



WHO technical meeting on sleep and health

Bonn Germany, 22-24 January 2004

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European Centre for Environment and Health
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ABSTRACT

Twenty-one world experts on sleep medicine and epidemiologists met to review the effects on health of disturbed sleep. Invited experts reviewed the state of the art in sleep parameters, sleep medicine and long-term effects on health of disturbed sleep in order to define a position on the secondary and long-term effects of noise on sleep for adults, children and other risk groups. This report gives definitions of normal sleep, of indicators of disturbance (arousals, awakenings, sleep deficiency and fragmentation); it describes the main sleep pathologies and disorders and recommends that when evaluating the health impact of chronic long-term sleep disturbance caused by noise exposure, a useful model is the health impact of chronic insomnia.

Keywords

SLEEP
ENVIRONMENTAL HEALTH
NOISE

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TABLE OF CONTENTS

Introduction	2
Scope of the meeting.....	3
Summary of the meeting discussion	4
Working Groups	13
Conclusions and recommendations.....	14
Annex 1 – Technical papers	23
Adult’s sleep physiology, sleep quality and indicators of disturbed sleep. Short-term effects on health of disturbed sleep in adults - Alain Muzet	24
Sleep characteristics and sleep deprivation in infants, children and adolescents - Kahn A, Franco	38
Sleep disorders in adults ; biological mechanisms through which sleep disorders affect the health of adults. Identification of environmental factors leading to clinical sleep disorders - Michel Billiard.....	62
Sleep disorders in children, mechanisms through which sleep disorders affect the health of children – A. Wiater	82
Medium and long term effects of sleep disturbance (by disorders and/or by stressors) on the health of adults - Sona Nevsimalova.....	107
Medium and long term effects of disturbed sleep on the health of children - Oliviero Bruni	126
Sleep - gender, age, stress, work hours, Torbjörn Åkerstedt.....	156
Annex 2 –Participants List	181

Introduction

We spend almost a third of our life sleeping. Good quality sleep is essential for good health and well-being. However, lifestyle and environmental factors are increasingly causing difficulties in sleeping. Sleep disturbance is frequently considered the most serious consequence of environmental noise.

The WHO European Centre for Environment and Health expanded its work on sleep disturbance (focusing on the health consequences of poor sleep as well as on noise disturbance itself) in order to define a position on the secondary and long-term effects of noise on sleep for adults, children and other risk groups. 21 international specialists on sleep, including psychiatrists and psychologists, gathered in Bonn from 22 to 24 January 2004.

This document describes the meeting discussion and presents the conclusions and recommendations. Dr Christopher Drake reviewed the conclusions and recommendations.

A note on sleep

Sleep is a basic human need and is essential for good health, good quality of life and performing well during the day. Several indicators can be used to describe sleep disturbance or sleep disorders. These indicators are:

- 1) Sleep latency
- 2) Number and duration of nocturnal awakenings;
- 3) The total sleep time
- 4) Modifications in amount and proper rhythms of particular sleep stages such as slow wave sleep (SWS, or stages 3 and 4);
- 5) Rapid Eye Movement sleep (REM sleep), together with modifications in the autonomic functions (heart rate, blood pressure, vasoconstriction and respiratory rate);
- 6) Repetitive nights of sleep disruption among one week or one month.

Self-reported sleep can also be used as an indicator: it is considered the least reliable objectively but perceived as the most important by the individual.

Health effects of not sleeping

The main effects of sleep deprivation include **physical effects** (sleepiness, fatigue, hypertension) **cognitive impairment** (deterioration of performance, attention and motivation; diminishment of mental concentration and intellectual capacity and increase of the likelihood of accidents at work and during driving) and **mental health complications**. Inadequate rest impairs the ability to think, to handle stress, to maintain a healthy immune system, and to moderate emotions. Maintained total sleep deprivation is fatal in some animal species.

The day after a night of abnormal or poor sleep is, whatever the cause, a disturbed day. People can fall asleep at work, at school or when driving; feel tired; have concentration and vigilance detriments; have memory blanks; irritability; frustration; and have a higher probability of accidents or injury (WHO, 1998).

Scope of the meeting

The main purpose of this meeting was to identify the current links between sleep disturbance (under all its modalities) and health status of adults, children and risk groups (shift workers, elderly, insomniacs), both on a long term and short term basis.

The following figure illustrates the reasoning and logic behind the meeting preparation and the starting point for the writing of the meeting background papers.

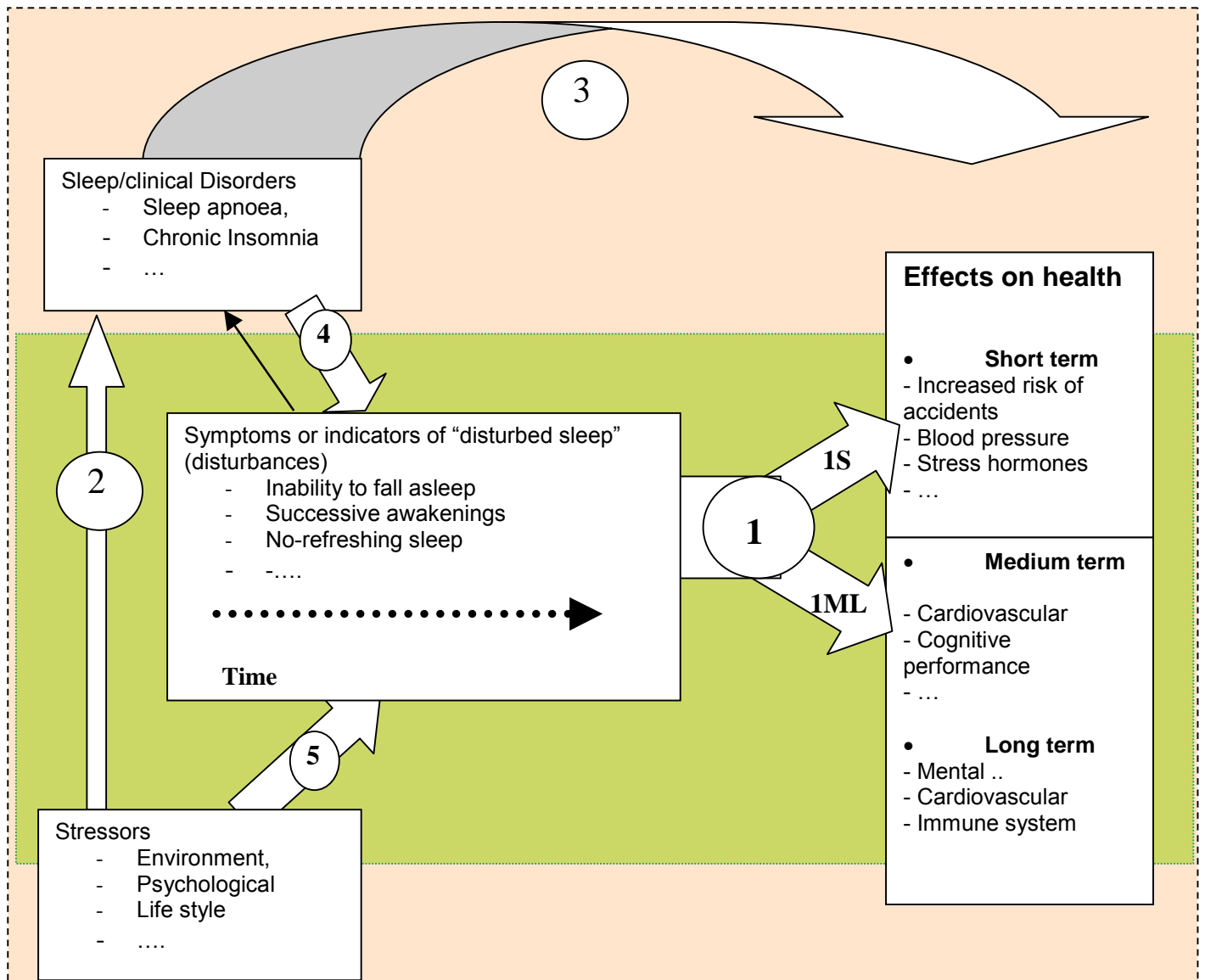


Figure 1 – Scope of the meeting

Main themes for the technical papers of the meeting Results

(1) - Most unknown ; (2) - Little known ; (3) Important body of knowledge ; (4) Important body of knowledge ; (5) Important body of knowledge

With three groups of population in mind (adults, children and specific risk groups) the meeting reviewed:

1. Sleep physiology: what is a “normal” sleep? What are the various types of sleep disturbances? What kind of indicators are used to describe each of these types of disturbances? (Awakenings, arousals, body movements, changes of sleep stages, cortisol secretion etc.);
2. Are there specific sleep disturbances that are of special relevance for some “risk groups”, and why? (This will cover children, elderly, shift workers, etc.).
3. The various health end points than can be linked to sleep disturbances.

Summary of the meeting discussion

Dr G. Klein welcomed the participants on behalf of Dr. M. Danzon, Regional Director of the WHO Regional Office for Europe. He introduced the WHO Regional Office for Europe and the work on noise and health and provided some key figures for noise and sleep in Germany.

Mr. Bonnefoy explained the background and the goals of the meeting and how it escapes the traditional work of the WHO noise and health unit and how the results will be used for the unit's future actions.

Mrs. C. Rodrigues presented the meeting objectives and provided some methodological guidance in order to optimize the work during the meeting.

In summary, the group was challenged to provide a definition of a normal sleep, of arousals and their significance, sleep deficiency, sleep fragmentation, and, awakenings, using scientifically based and accepted evidence and to answer some central questions:

- Can we use the knowledge gained in evaluating the impact on health of a sleep pathology to assess the impact on health of sleep disturbed by noise? If yes which pathology would be best suited and what would be the limits to such an assumption? This would help to translate the knowledge gained by clinicians to support advice to Member States on their noise and health policies.
- Can we list and describe the causes of sleep disturbances, the sleep changes and the health effects (figure 2) having for each arrow the evidence, the gaps in knowledge, public health significance and the consideration of confounding factors?

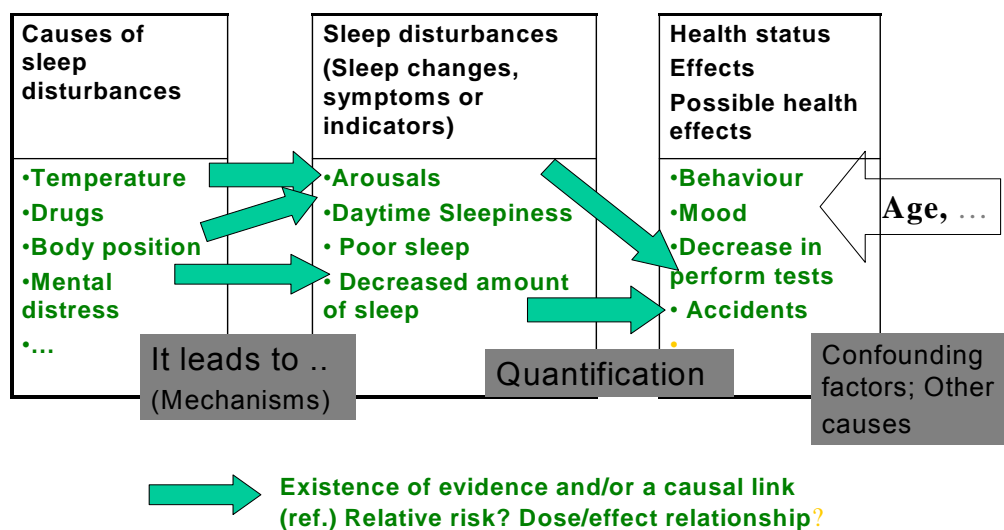


Figure 2 – Illustration of some points proposed for discussion

The invited experts presented seven papers, followed by a short discussion within the whole group. More detailed in-depth discussions about these presentations took place during working groups on adults and children.

The seven papers are attached as annex 2. They were dealing with the following topics :

1. Adult's sleep physiology; sleep quality and indicators of disturbed sleep. Main causes of sleep disturbances on adults - Alain Muzet
2. Sleep characteristics and sleep deprivation in infants, children and adolescents - André Kahn
3. Sleep disorders in adults; biological mechanisms through which sleep disorders affect the health of adults. Identification of environmental factors leading to clinical sleep disorders - Michel M. Billiard
4. Sleep disorders in children, mechanisms through which sleep disorders affect the health of children - Alfred Wiater
5. Medium and long term effects of sleep disturbance (by disorders and/or by stressors) on the health of adults - Sonja Nevsimalova
6. Medium and long term effects of disturbed sleep on the health of children - Oliviero Bruni
7. Sleep - gender, age, stress, work hours - Torbjörn Åkerstedt

“Adult’s sleep physiology; sleep quality and indicators of disturbed sleep. Main causes of sleep disturbances on adults led by Prof. Alain Muzet

In order to answer questions about the effects of sleep disturbances on health an agreement on definitions of sleep patterns and different types of sleep disturbances is essential. The paper dealt with “normal” sleep physiology, the factors that could interfere with the physiologic processes and the immediate effects observed when sleep is disturbed.

The author suggested that very little is known on why we sleep, a little more is known on how we sleep. He then introduced what could be understood as a “normal” sleep.

To some degree, sleep disturbance may be quantified by EEG measures, autonomic variables, motor and hormonal responses. The normality of sleep can be influenced by stages of sleep, individual factors, and context factors. We can measure it in adults with **subjective** complaints (poor sleep quality, daytime fatigue, changes in mood, ..) and **behavioural** changes the next day (daytime drowsiness, performance decrement, drug consumption, ...).

There is no habituation of the cardiovascular responses to noise. Each noise stress on the human body is associated with a cardiovascular response that is composed of a vasoconstriction of peripheral circulatory system and an increase of blood pressure even if the sleep itself is not affected.

The questions raised at this session were used as the basis for defining the working groups’ terms of reference. The main points are the following:

- Sleep should be defined according to age and gender;
- Attention has to be paid to pharmacological effects;(related to sleeping drugs). There are a number of factors that influence sleep quality and quantity;
- Arousals and interactions with sleep stages seem to be important,
- Sleep stages are important. What the brain is performing during the different sleep phases when it gets interrupted is important!
- Not only awakenings are important! Autonomic responses/repeated cardio vascular responses have no habituation to noise.
- The REM sleep has a tissue-repairing function, both macrostructure of sleep and microstructure (cortical arousals, sub cortical arousals) are important.
- The cardiovascular responses are independent from sleep disturbance! A person may sleep with a relatively high noise level, nevertheless he/she continues to have autonomic responses. Similarly what happens at the level of the heart does not affect the sleep. Cortical responses are always related with cardio vascular responses.
- During sleep the cortex is switched off.
- For decision makers it is important to provide guidelines and references easy to transfer to legislation.
- How to evaluate sleep quality and sleep quantity? Is sleep satisfaction a good measurement?
- Is sleep a fragile state or is it because of the sleep function that we are more fragile?

Most of these questions were answered in the working groups.

Sleep characteristics and sleep deprivation in infants, children and adolescents – led by Prof André Kahn.

A normal childhood is crucial to a healthy adult life. Children's sleep patterns are very different from adults, deserving therefore special attention. The existing knowledge of health effects of sleep disturbance on children is not very large.

Prof André Kahn provided a review of a child's "normal" sleep, the factors that have an influence on it and the immediate effects observed when their sleep is disturbed. Sleep recording techniques, normal sleep characteristics, and some of the effects of sleep deprivation in children were described. The presentation focused then on normal sleep characteristics for fetuses, infants, children and adolescents, the short-term effects of sleep deprivation and on the effects of repeated sleep deprivation /co-morbidity.

Short-term effects of sleep deprivation in school-age children appear to be manifested by daytime fatigue only; medium-term effects have been associated with daytime sleepiness and behaviour problems. Attention-deficit/hyperactivity disorder has been suggested as a possible consequence of non-sleep among children. On the medical level the body of evidence is still poor.

Effects of repeated sleep deprivation in infants, children and adolescents are multifactorial and complex, but repeated or chronic sleep disruption in children could be pervasive, affecting the children's physical, mood and cognitive well being. Changes in sleep quantity and quality together with autonomic reactions are seen during exposure to ambient stressors during sleep, reflecting modifications within the brain of the sleeping child. It remains, however, to be determined what long-term effects pervasive ambient stressors have on the child's cognitive, mood and physical development.

One might predict that the effects of sleep deprivation on the child's sleep and health depend upon the stressor responsible for the deprivation or fragmentation of sleep, temporal aspects of the stressor, genetic predisposition, psychological responses to the stressor, and the nature as well as the duration of the evaluation.

All research on sleep and health in children needs to follow very strict ethical rules. This explains partly the lack of knowledge observed in some areas.

Important points raised at the discussion:

- The definition of the "normal child sleep" parameters is extremely important, they should be listed before starting to identify a disturbed sleep in order to be able at a further stage to identify its consequences.

- Repeated sleep deprivation or insomnia were discussed in detail. A child cannot accurately report about his/her sleep, so it is difficult to define sleep efficiency and to base further findings on this evaluation technique.

- Special attention has to be paid to the methods of evaluating the status of a child after a deprived night. Fatigue does not reflect equally in adults and children: a child can be hyperactive due to a disturbed sleep.

- We need indexes and indicators that measure sleep quality in children.

- The different parts of the night, in children for example, play different roles. The growth hormone is released in the first part of the night and it does not happen in the second part of the night, but there is little data to show this.

- Are children less sensitive to noise?, It is true that a child can sleep with high noise levels. This faculty decreases with age. Most of the evidence is based on parents' reports as the main source of information and it is likely that the child did sometimes wake up but the parent did not notice it.

Sleep disorders in adults; biological mechanisms through which sleep disorders affect the health of adults. Identification of environmental factors leading to clinical sleep disorders led by Prof. Michel M. Billiard

There are several types of sleep disorders. Insomnia, sleep apnoea, and restless leg syndrome are some examples of clinical sleep disorders that can affect adults and interfere with normal functioning. These sleep disorders can contribute to medical or emotional problems. This is a field where a vast body of knowledge exists. For this meeting over-information was avoided and the paper reviewed and presented the main sleep disorders in adults and the health and well-being consequences of these diseases. It focused on sleep disorders that were considered interesting, in the expert's opinion, for discerning the health impacts of sleep that is occasionally or chronically disturbed by noise.

According to the Diagnostic and Statistical Manual of Mental Disorders there are four categories of sleep disorders, i) primary sleep disorders including dyssomnias, ii) parasomnias, iii) sleep disorders related to medical/psychiatric disorders including insomnia and hypersomnia; iv) and other sleep disorders including disorders due to a general medical condition or a substance-induced sleep disorder. The presentation concentrated on dyssomnias, parasomnias, medical/psychiatric sleep disorders, obstructive sleep apnea/hypopnea syndrome, narcolepsy-cataplexy, environmental sleep disorder and periodic limb movement disorder.

Primary insomnia is a dyssomnia and it has been shown that the pathophysiology of the disorder is considered to be based on the confluence of predisposing, precipitating and perpetuating factors. In a predisposed subject, noise may certainly act as a triggering factor. Narcolepsy-cataplexy is most often remarkable for sleep fragmentation. However, in contrast to the obstructive apnea/hypopnea syndrome there is no correlation between sleep fragmentation and excessive daytime sleepiness.

Moreover the pathophysiology of narcolepsy is based on an imbalance between acetylcholine and monoamines and on an impairment of the hypocretin system, which are not found in noise induced insomnia.

A polysomnographic feature of obstructive sleep apnea/hypopnea syndrome and upper airway resistance syndrome, consists in recurrent arousals and awakenings. Interestingly, most of subjects with these conditions do not complain of poor sleep, but of non-restorative sleep, fatigue and/or headache on morning awakening, and excessive daytime sleepiness. These clinical features are certainly an incentive to look for morning symptoms and excessive daytime sleepiness in subjects submitted to an abnormal level of noise.

Environmental sleep disorder has noise as one of its possible sources, possibly the most important one. Two issues have been emphasized. First, environmental disorder does not refer only to insomnia but also to excessive sleepiness, so that the possibility of excessive daytime sleepiness in subjects undergoing a noisy environment must be kept in mind. Second, vulnerability to either insomnia or hypersomnia, must be considered when reviewing the risks from environmental sleep disorder.

One of the polysomnographic features of periodic limb movement disorder is arousals and awakenings. However periodic limb movements do not seem to be the cause of arousals and awakenings. Even if noise disturbance manifests by arousals and awakenings the biological mechanisms that act on the basis of these disorders are different and in some cases due to chemical unbalances, or respiratory mechanisms, so the consequences will be different as well.

The symptoms of insomnia are very similar to the ones experienced by the people reporting noise sleep disturbance. But the single fact of having noise does not make everybody exposed insomniac. It is a very interesting finding but has to be analyzed with some caution. An insomniac is hyper-aroused, he is never sleepy.

Is there evidence that people suffering from insomnia have an increased mortality risk? Not really: there is a statistical association but we cannot say with the present state of knowledge that insomnia per se brings an increases risk of mortality. Some causality was found with hypnotic drugs taken when suffering from insomnia!

Misinterpretations and misperception of sleep is common among insomniac people, they affirm not having slept and when surveyed in a laboratory they actually sleep.

The insomniac subjects followed by Professor Billiard showed an increased body mass index, but obesity was not covered by the study.

Sleep disorders in children, mechanisms through which sleep disorders affect the health of children led by Dr Alfred Wiater

Healthy sleep is crucial for normal development and common sleep problems are seen in general paediatric practice. Children's sleep patterns are different from adults and so are their clinical sleep disorders. Nightmares, bedwetting, sleep walking are some examples of common sleep disorders experienced by children that can affect and compromise children's development. These sleep disorders can contribute to medical or emotional problems. The specific influence of noise on children's sleep should be examined in order to find appropriate measures for reduction.

Dr Wiater's presentation concentrated on the main sleep disorders that affect children's sleep and the main findings of a study carried out in Germany in 2000 by a group of paediatricians and child psychiatrists to evaluate sleep disorders and behaviour problems in 5-6 year-old and 9-10 year-old children.

Sleep disorders in children include intrinsic and extrinsic sleep disorders as well as parasomnias. Intrinsic sleep disorders comprise disorders such as the obstructive sleep apnea syndrome that can affect the health of children in the form of somatic disorders, e.g. cardiovascular or respiratory problems. Predominantly, extrinsic sleep disorders occur during childhood. Inadequate sleep hygiene, environmental sleep disorder, adjustment sleep disorder, limit-setting sleep disorder, and sleep-onset association disorder belong to this category. Extrinsic sleep disorders are strongly associated with behaviour problems such as hyperactivity or psychological symptoms.

Parasomnias, especially nightmares, can also be associated with psychological problems. Up to 35% of elementary school children of the Köln study presented sleep onset problems and 21% of this group have problems sleeping through the night. Usually, several sleep disorders can be diagnosed in one child. Environmental factors such as noise disturbances, can influence children's sleep. 15% of elementary school children complain about noise disturbances during sleep. The main source of noise is road traffic.

Sleep disorders in childhood are an important paediatric problem because of their influence on children's health and their strong correlation with behaviour problems. Parents often do not recognize their children's problems and disturbances. Educational efforts to make the children used to regular bedtimes and wake-up times from early childhood could be helpful for a normal sleep-wake-rhythm.

On the Cologne study the presence of a television set in the child's bedroom and reporting sleep problems by the child show strong association in this study. The children wake up earlier and go to bed later because they are watching TV. Some TV programmes in the early morning are specially designed for children.

Medium and long term effects of sleep disturbance (by disorders and/or by stressors) on the health of adults – led by Prof. r Sona Nevsimalova

The aim of the presentation was to examine the effects which the most frequent sleep disorders have on adults' health, knowing that at least 30% of the population suffer from some sort of sleep disturbance. The greatest impact on physical and mental health is seen in patients suffering from the sleep apnoea syndrome (neurocognitive, cardiovascular, social consequences and higher mortality), from insomnia (behavioural, psychiatric and medical consequences), and from narcolepsy and hypersomnia (neurobehavioral and personality changes, medical and social consequences). Patients suffering from the restless legs syndrome complain of neurobehavioral problems and lower quality of life, while the secondary forms of the disease are associated with other medical conditions. Parasomniacs are endangered by violent and injurious behaviour during attacks that can even involve the law.. Behavioural, cognitive and social consequences also affect patients with circadian rhythm disorders. Therefore, understanding the patient's health requires consideration of the state of the patient asleep and also awake.

The consequences of insomnia can be **behavioural** manifesting in poor performance at work, fatigue, memory difficulties, concentration problems, car accidents, **psychiatric problems** - depression, anxiety conditions, alcohol and other substance abuse, **medical** - cardiovascular, respiratory, renal, gastrointestinal, musculoskeletal disorders, impaired immune system function and an **increased** risk of mortality.

Is the sleep of pregnant women more susceptible to external stressors? We do not have evidence for this, but they are more prone to have some sleep disorders like restless legs syndrome, sleep disordered breathing or insomnia.

Insomnia increases the mortality risk, but in fact there are no accurate data, it's most probably linked with work-related accidents among sleep disturbed people. The "simple" fact of not sleeping does not lead to increased mortality associated with intrinsic health conditions.

Medium and long term effects of disturbed sleep on the health of children – led by Prof. Pr Oliviero Bruni

Sleep disorders during childhood represent an important children's health issue, these may affect cognitive development and learning during a critical brain growth period. The possible long-term effects (at the adult age) of chronically disturbed sleep during childhood were also considered.

Children with disturbed sleep presented cognitive dysfunction and behavioural disturbances, abnormal growth hormone release and increase of diastolic blood pressure, are all related to sleep fragmentation.

Environmental noise at home at night could lead to sleep disruption without leading to behavioural awakenings through the alteration of sleep microstructure, in a similar manner as other sleep disturbing events such as respiratory disturbances

A major issue is that children who have experienced prolonged sleep disruption during a period traditionally associated with major brain growth and substantial acquisition of cognitive and intellectual capabilities may suffer from a partially irreversible damage, compromising their potential for academic achievement

In children, indicators of sleep disruption such as behavioral awakenings evaluated by actigraphs or sleep architecture abnormalities are not sufficient to evaluate correctly the consequences on growth, cognition and behaviour in children.

Professor Bruni suggested the respiratory disturbances during sleep as theoretical model to evaluate the effects of disturbed sleep in children because it manifests with arousals, and there is a lot of evidence on these disorders in children. This could raise controversy because the respiratory problems have other mechanisms associated that never occur when the sleep is disturbed by noise.

Sleep physiology, sleep quality and indicators of disturbed sleep on risk groups (elderly, shift workers; Main causes of sleep disturbances/disorders on specific risk groups and their known consequences- led by Prof Torbjörn Åkerstedt

Specific population groups linked by behaviour, life style, age, and gender, among other factors, can be at increased risk of having health problems from sleep disturbance. Stress due to work or family seems to be one of the major causes of disturbed sleep. The effect of stress on the risk of insomnia is well established, but reduced sleep in itself seems to yield the same physiological changes as stress. This suggests that several of the major civilization diseases in Europe and the US (diabetes, cardiovascular disease, burnout) could be mediated via disturbed sleep. This link clearly warrants longitudinal studies with interventions.

Shift workers constitute a group that suffers from disturbed sleep for most of their occupational life. The reason is the interference of work hours with the normal timing of sleep. This leads to an increased risk of accidents, directly due to excessive sleepiness, but also to cardiovascular and gastrointestinal disease, although it is not clear whether the latter effects are sleep related or due to circadian factors - or to a combination.

Data suggests that the risk of disturbed sleep increases with age but there also seems to be a recent stress related increase in sleep disturbances in young adults. The long term health consequences are not understood.

The relationship between gender and disturbed sleep is confusing. Females, as a rule complain more of sleep problems, but do not exhibit any objective indications of more disturbed sleep, at least not among otherwise healthy women. With increasing age the sleep of males deteriorates whereas that of women is relatively well upheld. Pregnancy, however, is a period of increased risk of disturbed sleep, whereas the menstrual cycle and menopause show less evidence of disturbed sleep. Clearly there is a great need of longitudinal research on gender and sleep and in particular on the possible health consequences around pregnancy.

Working Groups

On the second day the participants split into two working groups: one for children and one for adults. They examined the reviews presented the day before and tried to reach consensus on the report outline.

Working group 1 – children – rapporteur – Dr Alfred Wiater

Working group 2 – adults – rapporteur – Dr Damien Leger

The working groups tried to reach a consensus based on the meeting presentations and expert opinions about what is a “normal sleep” (depending upon age) what are “arousals” and the significance of arousals, including which are physiological and which can lead to health effects), how should the number of arousals be used as an indicator of disturbed sleep, “sleep deficiency”, “Sleep fragmentation” and “awakenings”.

The groups were challenged also to fill in a table (figure 2) providing for each arrow a quick review of the existing evidence and the identification of existing gaps in knowledge. For health effects, they were asked to explore the public health significance and to take into consideration all the confounding factors when describing them:

Both working groups were asked the following question: “To what extent can we assimilate the “sleep disturbances pattern” of various sleep diseases to those caused by external stressors and more specifically noise?”

The work of the working groups informed the conclusions and recommendations of this report.

Conclusions and recommendations

The following conclusions and recommendations have been agreed upon for children and adults:

Conclusions

1. Healthy sleep is necessary for children and adults' health and well-being. During normal sleep several physiological events take place such as cortical and sub cortical arousals and awakenings. The pathological increase of these physiological events could lead to sleep fragmentation and un-restorative sleep with several diurnal consequences.
2. The group evaluated the impact of disturbed sleep on the health of the general population. Children, pregnant women, peri menopausal women and elderly are major sub-divisions of the population that warrant special attention. There is some evidence that disturbed sleep among these groups may have more deleterious health effects than those observed among the general population.
3. Environmental stressors, such as noise, can alter the quality and the quantity of sleep. Nearly all findings relate to short-term sleep disturbances. The long-term effects of disturbed sleep due to noise need to be more carefully evaluated in prospective longitudinal studies.

For adults:

1. Normal sleep in an adult population can be characterized using specific methodologies:
 - a) Questionnaires¹: The "normally sleeping" population can be identified through positive response to questions such as the following:
 - Are you satisfied with your sleep?
 - Do you feel alert most of the day?
 - Do you feel refreshed by your sleep?
 - Sleep diaries/logs²
 - b) Objective measures³:
 - Sleep duration could be defined by the number of minutes $\pm 2\sigma$ (to be provided by age groups and sex)
 - Number of arousals can be expressed in the number of hours $\pm 2\sigma$

¹ References:

- Naresh M. Punjabi, MD, PhD; Karen Bandeen-Roche, PhD; Terry Young, PhD (2003); "Predictors of Objective Sleep Tendency in the General Population", [Electronic version] *SLEEP*, Vol. 26, No. 6;
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² Reference:

- Naomi Breslau; Thomas Roth; Leon Rosenthal; Patricia Andreski (Oct. 1997); "Daytime sleepiness: An epidemiological study of young adults"; [Electronic version] *American Journal of Public Health*; 87, 10; *ABI/INFORM Global*

³ References:

- Weissman et al. (1997); *General Hospital Psychiatry* 19 (245-250);
- Ford kamarow (1989) *Jama* 262, 1479-1484;
- Breslav at al. (1996) *Biological psychiatry*

- Sleep latency is the number of minutes $\pm 2\sigma$ (to be provided by age groups and sex)
- Sleep efficiency $\geq 85\%$ (to be provided by age groups and sex)
- Number of awakenings

c) In addition the following two parameters have sometimes been considered. It should be noted that they do not reflect objective measurements:

- Actigraphic measures (i.e. sleep latency, sleep efficiency, total sleep time)
- Awakenings with behavioural response (e.g. button press)

2. The possible health consequences of chronic insomnia are becoming well documented⁴:

- a) higher risk of mortality (secondary to another psychiatric or somatic disorders)
- b) higher risk of depression (and other affective disorders) up to 5 times⁵ more than general population
- c) increased somatic disorders: cardiovascular, gastrointestinal,
- d) twice as many medical visits, and hospitalizations (all causes included, four times more accidents than the general population)
- e) lower quality of life
- f) problems in family, work and school

3. Different epidemiological data suggests that about 30 to 35% of the general population complain about sleep problems and 9 to 11% suffer from chronic insomnia. These sleep problems have been related to:

- a) Co-morbid mental disorders (depression, anxiety, substance abuse)
- b) Primary insomnia
- c) Co-morbid medical disorders
- d) Restless legs syndrome
- e) Environmental sleep disorders, with noise being only one of the factors
- f) Hypnotic, stimulant, dependent sleep disorders

4. Noise is one of the most important known environmental stimulus disturbing sleep.

5. Noise is known to have a short-term impact on sleep. This impact can be assessed:

- a) Subjectively: sleep satisfaction, refreshment
- b) And objectively using psg, actigraphs based on mean values of total sleep time, sleep latency, index of arousal, sleep fragmentation.

6. It is scientifically established that sleep disturbances due to noise can have a short-term impact on daytime function by:

- a) Excessive daytime sleepiness
- b) Accidents⁶ and drowsy driving
- c) Impaired neurobehavioral performance and mood

⁴ References:

- D. Leger et al, "Medical and Socio-Professional Impact of insomnia", SLEEP, Vol 25, No 6, pages 625- 629 , 2004
- D. Leger et al, "Les conséquences diurnes de l'insomnie: impact sur la qualité de vie » Rev Neurol (Paris) 2001 ; 157 :10, 1270-1278
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⁵Weissman et al. (1997); General Hospital Psychiatry 19 (245-250);

⁶ R. Moore, D. Ormandy.

7. In the absence of experimental studies directly testing the long-term impact of noise on health, one way to assess the long-term consequences of noise is to adopt a model. Primary insomnia as defined by DSM-IV and DSM-III (Diagnostic and Statistical Manual of Mental Disorders) has been considered by the expert group as an acceptable model. The key criteria for defining insomnia are the following:
- a) At least three awakenings per night with difficulty getting back to sleep
 - b) At least twice a week for at least one month

This model would help us to estimate the possible impact of noise on health⁷.

8. The impact of noise on sleep is heavily mediated by the psychological status of the individual. It can be argued that noise exposure can lead to the following sleep disturbances:
- a) Arousals and awakenings
 - b) Sleep reduction
 - c) Decreased sleep efficiency
 - d) Increased sleep latency
 - e) Subjectively decreased quality of sleep

In turn, these sleep disturbances, depending upon their severity, frequency of occurrence and chronicity may lead to:

- a) Decreased attention
- b) Accidents
- c) Reduced job performance and burn out
- d) Excessive daytime sleepiness
- e) Decreased quality of life

There are tentative associations between sleep disturbance and:

- a) Cardiovascular disorders, diabetes and obesity through mediation by cortisol excretion, decreased glucose assimilation and lipids
- b) Hypertension and possibly non-dipping of blood pressure during the night.

9. Based on the following accepted evidence:
- a) Noise, stress, and shift work can cause reduced sleep and fragmented sleep (TST, Sleep efficiency, microarousals).
 - b) Sleep fragmentation can cause reduced glucose tolerance (dose-response is not well described)
 - c) Reduced/fragmented sleep causes sleepiness and performance impairment in a dose-response fashion
 - d) Reported poor sleep is associated with excess mortality, and cardiovascular disease. (Here we lack evidence of any causal mechanism but the metabolic changes can at least provide a likely explanation for the third outcome)⁸

It can be concluded that well established indicators of disturbed sleep are relevant to evaluating the impact of external stressors such as noise or stress. It is known that populations demonstrating "abnormal indicators" are associated with excess metabolic changes, mortality, and morbidity. Unfortunately there are no clear causal links, and one has to extrapolate based on the existing cause-effect relationship.

⁷ References:

- D. Leger et al, "Prevalence of insomnia in a survey of 12 778 adults in France" European sleep research society, 1999, pages 35-42

- D. Leger et al, "Evaluation of quality of life in severe and mild insomniacs compared with good sleepers", Psychosomatic medicine, No 63, 49-55

⁸ Reference: Allen RP, Mortality associated with sleep duration and insomnia. Sleep Med 2002 ; 3 : 373-375

10. Wide variations exist in sensitivity among individuals to sounds during sleep. Consequently it is important that the clinician (and the WHO) not focus solely on the intensity of the noise, but additionally on its informational (cognitive or emotional) value.

For children

1. The group agreed upon the following set of definitions for the child population⁹:

a - **Normal sleep** is the sleep that satisfies a child's need according to age and culture and fulfils measurable parameters, somatic criteria, and psychological and behavioural criteria as described in literature

b - **Awakenings** – are a behavioural change where a child wakes up from sleep, opens the eyes and/or cries.

c - **Arousals** – sub cortical arousal is manifested by autonomic changes with no EEG changes; cortical arousal is manifested by concomitant autonomic and EEG changes.

d - **Sleep deficiency** – is characterized by too little sleep according to age, due to short or fragmented sleep.

e - **Sleep fragmentation** – is sleep with repeated arousals or awakenings that can lead to sleep deprivation and/or non-restorative sleep.

2. Children's sleep quality can be assessed through:

a) Subjective measures

- Parental reports based on standardized questionnaires
- Paediatric Sleep Questionnaire (Chervin)
- Children Sleep Habits Scale (Owens)
- Sleep Disturbance Scale for Children (Bruni)
- Cognitive consequences (Sadeh)

b) Indirect measures that evaluate day time consequences

- Child Behaviour Checklist (Achenbach)
- Conners Parent rating scales
- Paediatric Daytime Sleepiness scale (PDSS)¹⁰
- etc.

c) Information may be obtained from actigraphic techniques;

d) Objective measures mostly obtained through polysomnography:

- Arousals
- Awakenings
- Sleep deficiency
- CAP rate increase or modification

3. In children, noise exposure during night time leads to:

- a) Arousals (cortical/sub cortical)
- b) Sleep fragmentation
- c) Awakenings
- d) Sleep deficiency

4. These sleep disturbances, depending upon their severity, frequency of occurrence and chronicity as well as the age of the child may lead to:

⁹ References:

- McNamara F, Lijowska AS and Thach BT. Spontaneous arousal activity in infants during NREM and REM sleep. *Journal of Physiology*, 538.1: 263–269, 2002;
- Stores G, Crawford C. Arousal norms for children age 5-16 years based on home polysomnography. *Technology & Health Care*. 8(5):285-90, 2000;
- Tasali EF, Mendelson WB, Spire JP, Kohrman MH. Arousal Index in 100 Children: normative data. *Sleep*, 24 (Suppl.): A208,2001
- Bruni O, Ferri R, Miano S, Verrillo E, Vittori E, Della Marca G, Farina B, Mennuni G. Sleep cyclic alternating pattern in normal school-age children. *Clin Neurophysiol* 2002; 113: 1806-1814
- Marcus CL. Sleep-disordered Breathing in Children. *Am J Respir Crit Care Med* 2001; 164: 163

¹⁰ Reference: Drake and al, 2003 Sleep

Cognitive-behavioural dysfunction
Affective disorders
Daytime fatigue
Autonomic changes

5. Children subject to sleep disturbances are more prone to attention deficit /hyperactivity behaviour¹¹

6. The possibility exists that sleep disturbances can also lead to

Parasomnias
Weight excess
Immune system changes
Metabolic changes
Increased occurrence of accidents
Substance use/abuse (*evidence needed*)

Although more evidence should be gathered to substantiate these relations

7. For physiological reasons, children do not respond primarily to environmental stimuli with awakenings, but with arousals and sleep fragmentation. Therefore, children's sleep disturbance needs to be assessed using specific tools and methods.

8. Environmental stressors, such as noise, can alter the quantity and quality of sleep in children. Most findings have been related to short-term deprivations. The long-term effects of disturbed sleep due to chronic noise should be evaluated using longitudinal studies through adulthood.

¹¹ References :

- Chervin RD, Archbold KH, Dillon JE, et al. "Inattention, hyperactivity, and symptoms of sleep-disordered breathing." *Pediatrics*. 2002;109:449–456
- Corkum P, Moldofsky H, Hogg-Johnson S, Humphries T, Tannock R. "Sleep problems in children with attention-deficit/hyperactivity disorder: impact of subtype, comorbidity, and stimulant medication". *J Am Acad Child Adolesc Psychiatry*. 1999;38:1285–1293
- M. Thunström, "Severe sleep problems in infancy associated with subsequent development of attention-deficit/hyperactivity disorder in 5.5 years of age", *Acta Paediatrica* 2002;91:584-592.
- Gregory A. et al, "Sleep problems in childhood: a longitudinal study of development change and association with behavioural problems". *J Am Child Adolesc Psychiatry* 2002; 41:964-971
- O'Brien LM, Holbrook CR, Mervis CB, Klaus CJ, Bruner JL, Raffield TJ, Rutherford J, Mehl RC, Wang M, Tuell A, Hume BC and Gozal D. "Sleep and Neurobehavioral Characteristics of 5- to 7-Year-Old Children With Parentally Reported Symptoms of Attention-Deficit/Hyperactivity Disorder" *Pediatrics* 2003;111:554 –5

Recommendations

1. Sleep disturbances caused either by pathologies such as insomnia, sleep apnoea, narcolepsy, or by external factors such as work stress, light or tobacco smoke may be the origin of a number of disease states however, this has been insufficiently explored. Sleep disturbances caused by night noise (or day noise for shift workers) may be at the origin of this burden of disease, and its relative importance deserves to be evaluated more extensively.
2. It is difficult to identify a pathology creating sleep disturbance similar to that caused by noise. For the purpose of evaluating the global health impact of chronic long-term (over six months) sleep disturbance caused by noise exposure, the impact of chronic insomnia on health (described as a minimum of three awakenings per night with difficulties to fall back asleep for at least one month) will be used as a model.
3. To compare primary insomnia and sleep disturbance provoked by noise it is advisable to use standardized and well validated questionnaires designed to evaluate sleep disturbance in insomnia:
 - i. Severity scale
 - ii. Psychological scale
 - iii. Pittsburgh sleep quality index¹²
 - iv. Thoughts and beliefs sleep scale
4. The health consequences of usual coping strategies to deal with noise induced sleep disturbance should be evaluated. This covers the use of sedating and alerting drugs (e.g caffeine, tobacco, hypnotics, ...)
5. There are important health effects of noise exposure that are observed during sleep and seem not to be associated with sleep disturbances. For public health purposes, these effects are important and need be explored in detail. They include cardiovascular diseases, and are mostly effects related to body responses to stress induced hormonal excretion.
6. Important aspects of the responses of sleep in children to environmental stressors and the resulting sleep deprivation need further evaluation. In particular, the potential effects of noise induced sleep deprivation on children' immune system, carbohydrate metabolism and endocrine functions should be evaluated.
7. Several longitudinal studies are needed in different countries following individual's polysomnographic and metabolic parameters and measures of noise, stress and health. In subgroups, intervention should include frequent blood sampling during sleep. Also, long-term experimental studies of disturbed sleep should be carried out with polysomnographic and metabolic measures.
8. A large epidemiological study should be undertaken on subjects exposed to night-time noise during which polysomnographic measures (PSG) and neuroimaging records (fMRI and PET) are performed. The study's aim would be to objectively measure changes in PSG in relation to noise exposure and to relate such changes to their localization in the brain (fMRI and PET).

¹² Reference: Buysse DJ, Reynolds III CF, Monk TH, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res* 1989;28:193-213.

9. It is important to look at existing animal studies dealing with sleep deprivation, and more specifically with insomnia caused by noise
10. Sleep and noise researchers should use the commonly agreed upon terminology as described in the minutes of this meeting when using the terms: Normal sleep, Awakenings, Arousals, Sleep efficiency, Sleep deficit and Sleep fragmentation.

Policy

11. Since noise is an environmental factor that can be reduced through various technical means, it seems to be relevant and efficient to promote noise reduction campaigns for achieving improved sleep quality in the general population.
12. Traffic noise as well as neighbourhood noise play a significant role in terms of sleep disturbance. Besides noise reduction at the source, governments should provide various mechanisms, including financial support and programmes aimed at noise insulation of dwellings.

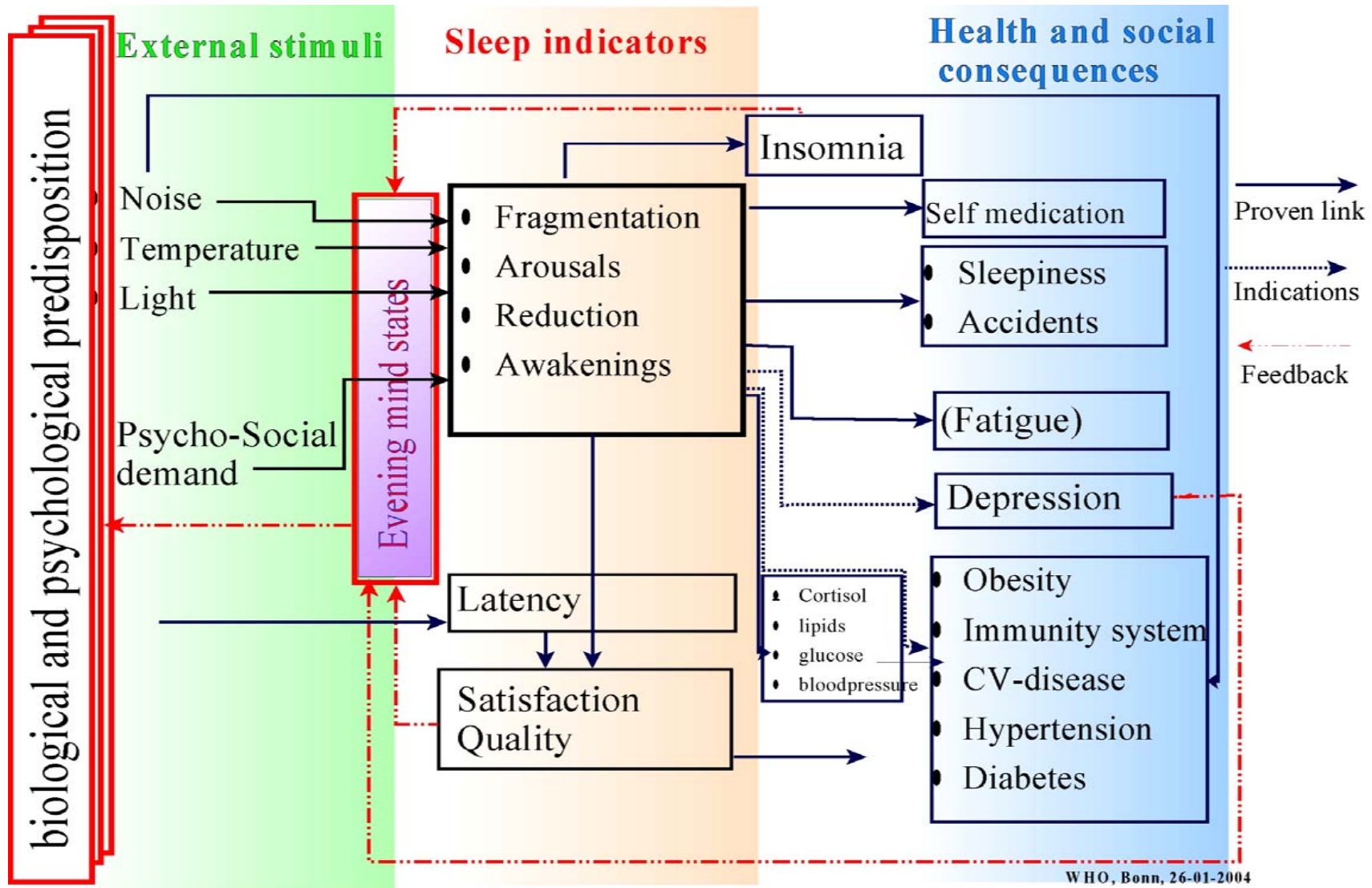


Figure 3 – Results of the working group 1