framework for this thesis (Ursin & Eriksen, 2004). According to CATS a high as well as a low awakening response reflects the individuals expectations to the upcoming day (Fries et al, 2009). A flat diurnal curve, with a low decrease in cortisol from morning to evening, and high evening values, may represent lack of recovery, or sustained activation (Kristenson, Eriksen, Sluiter, Starke, & Ursin, 2004). Higher CAR on weekdays compared to weekend days may also be due to the anticipation of a stressful day (Clow, et al., 2004). High cortisol levels in the evening appear to relate to complaints of “stress” and poor self rated health (Dahlgren, Kecklund, Theorell, & Akerstedt, 2009), chronic widespread pain (McBeth et al., 2007), chronic fatigue syndrome (Nater et al., 2008), long term job strain (Rydstedt, Cropley, Devereux, & Michalianou, 2008), and low scores on control in working life (Harris, Ursin, Murison, & Eriksen, 2007). Other studies have not found any association between high cortisol levels in the evening, and negative health outcomes like anxiety (Vreeburg et al., 2010), or metabolic abnormalities (Licht et al., 2010).

### **1.3.2 Seasonal variation in cortisol**

Seasonal variation in cortisol may be due to variation in daylight that affects the individual sleep/wake cycle, even in populations living at latitudes with much less seasonal variation in daylight, than the Arctic and Antarctic. Higher cortisol levels in the winter is the general findings, in Denmark (55° N) (urine) (Hansen, Garde, Skovgaard, & Christensen, 2001), Italy (41° N) (blood) (Del Ponte, Guagnano, & Sensi, 1984), and the United States (42° N) (saliva) (King et al., 2000). In the Danish

study (55° N), where month to month changes in diurnal saliva cortisol variation was studied for 12 consecutive months, the highest concentrations were found in February, March and April, and the lowest concentration in July and August (Persson et al., 2008). In the Danish study, the CAR and the cortisol slope during the day (the dynamics of the HPA axis) appeared relatively unaffected by seasonal variation (Persson, et al., 2008). A Dutch study (53° N) did not find any seasonal variation in urine levels of cortisol (Van Dongen, Kerkhof, & Souverijn, 1998).

In the Arctic and Antarctica the seasonal variations in daylight are extreme. If the absence of daylight during winter or absence of darkness during summer leads to free run of daily routines, the rhythms are “free running” and the diurnal cycle disturbed, even if the subject has knowledge of time (Kennaway & Van Dorp, 1991). In addition, when the free run of routines is avoided, there are still seasonal changes. Cortisol in urine sampled at 6 hour intervals for 24 hours, at approximately 3 month intervals during the Antarctic year, varied considerably across the four seasons (Griffiths, Folkard, Bojkowski, English, & Arendt, 1986). The 24 hour cortisol rhythm was maintained through the year with little change in amplitude, but the timing of peak levels varied greatly with each season (Griffiths, et al., 1986). The hormone melatonin seems to be phase delayed, in winter compared to summer, especially in polar regions (Broadway, Arendt, & Folkard, 1987). This indicates that sleep onset is later than normal. Palinkas (2007) investigated environmental influences on cortisol and thyroid hormone in workers on two different Antarctic stations; McMurdo (latitude 78.48S, elevation 12 m) and the South Pole (latitude 90S, elevation 3880 m). He found lower serum cortisol in workers at the South Pole, which is located at the highest latitude, with the coldest outside temperature. However, personnel spending the winter in Antarctica spend most of their time indoors.

### 1.3.3 Sleep, awakening and cortisol

During sleep there is a gradual increase in cortisol levels from the lowest levels in the first part of the sleep, through the second half of the sleep, followed by a characteristic peak after awakening (Weitzman et al., 1971; Wilhelm, et al., 2007). There is a consistent positive association between sleep duration and cortisol levels at awakening (Hsiao et al., 2010; Kumari et al., 2009; Stalder, Hucklebridge, Evans, & Clow, 2009). Sleep quality, feeling of recovery, and sleep disturbance show inconsistent associations both to cortisol in the morning, and to the difference between morning and evening values (Backhaus, Junghanns, & Hohagen, 2004; Gustafsson, Lindfors, Aronsson, & Lundberg, 2008; Kumari, et al., 2009; Williams, Magid, & Steptoe, 2005).

The characteristic peak in cortisol levels seen after awakening (CAR) has been associated with wake up time, and early morning shift, but the results are not consistent. Reduced cortisol levels have been found in early morning shifts studies (Stalder, et al., 2009; Williams, et al., 2005). Workers with an early morning shift had a more flattened curve with lower cortisol at waking, followed by higher relative awakening response than workers on regular daytime work (Karlson et al., 2006). Other studies have not found this (Kunz-Ebrecht, Kirschbaum, Marmot, & Steptoe, 2004; Pruessner, et al., 1997; Wust et al., 2000), or found the opposite result, were workers waking up early, had the high or pronounced CAR (Edwards, Evans, Hucklebridge, & Clow, 2001; Kudielka & Kirschbaum, 2003; Stalder, Evans, Hucklebridge, & Clow, 2010).

## 1.4 Diurnal rhythm

Rhythms or cycles with periods of about 24 hours are known as circadian rhythms, and include the sleep-wake cycle and other activity of arousal rhythms, for instance, core body temperature, alertness and the synthesis and secretion of many hormones,

including cortisol, melatonin, prolactin, and growth hormones (Rajaratnam & Arendt, 2001). In the absence of time cues, the circadian rhythm will free-run with a period close to, but not exactly 24 hours (Czeisler et al., 1999). Under these circumstances rhythms are driven only by an endogenous mechanism. The endogenous pacemaker, suprachiasmatic nucleus (biological clock) located in the hypothalamus, is the underlying mechanism. This biological clock needs external cues or “zeitgebers” to adjust to the 24 hours day/night schedule. The most important “zeitgeber” in humans is the alteration of daylight and darkness, but social and cognitive cues like work schedules, timing of meals and awareness of clock time also contribute to the process of synchronising rhythms in humans (Czeisler, et al., 1999).

The body temperature is an important marker of the circadian process. In humans the temperature is highest during the late afternoon and early evening and lowest during the early morning hours, labelled the nadir of the circadian process. A misalignment of the internal biological rhythms and the work-rest schedule may be a result of night work or travelling across different time zones (jet-lag). In Antarctica the rhythms may be disturbed when natural zeitgebers are weakened (Gander, Macdonald, Montgomery, & Paulin, 1991). Melatonin and rectal temperature were phase delayed and substantially influenced by the photoperiod while sleep and activity were predominantly reset by the work schedule (Yoneyama, Hashimoto, & Honma, 1999).

## 1.5 Shift work

The society changes rapidly and in order to maximise the production, safety, and service; modern working life includes the whole 24-hour period. More and more people work during “non-standard” working hours like night shift, late afternoon and early morning shift (Rajaratnam & Arendt, 2001). Only a quarter of the European employed workforce, or less than 10% of self-employed workers are engaged in regular day work (Costa et al., 2004). Shift work is defined as work which takes place



between 1900-0600 hours (Monk & Folkard, 1992). In recent years, 12 hour shifts has been more common in Europe. The 12 hour schedule is compensated by more days away from work, leaving time for personal interests and reduces the cost and stress of commuting (Akerstedt & Kecklund, 2005; Smith, Folkard, Tucker, & Macdonald, 1998). This is the reason most often given for why these schedules are preferred by many employees (Mitchell & Williamson, 2000; Tucker, Barton, & Folkard, 1996; Tucker, Smith, Macdonald, & Folkard, 1998). In the offshore oil and gas industry, 12 hour shifts secure 24 hours production of oil and gas with less people living on the rig.

Shift work and especially night work have been associated with a broad range of diseases and health complaints like ischemic heart disease (Frost, Kolstad, & Bonde, 2009; Puttonen, Harma, & Hublin, 2010), increases risk for peptic ulcers and gastrointestinal symptoms (Knutsson & Boggild, 2010), and cancer (Costa, et al., 2010; Kolstad, 2008). The prevalence of fatigue is higher among night workers compared to day workers (Uehata & Sasakawa, 1982), and the night workers reported to have poorer mental health than daytime workers (Bildt & Michelsen, 2002). Early morning shifts and night shifts have been linked to reduced sleep due to circadian interference with sleep, (Akerstedt, 1995). In laboratory studies reduced sleep has been linked to reduced concentration and decision making (Van Dongen, Maislin, Mullington, & Dinges, 2003). Early morning shifts and night shifts have been associated with increased sleepiness and poor performance on reaction time test, in controlled laboratory studies (Dinges, 1995; Lamond et al., 2003) and field studies (Kecklund, Akerstedt, & Lowden, 1997; Tucker, Smith, Macdonald, & Folkard, 1999). Circadian disruption due to shift work or jet lag will normally be adjusted about 1 hour per day in the absence of countermeasures (Arendt, Stone, & Skene, 2000). Adaptation, defined as how quickly the workers change their normal sleep/wake rhythm, seems to go faster in isolated environments (Barnes, Deacon,

Forbes, & Arendt, 1998; Bjorvatn, Kecklund, & Akerstedt, 1998; Gibbs, Hampton, Morgan, & Arendt, 2002, 2007).

## 1.6 Research settings

Since the first oil rig in the North Sea was installed in the Ekofisk field in 1971, the oil and gas industry has developed to be Norway's largest industry, accounting for 22% of the country's national value creation (Ministry of Petroleum and Energy, 2010). The offshore oil and gas industry operates around the clock, requiring most workers to work a combination of day and night shift of 12 hours, for periods for at least 2 weeks (Miles, 2001). On the Norwegian continental shelf the crews are transported by helicopter to the offshore installation that is located 40 to 185 miles from the coast (Figure 3). The work environment includes a harsh physical environment with rough seas, exposure to noise, accident hazard, limited space, and isolation from the community and family (Cooper & Sutherland, 1987; Parkes, 1992b, 1994). There is also concern about the potential risk connected to the travel by helicopter to and from the platform.



Figure 3. Offshore platform, working environment and staff restaurant on oil rig (Photo ©StatoilHydro.com)

Antarctica is regarded as the coldest, driest, highest (on average) and windiest continent on the earth (Figure 4) (McGonigal & Woodworth, 2001). There are no permanent human residents in Antarctica, but a lot of people conducting and

supporting research and other work on the continent. In 2007 as much as 20 nations operated 47 winter permanent stations on the continent (Palinkas & Suedfeld, 2008). During the summertime the number of people is approximately 4500; this decreases to about 1100 in the winter (Antarctica - factbook, 2010). Living and working in the Antarctic involves a wide range of activities that may expose the workers to some form of risk. Adaptation to the environment is necessary for the health and safety of the staff.



Figure 4. Research stations in Antarctic (Halley, Rothera) (Photo: ©British Antarctic Survey)

The Arctic region is not as harsh as the Antarctic. The low arctic area is relatively benign with extensive vegetation and animals to provide food and material for clothing and shelter. Svalbard is located about midway between mainland Norway and the North Pole ( $74^{\circ}$  to  $81^{\circ}$  north and  $10^{\circ}$  to  $35^{\circ}$  east) (Figure 3). In 2010 the population in Svalbard included 2529 people from many different nations (Statistic Norway 2010). In addition to research outposts there are 4 settlements on the islands; the administrative centre in Longyearbyen with hospital, schools, and culture centre etc., the Russian community of Barentsburg, the research community of Ny-Ålesund, and the mining outpost of Svea.



Figure 3. Longyearbyen and the mining outpost Svea (Photo: Bente Moen)

## 1.7 Outcome variables and statistics (choice of methods)

### 1.7.1 Diurnal rhythm (saliva cortisol)

A challenge in isolated and extreme environments, like in this thesis, is whether the personnel are able to maintain their diurnal rhythms, in spite of absence of ordinary zeitgebers, as well as changes in daylight. Diurnal rhythms affect many psychological and physiological processes. One simple way of monitoring the diurnal rhythm is to measure cortisol (Weitzman, et al., 1971). The non-invasive method of measuring cortisol from saliva by using a sampling device called salivette (Salivette®), makes sampling and storage in field studies easy and inexpensive. Cortisol is also very sensitive to any kind of stress stimuli. The cortisol awakening response (CAR), where a high awakening response is an indication of high arousal, may give us an indication of the workers anticipation of the upcoming day in these extreme environments (Fries, et al., 2009; Ursin & Eriksen, 2004). The evening levels may give us an indication of the workers ability to restore or recover after a working day and low evening levels indicate restitution (Kristenson, et al., 2004). The physical and stressful nature of life in these extreme and isolated environments may therefore also be reflected in the diurnal variation in cortisol levels.

### 1.7.2 Health

Exposure to isolated and extreme environments may involve health risks, even if we no longer live in the “heroic period”. Modern installations have reduced many of the risk factors. Even so, there are still psychological challenges that may represent health risk factors. However, the participants involved in the studies in this thesis were highly selected and expected to have low prevalence of somatic disease. In accordance with The World Health Organisation (WHO, 1998) definition of health; “A state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity” we therefore focus on subjective health complaints instead of somatic disease. Subjective health complaints refer to complaints without

pathological signs and symptoms or where the pathological findings are disproportionate to the illness experience (Eriksen, Ihlebaek, & Ursin, 1999; Ursin, 1997).

The subjective health complaints (SHC) questionnaire were used in all three studies (in paper 2, the results on subjective health complaints are published in a separate paper (Waage et al., 2010) ) (Eriksen, et al., 1999). The questionnaire consists of 29 items, and measures degree of subjective somatic and psychological complaints experienced during the last 30 days. The inventory yields 5 subscales in addition to the sum score; musculoskeletal complaints, pseudoneurology (sleep problems, tiredness, dizziness, anxiety, and depression), gastrointestinal complaints, allergy and flu. The scale has high validity and reliability (Eriksen, et al., 1999).

Since some research has suggested that as many as 50 % of the personnel that over winter in Antarctica suffer from “the winter over syndrome”, defined by depression, irritability, insomnia and reduce cognitive performance, (Palinkas & Suedfeld, 2008) we added the so-called Burnam Screen for Depression version (Burnam, Wells, Leake, & Landsverk, 1988) of the Center for Epidemiologic Studies–Depression Scale (CES-D) in the Antarctic study. The scale consists of 6 items derived from the original CES-D version, (Radloff, 1977) and 2 items from the National Institute of Mental Health’s Diagnostic Interview Schedule (DIS) (Robins, Helzer, Croughan, & Ratcliff, 1981). The questions from CES-D are about feelings during the past week, and the two questions from the DIS are about periods of depressed affect during the past year. The scale has high reliability and validity (Burnam, et al., 1988).

### 1.7.3 Performance

The ultimate test of adaptation to these environments is whether the physical and psychological challenges reduce performance or not. In these environments, reduced performance may represent a danger both for the individual and for the mission itself. Performance was measured with two different instruments. In the first paper; the offshore workers, we used a 10 minutes simple serial reaction time test, (Palm Inc, Santa Clara, CA, USA ®) on a handheld computer that has been validated as a measure of sleepiness and performance (Lamond, Dawson, & Roach, 2005). The reaction time is measured in milliseconds (ms). When a black square was displayed on the screen, participants were asked to respond to the stimulus by pressing a key to turn off the square. If no response was given within 1750 ms a new interval was started. If they pressed the key in advance or within 120 ms the response would be discarded and a warning signal would be displayed. Mean reaction time was calculated.

In the third paper; the personnel from Antarctica, performance was measured with the Base Commander's Evaluations of the personnel, just before departure. All participants were rated for psychological functioning, social adaptability, and work performance during the winter. The Base Commander's Evaluation is a standard interview based on 20 statements covering topics like; energy and enthusiasm, reliability, common sense, ability to work unsupervised, joining in base activities, helping others with their work, communicating with others, tact and co-operation, personal cleanliness, leadership, organising social events, doing his/her job, health and ailments, being miserable and depressed, excess alcohol consumption, aggressive behaviour, complaining about things, being inappropriately cheerful, irritating others, and shirking duties. The Base Commanders were asked to rate how much they agree with each of the statements on a scale of 1 to 10. Based on the sum score all participants were classified as "Poorly adapted", "Moderately well adapted", or "Exceptionally well adapted".

#### **1.7.4 Statistics**

Mixed effects models in SPSS (v 15.0) and PASW (v 17) for MS-windows have been used in all the analyses. The advantage with these methods is that they tolerate missing values, for individuals and time points. This is particularly important when the data has several samples per subject (Seltman, 1997). Another advantage is that within the model, you may model the correlation structure in the data in different ways, all depending on the nature of the data. This is often more appropriate than to treat them as independently distributed variables, for example as in strict repeated measure analyses for balanced data (ANOVA) (Seltman, 1997). The method assumes that the data is normally distributed, and therefore the analyses on cortisol data have been done on log-transformed data. The log-transformed data, showed to be more normally distributed than the non-transformed data (Tabachnick & Fidell, 2007). P-values less than 0.05 were considered to be statistically significant.

## 2. Aims of the thesis

The overall aim of the thesis was to explore how humans adapt to work and life in isolated and extreme environments. We have followed their cortisol rhythm, their health, and their performance. Many of human's important bodily factors are controlled by 24 hours rhythm, and maintenance of diurnal rhythm is therefore important for health and wellbeing. In addition to the extreme geographic and socially isolated environment, shift work and seasonal variation in daylight, may influence the adaptation of the cortisol rhythm. We have collected saliva cortisol samples, information on subjective health, and performance, from workers in three different isolated and extreme environments, all with different work schedules and different kinds of daylight exposure.

The first paper includes workers on a small oil rig in the North Sea, the second paper includes workers who are constructing a tunnel in the Arctic (78° north) and the last paper included personnel who spent the winter in the Antarctic (67° and 75° South).

The following research questions were formulated:

1. Are workers in extreme and isolated environments able to keep a normal cortisol rhythm? (paper 1, 2 and 3)
2. How do different work schedules influence the cortisol rhythm while working in extreme and isolated environments? (paper 1 and 2)
3. Does the variation in daylight (photoperiod) influence the cortisol rhythm? (paper 2 and 3)
4. Is working in extreme and isolated environments associated with health complaints? (paper 1 and 3)
5. How does working in extreme and isolated environments affect performance? (paper 1 and 3)



### 3. Summary of papers

#### 3.1 Shift Work, Cortisol and Health among Offshore Workers

Research question 1, 2, 4 and 5: Are workers in extreme and isolated environments able to keep a normal cortisol rhythm? How do different work schedules influence the cortisol rhythm? Is working in extreme and isolated environments associated with health complaints? How does working in extreme and isolated environments affect performance?

The first study was conducted on a small oil rig in the North Sea. The aim was to study if health, reaction time and cortisol rhythm were negatively affected, when a group of workers changed the work schedule from the ordinary day-night schedule (alternated between 2 weeks day shift and 2 weeks night shift, followed by 4 weeks at home every other work period) to a new schedule called swing shift (one week night shift, followed by one week day shift during every work period).

A total of 19 workers, 13 men and 6 women, participated in the study. The workers filled out a questionnaire twice; first at baseline when they work the ordinary day-night schedule and secondly 9 months after implementation of the swing shift schedule. Saliva cortisol was collected 5 times a day for 4 days in the workers leisure time, (2 days one week before the work period, and 2 days one week after the work period) and 3 different days when they were offshore, working day and night shift, and 4 days when they were offshore working swing shift (start, middle end the end of the work period). Reaction time tests were performed only when they were working offshore, and were done at the start, during the middle, and at the end of the work period.

The results showed that working a 12-hour day shift for two weeks in an isolated environment, did not affect the cortisol rhythm. In the period with two weeks night shift, the workers adapted to night shift within a week but readaptation took a longer time. One week after returning home from the oil rig, the workers on swing shift had readapted the cortisol rhythm to normal values, while workers on 2 weeks with night shift needed more than one week to recover their cortisol rhythm. Implementation of swing shift did not give any negative health effects or any negative changes in reaction time, (performance) during the day they shifted from night work to day work.

First of all, this study showed that workers easily adapt their cortisol rhythm to night work, when they work and live in an isolated environment, away from daily family, and social activities, that normally affect adaptation to shift work. Readaptation to day rhythm, both after one week night shift when they were working swing shift, and at home after working two weeks with night shift, took more than one week. The results are in accordance with other studies on the same study population showing a fast adaptation to night shift, measured with melatonin, (Barnes, Deacon, et al., 1998) or by sleep or sleepiness assessment (Bjorvatn, et al., 1998; Bjorvatn et al., 2006). These studies explained the fast adaptation by a combination of environmental and social factors, (Barnes, Deacon, et al., 1998) or lack of light exposure in the morning (Bjorvatn, et al., 2006).

Since the participants in this study of oil rig workers collected the saliva samples at the same time of the year, with almost the same light conditions and with only minimal exposure to daylight before they went to bed in the morning, the study was not designed to detect any effects related to different daylight exposure. To explore this further we performed the next study in a harsher environment in the Arctic

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region, where the external light conditions vary from 24-hours with daylight to 24-hours with darkness.

### 3.2 Saliva cortisol levels in construction workers in the Arctic (78° N)

Research question 1, 2, and 3: Are workers in extreme and isolated environments able to keep a normal cortisol rhythm? How do different work schedules influence the cortisol rhythm? Does the variation in daylight (photoperiod) influence the cortisol rhythm?

The participants in the second study were 25 male workers, constructing a tunnel in Svea, which is located on Spitsbergen (78° north). The environment is isolated, extremely cold during the winter, and there are few other possible activities than work. The work schedule was 10 hours day- or night shift for 21 days followed by a 21 day free period. The aim of the study was to investigate how day shift and night shift in an extreme and isolated environment affected the diurnal rhythm of saliva cortisol. At this high latitude daylight varies from 24 hours daylight to 24 hours darkness. The fact that the workers were without daylight during the work hours gave a unique opportunity to explore the effects of light on diurnal rhythm of cortisol in a natural setting. In a previous study from the same population we have demonstrated that there were no negative health effects, (Waage, et al., 2010) or sleep problems associated with this work schedule (Forberg, Waage, Moen, & Bjorvatn, 2010).

The workers were tested three times during a nine month construction period; April/May (24 hours daylight), September /October (approximately 12 hours light/12 hours darkness) and November/December (24 hours darkness). Saliva cortisol was collected 4 times a day on day 14 in the three different work periods.

Mixed model analyses showed that regardless of whether the workers were on day- or night shift, the cortisol levels were significantly lower at all measure points in the period with 24 hours daylight compared to the period with normal light conditions. Contrary to our expectation, it was the day shift workers who showed disturbed cortisol rhythm in the period with 24-hour darkness.

There may be several reasons why the night shift workers adapted better than the day shift workers in the period with 24 hours darkness. The day shift started early (6:00 AM). It might be difficult to get to bed early enough to keep a normal day-night rhythm with a 7-8 hour sleep period. The change in cortisol rhythm might be related to less sleep and problems with keeping a normal day- night routine. Another possibility is that it is easier to phase delay, than to phase advance of the diurnal rhythm. Finally, the photoperiod, may have contributed to better adaptation, since the change in the cortisol rhythm was only seen in the period with 24-hour darkness.

To explore this further we therefore performed the next study in Antarctica, where we have the same extreme seasonal variation in light, but where the British Antarctic Survey, (BAS) has the logistic responsibility for the stations, and keep a strict normal day/night schedule, and where all the workers were on day shift.

### 3.3 Diurnal rhythm in British Antarctic personnel

Research question 1, 3, 4 and 5: Are workers in extreme and isolated environments able to keep a normal cortisol rhythm? Does the variation in daylight (photoperiod) influence the cortisol rhythm? Is working in extreme and isolated environments associated with health complaints? How does working in extreme and isolated environments affect performance?

For personnel who live and work in Antarctica, the “coldest and most hostile place on earth” (Bradbury, 2002), the long and dark winter and the long distance from family and friends is a challenge. Evacuation from the stations during the winter months is also difficult, for some stations even impossible.

Diurnal rhythm of saliva cortisol and the association to adaptation, performance, and health were examined in 55 healthy individuals who were overwintering in Antarctica. Saliva cortisol was collected 5 times a day for three consecutive days, in three different periods, during the winter appointment; first week after arrival, midwinter, and the last week before departure. Personnel were also screened for subjective health complaints (SHC) three times, while depression (Burnam screen for depression) and affect (PANAS) were measured only midwinter. At the end of the winter appointment, the Base Commander evaluated performance for all personnel.

The characteristic cortisol rhythm with peak levels after awakening, and a gradual fall towards the evening, were shown at all three measure points; arrival, midwinter and before departure. The first week after arrival the cortisol levels were relatively high and correlated positively with Base Commanders evaluation of performance. During midwinter, 58 % of the personnel scored for depression on the Burnam scale. The scores on SHC pseudoneurology, which includes questions on mood, were high but there were no significant increase in pseudoneurology during midwinter. Therefore the scores on single items from both, the Burnam screen for depression and the pseudoneurology scale form SHC. Only 4 (7 %) workers reported depression on the single item; “have you felt sad or depressed the last 30 days?” The high score on depression was based on the full 8 items Burnam scale. When analysing the single items in the scale, it was evident that sleep problems and tiredness were the items that carried the effect. The same was found for SHC pseudoneurology, were sleep problems and tiredness carried the effect.



## 4. Discussion

### 4.1 Are workers in extreme and isolated environments able to keep a normal cortisol rhythm?

The overall aim of the thesis was to explore how humans adapt to work and life in isolated and extreme environments by following their cortisol rhythm, their health and their performance. With one minor exception, all the participants in the three different studies were able to keep a normal diurnal cortisol rhythm. These extreme and isolated environments, with extreme variation in daylight, extreme cold in the Arctic and Antarctic winter, long workdays (10-12 hours) and long work periods, (14 days to months) did not affect the HPA axis and diurnal rhythm of cortisol. With only one exception all participants maintained their diurnal rhythm. An important factor for this achievement is, in our opinion, that their sleep wake cycle and meals schedule were regular. Social and family commitments that may be in conflict with these schedules were absent. Cognitive cues like work schedules and timing of meals are important factors that contribute to synchronise diurnal rhythm (Czeisler, et al., 1999). Based on the results, we therefore assume that as long as the workers keep a normal sleep/wake schedule, extreme or isolated environments, long workdays, or long work period will not affect the HPA axis and diurnal rhythm of cortisol.

The only group of workers who did not keep a normal cortisol rhythm was the construction workers, working day shift in the Arctic during the period with 24 hours darkness. We assume that this group did not follow such strict rules for their schedule as the other groups. The fixed schedules were not as strictly reinforced as for the British Antarctic stations. The construction workers were free to follow their own schedules, which may have led to social activities in the barrack after work and therefore less sleep (Forberg, et al., 2010).

All participants in this material, construction workers in the Arctic, oil platform workers, and Antarctic personnel, were highly selected. Workers on the oil platform and in the Arctic had extensive experience from this kind of work, including shift work experience. The offshore workers need an updated health certificate every year to be allowed to work offshore. Antarctic personnel went through a comprehensive evaluation and selection that included both a mental and physical screening, previous to the employment. It is therefore reasonable to assume a “healthy worker effect” (Costa, 2003; Knutsson & Akerstedt, 1992). The term “healthy worker effect” is used to explain that workers exhibit lower overall death rates than the general population, and relatively good health in older employees. Severely ill and chronically disabled men and women are ordinarily excluded from employment (Knutsson & Akerstedt, 1992). For shift workers only the healthiest and fittest, those who cope with that kind of work are the ones who continue their work for several years (Costa, 2003). The workers on the oil rig in the North Sea, the construction workers in the Arctic area of Svalbard, and the Antarctic personnel we had studies are healthier than the average employees in ordinary working life.

## 4.2 How do different work schedules influence the cortisol rhythm?

The oil rig workers adapted to night work within a week, but readaptation to day rhythm took longer time. The construction workers in the Arctic adapted to night work regardless of season and daylight. The day worker showed disturbed cortisol rhythm in the period with 24 hour darkness but not in the period with normal light and 24 hour daylight. In this case it appears to be easier to adapt to a night rhythm than to early morning shifts in the extreme and isolated environment.

The fast adaptation to night work seen in the oil rig workers are in accordance with other studies from isolated environments like oil rigs and Antarctica. A fast



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adaptation to night work has been reported for melatonin, (aMT6s) (Barnes, Deacon, et al., 1998; Broadway & Arendt, 1988; Gibbs, et al., 2002; Midwinter & Arendt, 1991) and sleep and sleepiness assessment (Bjorvatn, et al., 1998; Bjorvatn, et al., 2006). The findings are in contrast to observations from shift workers in general (Czeisler et al., 1990; Ross, 2009) and offshore fleet workers (Hansen, Geving, & Reinertsen, 2010). The fast adaptation could probably be explained by environmental factors and social factors, or lack of light exposure before they go to bed after work (Barnes, Forbes, & Arendt, 1998; Bjorvatn, et al., 2006; Ross, 2009). The readaptation to day work and the adaptation to an early morning shift in the Arctic seem to be more difficult.

The lack of adaptation to an early morning shift in the Arctic, in the period with 24 hours darkness, is in accordance with another study of workers from the London underground railway system, who showed lower cortisol levels on the early morning shift, compared to normal day shift and control days (Williams, et al., 2005).

One explanation to both the slow readaptation in the offshore workers and the lack of adaptation to early day work in the Arctic in the period with darkness could be that it is generally easier to phase delay than to phase advance of the circadian rhythm (Bjorvatn & Pallesen, 2009; Czeisler, et al., 1999). The lack of adaptation to early day work in the period with 24 hour darkness, but not in the period with normal light, or 24 hour daylight suggest that seasonal variation in daylight also may affect the results for the construction workers in the Arctic. The results are in accordance with studies from offshore workers, (Barnes, Forbes, et al., 1998) and personnel in Antarctica, (Francis et al., 2008; Broadway, et al., 1987) reporting that the diurnal rhythm of melatonin tends to be phase delayed in the winter compared to summer. To phase advance the diurnal rhythm, in a photoperiod that normally promotes a phase delay of the diurnal rhythm may therefore be extra difficult.

Another explanation may be that the lack of adaptation is associated to less sleep. Previous results from our studies shown that both groups, the offshore workers in the week when they readapted to day schedule, (Saksvik, et al., 2010) and the construction workers in the Arctic region of Svalbard on day work (Forberg, et al., 2010) reported less total sleep time. This has been associated with both a flatter diurnal cortisol curve, with lower CAR and higher evening values (Kumari, et al., 2009) and higher evening cortisol (Spiegel, Leproult, & Van Cauter, 1999).

### 4.3 How does variation in daylight influence the cortisol rhythm?

In the Arctic, but not Antarctic, variation in daylight seems to affect the level of cortisol but not the derived measures like the CAR, or the difference from morning to evening levels. Regardless of work schedule, (day or night work) the construction workers in the Arctic, showed significantly lower cortisol levels at all measure points in the period with 24-hour daylight, compared to the period with normal light conditions. They also showed lower cortisol levels in the morning, in the period with 24-hour darkness, compared to the period with normal light conditions. However, in the period with 24 hour darkness, the cortisol levels were not as low as they were in the period with 24 hour daylight. It therefore seems like the effect of 24 hour with daylight gives a stronger suppression effect on cortisol levels than 24 hours with darkness.

In Antarctica the variation in daylight, with darkness during the winter, and normal light conditions when the personnel arrived and departed, did not influence the cortisol rhythm. The participants have the normal peak after awakening and the decline during the day at all three measure points (arrival, midwinter, departure). However, the cortisol levels were significantly lower, especially in the morning midwinter, and the last week before departure, compared to the first week after

arrival. Since the cortisol levels were lower both in the period with 24-hour darkness during midwinter, and the period with normal light conditions during the last week before departure, we do not attribute it to differences in daylight, but to differences in workload. The first week after arrival is the busiest period. The research station has to be prepared for the winter (Mocellin & Suedfeld, 1991; Palinkas, 1992), and the cortisol awakening response (CAR) may reflect the individual's anticipation of the upcoming day (Clow, et al., 2004; Fries, et al., 2009; Ursin & Eriksen, 2004).

The significantly lower cortisol levels at all measure points in the period with 24 hours daylight in the Arctic, were in accordance with a previous longitudinal study showing lower saliva cortisol levels, but no differences in the derived measures during the summertime compared to winter (Persson, et al., 2008). Studies from Antarctica suggest that cortisol levels measured in urine vary across seasons, but differences in analyses and study design, in these studies make comparison impossible (Griffiths, et al., 1986; Kennaway & Van Dorp, 1991). A recent lab study found that bright light exposure significantly reduced plasma cortisol levels at both circadian phases, just after sunrise, and just after sunset while dim light exposure had little effect on the cortisol levels (Jung et al., 2010). Based on this, we suggest that the 24-hour daylight the workers were exposed to in the Arctic study (78° N), was great enough to suppress the cortisol levels, while the normal light exposure in the Antarctic (67 ° and 75° S) was not enough to suppress the cortisol levels.

In all studies from Antarctica it is difficult to fully dedicate any physiological change to the external climate and the lack of light, since for most stations, the majority of personnel spend most of their time indoors. At the Scot-Amundsen base it is not quite unusual to work in T-shirts and shorts. For our Arctic workers, the exposure to external climate and light conditions were limited during the work periods. They spent most of their time inside a tunnel or in the barrack with only artificial light.

However, when they were not working, they lived in Norway, many of them north of the polar circle, where the daylight also varies with the season.

## 4.4 Health and performance in extreme and isolated environments

One aim in this thesis was to investigate how adaptation in extreme and isolated environments was associated with health and performance. In all three studies, “the healthy worker effect” was demonstrated and the workers reported better health compared to the general Norwegian population (Ihlebaek, Eriksen, & Ursin, 2002; Waage, et al., 2010). The 12-hour shift schedule for 14 days, or the 10-hour shift schedule for 21 days, in extreme and isolated environments, was not associated with subjective health complaints. “Overwintering” in Antarctica was associated with some sleep problems and tiredness. Based on the results, we may therefore assume that these extreme and potentially “stressful” work environments, and work schedules, were not associated with any health problems. These highly selected men and women, coped with the challenges, and they had the ability to adjust to the surrounding milieu. This is assumed to have a positive beneficial health promoting effect (Antonovsky, 1987; Palinkas, 2003). The results are in accordance with the Cognitive Activation Theory of Stress (CATS) concepts of adaptation to extreme and isolated environments (Ursin & Eriksen, 2004).

The good health reported by the construction workers in the Arctic, and the offshore workers are in contrast to other studies of offshore workers reporting sleep problems, reduced sleep quality, and higher anxiety levels (Cooper & Sutherland, 1987; Menezes, et al., 2004; Parkes, 1992a, 1994). However, the results are in accordance with a study of construction workers, showing that working 84-hours a week with alternate weeks off were not associated with differences in subjective health complaints compared to a control group working 40 hours (Persson et al., 2003).

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The offshore workers were also tested for potential effects of swing shift. Swing shift cause a circadian desynchrony of the sleep/wake cycle twice on every work period instead of once every other work period, as in the regular day/night shift. Circadian desynchrony is thought to contribute to the increased health risk associated with night work (Lund et al 2001). However, implementation of the new schedule was not associated with any short-term health complaints in these workers. A simple serial reaction time test was used as a measure of performance in this study. The results showed that the workers performed well during all three shift schedules (2 weeks day shift, 2 weeks night shift, and swing shift that include one week night shift followed by one week day shift). There was one exception; there was a significantly higher mean score on reaction time, the second night offshore, when they were working night shift compared to day shift. This result corresponds with the fact that shift workers are most tired on the first night during a night shift (Akerstedt, 2003). However, the reaction time was slower, the first night when they were going to work 14 nights compared to first night on swing shift, where they were going to work for 7 nights followed by 7 days. The results were surprising, and we have no good explanation for it, but it may be related to expectation factors (Ursin & Eriksen, 2004). The results correspond well with the data on cortisol. The workers had higher cortisol levels after awakening the second night during swing shift, than they had the second night during the beginning of a period with night shift. Good performance on the reaction time test and higher cortisol levels after awakening may also be an indication of better sleep efficiency when they worked swing shift (Saksvik et al, 2010).

The normal cortisol rhythm seen in the personnel in Antarctica during the winter did not indicate any “overwinter syndrome”. The high prevalence (58 %) of depression, measured by the Burnan screen for depression scale, was related to sleep problems and tiredness. Only 4 participants (7%) reported depression on the single item; “have you felt sad or depressed last 30 days?” Other studies reporting depressive symptoms

during the Antarctic winter (Palinkas & Houseal, 2000; Steel, 2001) should be re-analysed for possible contamination of sleep problems. At Svalbard, the reports of sleep problems vary. More than 80 % of the Russian population in Barentsburg complain about sleep problems, while only 20% of the Norwegian population have sleep problems (Nilssen et al., 1997). The Svalbard study attributes the differences in sleep problems to the fact that the Norwegian population at Svalbard is recruited mainly from the northern Norway, and thus more familiar with the daylight and climatic conditions on Svalbard than the Russians, who were recruited from the southern part of Russia.

Normally sleep problems during stays in Antarctic has been attributed to disruption of circadian rhythm in both during the winter (Kennaway & Van Dorp, 1991) and during the summer (Steel, Callaway, Suedfeld, & Palinkas, 1995). Disruption of diurnal rhythm was not the reason for the sleep problems and tiredness reported in the workers in our study. Since the cold and darkness during the Antarctic winter force the workers to spend most of their time indoors, the workers may experience monotony and boredom, which again may lead to tiredness and sleep problems. Suedfeld and Steel (2000) describe this as the personality paradox; those who volunteers to work in extreme and isolated environments, often want adventure and challenges and they score towards the upper end of any scale of thrill-seeking or novelty seeking behaviour. Then they discover that they have committed themselves to monotonous, routine and boring tasks, in a confining environment, with the same group of people and without the choice to leave. Diaries of members of British polar expeditions, support the statement and describe the midwinter as the least stressful phase of the journey (Mocellin & Suedfeld, 1991).

At the end of the winter appointment in Antarctica, all personnel were rated for psychological functioning, social adaptability, and work performance by the stations

Base Commanders. Most personnel (62.3%) were evaluated as moderately adapted, 26.5% as exceptionally well adapted and only 11.3% as poorly adapted according to the Base Commanders evaluation. Those who were evaluated as exceptionally well adapted had a significantly higher cortisol awakening response at arrival and a greater decrease during the day at departure, compared to participants evaluated as moderately adapted. The result is in accordance with the Cognitive Activation Theory of Stress suggesting that as long as the individual expects to cope with the stressor, high activation may be positively associated to health and well being (Ursin & Eriksen, 2004).

The studies showed no negative short-term health effects of alteration of circadian rhythms in either the offshore workers or the construction workers in the Arctic. However, due to the short follow-up (less than one year) we cannot say anything about the long-term effects of alteration of circadian rhythms on wellbeing, alertness and performance.

## 5. Conclusions

Based on results from the three studies in this thesis, the conclusion is that humans adapt well to life and work in extreme and isolated environments. Keeping a strict organisation of diurnal routines, including a regular schedule of wake up times and meals, seems to be important. In addition, the isolated environment in it selves, may be conducive to better adaptation of the diurnal rhythm. It seems to be easier to adapt to a night rhythm than an early day shift, especially during the dark winter which normally is a period were people tend to phase delay their diurnal rhythm. Variation in daylight affects the levels of cortisol; lower cortisol levels were found in both the period with 24 hour daylight and 24 hour darkness. However, in the Antarctic, where the personnel kept a strict organisation of diurnal routines, the shape of the cortisol curve was not affected, while the day shift workers in the Arctic showed a disturbed cortisol rhythm, probably due to less sleep. Overall, working in extreme and isolated environments did not have any negative effect on health and performance. One exception was the workers in Antarctica, who reported tiredness and sleep problems in the middle of the Antarctic winter. The offshore workers were also tested for any potential health effect from swing shift. The implementation of swing shift was not associated with any changes in subjective health complaints, or scores on reaction time (performance) during the day they shifted form night work to day work. In Antarctica exceptionally good adaptation (performance) was associated with high cortisol awakening response.



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