Office Work and Physical Factors

Health Aspects of Electromagnetic Fields and Light

by

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Akademisk avhandling

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Abstract

The overall aim of this thesis is to increase our knowledge of the physical environment of office workers with special focus on electromagnetic fields and to address the question of whether electromagnetic fields can directly or indirectly contribute to symptoms or discomfort among video display terminal (VDT) workers. Furthermore, we have measured light modulation from various commonly used light sources in laboratory conditions and, as a second step, used modulated light as stimulus for provocation of neurophysiological responses in persons with perceived “electrical hypersensitivity” (EHS).

During the last 20 years work-related illness among office workers has received increased attention. Changes in the physical environment, the introduction of VDTs and other electrical equipment and changes in light conditions have been discussed in this context. The basis for this thesis is the interdisciplinary Office Illness Project in Northern Sweden. Using a questionnaire completed by 4,943 office workers, 150 VDT workers with or without facial skin symptoms were selected for a case referent study of the electromagnetic fields in offices.

When the measurements in the offices were performed in 1989, the general level of the 50 Hz magnetic fields in the offices was rather low, but in 5% of the offices the flux density exceeded 0.5 µT. At this level VDT monitors were shown to display detectable instability (jitter). Furthermore, the ability of test subjects (healthy volunteers) to detect jitter was shown to depend on both the amplitude and frequency characteristics of this instability. The study indicates that the instability of computer monitors and thereby the instability of the visual image of the VDT screen might be an increasing problem since it is known that the harmonic content of the general magnetic field in offices is on the rise.

VDT monitors contributed to the magnetic field level at VDT workplaces in both extremely low and very low frequency ranges. However, the dominant source of electric fields in rooms was ungrounded electrical equipment, not VDT screens.

High electric fields in the extremely low frequency range in the offices were associated with skin symptoms among VDT workers. The causal nature of this association cannot be determined since it may depend on undetected factors related to exposure. No associations were found, however, for any of the VDT-related electromagnetic fields and skin symptoms.

Commonly used fluorescent tubes in our office environment have a degree of modulation of the light (flicker) that varies widely from less than 1% (fluorescent tubes with high frequency gear) up to nearly 100%. When persons with perceived EHS were exposed to flickering light, a higher amplitude of brain cortex responses were found at all tested frequencies compared with control subjects. These findings are of considerable interest, but further studies are required in order to establish a possible relationship between flickering light and discomfort/symptoms in persons with perceived EHS.

Keywords: Facial skin symptoms, office illness, electrical hypersensitivity, physical environment, flicker, jitter, neurophysiological effects.
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Abbreviations & Definitions

Technical terms

EM-fields Electromagnetic fields
B-field “Magnetic field”, i.e. magnetic flux density
E-field “Electric field”, i.e. electric field strength
H-field “Magnetic field” i.e. magnetic field strength
ELF Extremely Low Frequency: 0–300 Hz
VLF Very Low Frequency: 3–30 kHz
CRT Cathode Ray Tube
VDT Video Display Terminal
rms root mean square
DC Direct Current
AC Alternating Current
Jitter Spatial instability of the picture on the screen
Flicker Periodic luminance variation
Band I 5–2 000 Hz is the frequency range defined and used by SWEDAC and TCO for measurements in front of the VDT screen and include the refresh rate frequency.
Band II 2–400 kHz is the frequency range defined and used by SWEDAC and TCO for measurements in front of the VDT screen and include the line frequency.

In this thesis only the expression ELF and VLF are used to describe the two frequency ranges.

“HF fluorescent tubes”, i.e. fluorescent tubes with high frequency gear

Statistical terms

OR Odds Ratio
SD Standard Deviation
CI Confidence Interval

Medical terms

SBS Sick Building Syndrome
EHS Electrical hypersensitivity
ERG Electroretinogram
VEP Visual Evoked Potential
EEG Electroencephalogram

Units

Hz Hertz: unit for frequency
µT microTesla: subunit for magnetic flux density
mT/s milliTesla/second: unit for time derivative of the magnetic field
A/m unit for magnetic field strength. 1 A/m = 1.26 µT
V/m unit for electric field strength
Cd/m² unit for luminance

Other abbreviations

MPR The Swedish National Council for Metrology and Testing
SWEDAC The Swedish Board for Technical Accreditation
Original papers

This thesis is based on the following papers:


Papers I–III, V and VI are reprinted with the permission from the publishers.
Introduction

Work-related illness is a well-known concept among blue collar workers, but during the last 25 years office workers and their work-related illnesses have received increased attention. One of the discussed reasons for this is the rapid introduction of visual display terminals (VDTs) (Hedge 1989). In Sweden, one out of four persons worked with VDTs in 1985. Ten years later 54% of men and 48% of women worked with VDTs (Järvholm 1996). This new technology called for a new layout of the office. Furthermore, the content of the work has changed and new professions and workplaces have been established. Aronsson and coworkers (Aronsson et al. 1988; Ålborg et al. 1992) refer to “winners and losers” to illustrate the effect of computerisation at different workplaces.

The discussion of health problems in connection with VDT work started in the 1970s with the problem of eye discomfort (Hultgren and Knave 1974). These symptoms were mainly related to the ergonomic design of workplaces and light ergonomic factors of VDT screens, but also psychosocial factors at the workplace (Bergqvist 1984; Bergqvist 1993).

Electromagnetic fields (EM-fields) emitted from VDT screens came into focus in the beginning of 1980s when groups of women who worked with VDTs reported that miscarriages appeared in clusters at their workplace (see further Suess 1986). At about the same time Delgado et al. (1982; Ubeda et al. 1983) showed in a number of experimental studies that chick embryo development was affected by very weak magnetic fields ($B$-fields) with a time derivative of the same order as that of the $B$-field in front of a VDT screen. These reports prompted a series of epidemiological studies to examine whether or not pregnancy outcome was affected by the use of VDTs. Extensive replication studies of chick embryo development began and other established methods to study interaction between biological systems and VDT associated $B$-fields were used (see further Hansson Mild and Sandström 1994b).

In the beginning of 1980s another VDT-related illness appeared, facial skin symptoms and signs (Lindén and Rolfsen 1981; Nielsen 1982; Stenberg 1986). An increasing number of patients were referred to dermatological clinics in Sweden. This new group of patients with facial symptoms and signs had much in common with an earlier known group of patients with indoor air quality problems or “Sick Building Syndrome” (SBS). However, while the skin symptoms dominated for the “VDT patient” group and, according to the
patients’ own experience, the symptoms were clearly related to VDT use, the SBS group had a larger range of symptoms including general symptoms that included not only skin symptoms, but also headaches, fatigue and mucosal symptoms. Additionally, the symptoms were related to the workplace and/or indoor air quality (Stenberg 1989).

Rather soon the discussion of a possible connection between skin symptoms and the EM-fields emitted from VDTs started. The capacity of the electrostatic field to enhance particle deposition on the face of a VDT worker was proposed first (Cato Olsen 1981), followed by a number of provocation studies which included all of the EM-fields emitted from VDT screens (for an overview see Hansson Mild and Sandström 1994b).

In 1989 Knave et al. interviewed a group of patients characterised by multisymptomatic health complaints, i.e. skin symptoms as well as symptoms of neuroasthenic character which they related not only to VDTs, but also to being near other electrical equipment. This is known as electrical hypersensitivity (EHS) (Knave et al. 1989). An expert group set up by The Swedish National Board of Health and Welfare pointed out that among the public there is usually no distinction between persons with VDT-related skin symptoms and persons suffering from EHS (The Swedish National Board of Health and Welfare, Socialstyrelsen 1995).

In addition to VDTs and TV sets, fluorescent light was considered as the most common provoking factor for symptoms. Modulated light is a common factor for VDTs and fluorescent light in addition to EM-fields (Hansson Mild 1992) and might therefore be of interest to study in provocation tests of persons with EHS.

Image quality of VDT screens is an important factor when discussing symptoms, such as visual fatigue and eye discomfort among VDT users (Bergqvist 1993). Insufficient accuracy of the screen control circuitry in Cathode Ray Tube (CRT) monitors can result in a disturbance of the image quality. External $B$-fields can also cause instabilities of the screen (Baishiki and Deno 1987). It is therefore of interest to study levels of the $B$-field when a detectable disturbance of the screen image can be noted.
Aims of the thesis

The overall aim of the thesis is to increase our knowledge of the physical environment of workers who use VDTs with special focus on the electrical environment and light conditions.

Specific aims

• Measure electromagnetic fields in the offices of VDT workers.

• Assess the relationship between the occurrence of skin symptoms among VDT workers and the electrical environment at workplaces.

• Study how the electrical environment indirectly can affect the visual image of VDT screens.

• Increase our understanding of modulated light in our environment.

• Find out if there are differences in neurophysiological responses to light exposure at environment-related frequencies and modulation depth between persons with perceived electrical hypersensitivity and control subjects.
Background

EM-fields at VDT workplaces

The electrical environment in offices has become more complex during the last 20 years due to the widespread introduction of VDTs and other electronic equipment. This has resulted in an increased harmonic content of the fields in offices (Redl et al. 1997) and therefore also to an increased fluctuation of the magnitude of the fields over time (Sandström et al. 1993a; Nair and Zhang 1995).

To describe a workplace from an electrical point of view, it is necessary to perform a large number of measurements in order to cover all the possible frequencies of the fields. Most of the studies done so far have focused on one type of field in one frequency range depending on the purpose of the study.

Most computer monitors in use today are based on cathode ray tubes. This technique is the same as that used in television (TV) receivers. The basic principle is described here. CRTs have a cathode at one end that emits a narrow beam of electrons. At the other end in front of the operator is a screen, the inside of which is coated with a phosphor which glows when the electron beam strikes. The electrons are accelerated towards the screen by applying a high positive voltage, typically in the 10–25 kV range. The electron beam is moved across the screen by applying magnetic fields from deflection coils placed on the neck of the tube to obtain more than just one glowing spot. The operation of these high voltage and deflection circuits produces electric and magnetic fields which can be detected at the operator’s position. The different EM-fields of interest in a VDT workplace can be summarised as follows: electrostatic fields, electric and magnetic fields in the ELF range (mainly the refresh rate and the frequency of the mains, i.e. 50 Hz) and electric and magnetic fields with line frequency. For a more complete description see Hansson Mild and Sandström (1994b).

Measurements of VDT-related fields

One of the first to measure these type of signals was Richard Tell at the EPA, Las Vegas, USA, in 1982. He measured the time derivative of the line frequency $B$-fields and found values of a few hundreds of mT/s, to be compared to the Delgado studies which found effects on chick embryos with fields that had a time derivative on the order of 500 mT/s (Delgado et al. 1982).
Several reports have since been published on measurements of EM-fields near VDTs (Stuchly et al. 1983; Paulsson 1986; Tofani and D’Amore 1991). It is difficult to make comparisons between the various studies since the results are dependent on the measuring procedures, techniques and instrumentation. In short, there is a lack of a standardised measurement procedure.

The first effort toward a standard procedure came in 1987 as a result of the Swedish Government announcement that voluntary testing of VDTs would begin. The National Council for Metrology and Testing (in Swedish abbreviated MPR and now known as the Swedish Board for Technical Accreditation, SWEDAC) developed test methods that included the electrostatic fields in front of VDT screens and the B-field in the VLF range (MPR I) (SWEDAC 1987). The first recommended standard procedure covering measurements from DC up to the VLF range for both electric and magnetic fields came 3 years later (MPR II) (SWEDAC 1990a). The fields around VDTs have very complex time variations and therefore complex frequency spectra. The above mentioned test procedures use time domain measurements. They have been criticised for being too specific both in terms of the phenomena covered and their confinement to VDTs alone. The Swedish Electrotechnical Commission, SEK, a national commission of the IEC, has developed a Swedish standard, SS 436 14 90, on methods and equipment for measuring the frequency domain of electric and magnetic near-fields in the frequency range DC to 10 MHz from computers and equipment found in offices (SEK 1989). However, MPR I and II are the test procedures used by manufacturers and the suggested recommendations in MPR I and II are regarded as a “standard”.

The measuring standards though are for laboratory tests of the equipment. It is important to be aware of the difficulties in comparing those measurements with measurements performed in an office environment where background fields can contribute to increasing or even decreasing the value depending on the interaction (direction and phase) of the different fields.

**Image instability of VDT screens**

Several organisations and standards require that VDT screen be free from flicker or other disturbances in order to achieve good image quality (Council-Directive 1990, SWEDAC 1990b, AFS 1992, ISO 1992 and TCO 1995). Jitter is defined as a disturbing motion of the total image or parts thereof. Jitter can be seen on the screen if the frequency of the movement is slow. These
movements can be due to improper variations in the magnetic field used to deflect the electron beam of the monitor. They usually have a frequency of less than 0.5 Hz and might be a source of irritation and fatigue for VDT users (Bergqvist 1984). If the movement on the other hand is rapid, the result will be a blurred picture which can result in poor screen legibility and has been found to be associated with more frequent reports of ocular symptoms (Collins et al. 1990).

These image instabilities can also be caused by external magnetic fields. CRT-based VDTs have magnetic deflection of the electron beam and, thus, can be affected by an external magnetic field resulting in image instability (Baishiki and Deno 1987; EPRI 1991).

Health aspects of flickering light in offices

Our physical and mental well-being are greatly affected by light and colour in our environment. The type and amount of light and colour variation and glare in the surroundings are important factors when planning indoor lighting. This is especially true in offices with a combination of VDT work and common paperwork.

Fluorescent light has elicited complaints of visual discomfort since its introduction (Stone 1990). One of the parameters of interest in this context is the ELF modulation of the light. Brundrett (1974) found detectable signals in the EEGs of people exposed to modulated light above the critical flicker frequency (CFF), the frequency above which people no longer perceive flicker. When individuals complaining of headaches were exposed to modulated light of increasing frequency he found that the slope of the brain responses measured as visual evoked potential (VEP) decreased less rapidly for this group compared with healthy subjects. By increasing the operating frequency of the fluorescent lighting system, a decreasing incidence of eyestrain, headache and other asthenopic symptoms was found (Wilkins et al. 1989; Lindner and Kropf 1993). Light modulation is more or less pronounced in all types of lighting systems, but discussions have focused on fluorescent tubes as the dominating source of light in our office environment.

Modulation of light is a common factor for both VDT screens and fluorescent light. Depending on the persistence of the phosphor used for the screen, the modulation of light integrated over a small area of the screen can be up to 100% (IBM 1991; Hansson Mild 1992).
Since individuals suffering from EHS relate their symptoms to being near VDTs as well as fluorescent lights, it is of interest to measure the light modulation from various commonly used light sources and to examine the question of whether there are differences in the neurophysiological responses of EHS persons and healthy subjects to light at frequencies common to their environment and modulation depth.

Skin symptoms and VDT work

Case reports

During the past decade skin problems among VDT workers have received increased attention. Case reports from the UK (Rycroft and Calnan 1984), the USA (Fisher 1986), Japan (Matsunaga et al. 1988), and Sweden (Stenberg 1986) have been published. Symptoms such as erythema, itching and burning sensations in facial skin have been described.

Reports of skin complaints among VDT workers first came from Norway (Lindén and Rolfsen 1981). In later reports (Nielsen 1982; Wedberg 1986) the electrostatic fields in front of screens in combination with aggressive pollution in the indoor air was suggested as one possible cause. In experimental set-ups they showed that air particles could be deposited on the operator depending on the potential differences between operator and the screen.

Stenberg (1986) reported an outbreak of rosacea-like skin rash in VDT operators in a newly computerised plant office. Nine out of 14 employees who started with VDT work broke out with more or less pronounced skin symptoms while only 2 out of 14 with no VDT work got the same symptoms. However, it was later seen that the symptoms could be aggravated in a non-VDT work situation supporting the hypothesis that other workplace factors could be of interest and perhaps also the existence of a synergistic effect of VDTs and other work-related factors (Stenberg 1989).

Epidemiological studies

There have been a number of epidemiological studies regarding worker complaints and VDT work. Eye discomfort and more general symptoms, such as fatigue and headache, were often the main target of the studies. Today there are a number of questionnaire studies which also include skin complaints. Unfortunately, it is often difficult to compare the studies because of the different ways the questions were posed. However, a higher prevalence of self-reported
skin symptoms were found among VDT users compared with non-VDT users in most of the studies (Knave et al. 1985; Berg et al. 1990; Castellino and Mattei 1989; Stenberg et al. 1993).

The Swedish survey from 1985 which primarily studied ocular and muscular discomfort among 535 office workers (Knave et al. 1985) found a higher prevalence of self-reported facial skin symptoms among VDT workers compared with non-VDT workers. In a clinical dermatological follow-up study no specific skin disorder was found (Lidén and Wahlberg 1985), but they found an indication that previously known skin diseases, i.e. seborrhoeic eczema, acne vulgarise and rosacea, might be aggravated by VDT work.

In another Swedish clinical follow-up study among 809 randomly selected office workers, more patients with clinical facial skin diagnosis (both signs and symptoms) among VDT workers were found. But when the prevalence of clinical diagnosis was compared to time in front of VDTs no clear positive trend was found (Berg 1989).

The questionnaire study performed during 1988 and 1989 in Northern Sweden among 5,000 office workers (the basis for Papers I and II) confirmed the exposure-response relationship between time of VDT work and frequency of self-reported facial skin symptoms (Stenberg et al. 1993).

Provocation studies

In order to verify possible associations between skin symptoms and environmental factors, mainly work-related physical factors, a number of provocation studies have been performed on selected groups of people with VDT-related facial skin symptoms. Swanbeck and Bleeker (1989) tested electrostatic and line frequency fields from VDTs on 30 patients in a double-blind manner, but found no association between the applied fields and the prevalence of skin symptoms and signs. This study was followed by a number of provocation studies using different experimental set-ups to expose test subjects to fields similar to those emitted by VDTs or other electric equipment. Some of the studies also included EHS persons.

Sandström et al. (1993b) found that the reaction pattern in time varied between the patients and that no specific VDT-related field could be connected with the symptoms. In order to correlate the appearance of symptoms in time with exposure to different EM-fields, Wennberg et al. (1994) exposed EHS persons
in a double blind manner, but found no repeatable association between the applied fields and self-reported symptoms. The same result was found by Hamnerius et al. (1992) who also included fields in the MHz range corresponding to the clock frequency of the VDTs. In a workplace study a number of employees with more or less pronounced skin symptoms and/or general symptoms associated with VDT work were exposed under highly controlled conditions to VDTs with low or extremely low emission of fields. A positive trend for identification of when the “field was on” was found (OR = 2.74), but it was not statistically significant (Sjöberg and Hamnerius 1995).

In two Norwegian studies the effect of changing the electric fields \((E)\) in VDT workplaces has been studied. Oftedal et al. (1995) studied whether applying filters on VDT screens, i.e. reducing the electrostatic field and in some cases extending the alternating \(E\)-fields, decreased skin symptoms among a selected group of VDT workers. A weak connection was found between the prevalence of some skin symptoms and \(E\)-fields, but in a follow-up study these results could not be confirmed (Oftedal et al. 1997). Skulberg (1996) studied the effect of reducing the electrostatic fields of VDTs as well as the electrostatic charge of test subjects in workplaces with different amounts of air bound particles. The study indicates that the reduction of electrostatic fields in rooms with high levels of air bound particles might reduce the prevalence of skin symptoms.

One of the main unsolved problems in performing provocation studies is to find an effective and objective method for evaluating the response. Rea et al. (1991) at the Environmental Health Center in Dallas showed an effect on the autonomic nervous system after exposing EHS patients to magnetic fields. The effect was measured with a binocular iriscounter, which measures pupil area, time at which constriction and dilation occurred and constriction/dilation. In a multiphase study he found that 16 out of 25 patients who complained of EM field sensitivity reacted with signs, symptoms and autonomic nervous system changes measured as the speed of change of pupil dilatation when exposed to \(B\)-fields of various frequency, while none of the 25 controls reacted. In an attempt to repeat this study Wang et al. (1994) found no such reaction to EM-fields.

Berg et al. (1992) found that VDT workers with skin symptoms had higher levels of stress-related hormones during a day of VDT work compared with VDT workers without such symptoms. The authors suggest that the VDT workers with symptoms suffered from occupational strain, which results in
physiological changes, such as increased dermal blood flow. The association between VDT work and psychosocial stress was further supported by studying levels of hormones associated with psychosocial stress (Arnetz and Berg 1996). However, the same result was not found in a later provocation study performed by the same research group when EHS persons were exposed to VDT screens in a double-blind provocation situation. This indicates that the EM-fields emitted from VDTs do not act as a provoking source for symptoms (Andersson et al. 1996).

**EM-fields — skin symptoms**

It has been suggested that alternating EM-fields emitted from VDTs or other electrical equipment could trigger skin symptoms. Possible mechanisms and/or receptors are unknown for direct field connections of such low field strengths as found in office environments. Another hypothesis is that EM-fields stress the biological system resulting indirectly in skin symptoms. However, provocation studies have so far not given any conclusive evidence to support any of these hypotheses. Furthermore, there is no current scientific support for the theory that alternating EM-fields at very low field strength affect or are even perceived by humans.

Electrostatic fields have on the other hand been discussed as transducers of aggressive particles to the facial skin of VDT workers and are thereby suggested to cause skin symptoms.

Therefore, to study the electrical environment in an office and to compare the field strengths found to the occurrence of symptoms is on the whole based only on the experience of patients and physicians as there is a lack of theoretical and scientific evidence to support for the perception of such low field strengths.
The Office Illness Project in Northern Sweden

The basis for Papers I and II is the interdisciplinary study performed in Northern Sweden during 1988 and 1989 entitled *The Office Illness Project in Northern Sweden* which was initiated by Dr. Berndt Stenberg at the Department of Dermatology at the University of Umeå, Sweden. The overall aims of the project were focused on health problems in offices and their relation to personal, environmental and psychosocial factors. The project design is illustrated in Fig. 1.

![Fig. 1 The structure of the Office Illness Project in Northern Sweden, The shadowed section is the basis for Papers I and II.](image)

The staff at the county Labour Inspectorate classified and listed all workplaces with office workers in the three cities in the county: two cities with coastal climates, but with different infrastructures, one industrialised city (Skellefteå) and one focused more on administration and education (Umeå). The third city (Lycksele) has an inland climate and few industries. From this list a proportionally stratified sample of offices was selected. Furthermore, in order to be selected there had to be a minimum number of ten employees at the office. The study population included all workers spending more than half their working time at the office (i.e. in the building) during the preceding three months. A questionnaire was mailed to 5,986 office workers, about one third of the total number of office workers in the county. Data collection was accomplished during the period October to December 1988. The return rate was 95.7%, but
13% of the respondents had to be excluded as they did not fulfil the criteria, mainly because they had been absent from work during the proceeding period or did not spend half their working time at the office. A total of 4,943 questionnaire forms were processed.

The main screening questionnaire used in this project was originally designed for surveying indoor air quality-related problems and has been used on a large scale in the Nordic countries since 1986 (Kukkonen et al. 1993). The validation of the skin symptom questions showed a sensitivity of 75–98% and a specificity of 60–80% (see further Stenberg 1994). The questionnaire included questions about demographic data and personal factors, work conditions, building and room characteristics, perception of psychosocial conditions and perceived symptoms. Symptoms were registered regardless of perceived work-relation.

The screening questionnaire was used as a basis for two case referent studies, one addressing Sick Building Syndrome (SBS) and the other VDT workers and skin symptoms. Papers I and II focus only on the latter problem.

**Selection of office workers for the case and referent study of skin symptoms among VDT workers.**

As there was no established definition of a “VDT-skin symptom case” the selection of cases was based on clinical experience mainly from the dermatological clinic at the region hospital (Stenberg 1986). A case was consequently defined as an office worker with at least one hour of VDT work per day who reported itching, stinging, tight or burning sensations in facial skin and facial erythema or dry skin every week during the recall period. Referents were matched for age, gender and geographic area and also had at least one hour of daily VDT work, but did not fulfil the case criteria.

A total number of 133 VDT workers fulfilled the criteria for a VDT-skin symptom case. Seventy-five of these cases and the same number of matched referents were randomly selected to a case referent-study including clinical dermatological investigations, psychosocial and organisation factors, indoor air quality investigations and measurements of the electrical environment at their workplaces. Papers I and II focus mainly on the latter factor. All investigations were done in a double blind manner, i.e. neither the staff nor the selected office workers knew if they were selected as case or referent.
The survey of the electromagnetic fields (Paper I)

Material and methods

The levels of the electromagnetic fields in offices were expected to be rather low compared to other workplaces. However, many sources emit EM-fields that contribute to a complex electrical environment. Rather comprehensive measurements must be taken to obtain a full description of the fields. The lack of standard procedures for measurements in offices resulted in that we developed and used a procedure revised from methods normally used in laboratory conditions. In the survey measurements were done for the following.

- Electrostatic charging of people,
- Magnetic and electric background fields in the ELF-range in the offices,
- VDT-related fields:
  - electric and magnetic fields in the ELF-range associated with the vertical deflection coil and power supply,
  - electric and magnetic fields in the VLF-range associated with the horizontal deflection coil, and
  - the electrostatic fields in front of the screen.

All of these are spot measurements carried out during one visit to the workplace.

Results

The background power frequency magnetic fields in offices was as expected rather low. The median value of the 150 offices was 0.07 μT. However, in 5% of the offices the flux density was higher than 0.5 μT. Corresponding measurements of the ELF electric field in the offices gave a median value of 10 V/m with some extremes up to 100 V/m. The dominating source for electric fields in the ELF-range was ungrounded electrical equipment, not the VDTs. The highest level found was due to capacitive charging of a metallic frame of a desk from isolated cables in contact with the metal. The median value for the electric field in the VLF-range in front of the VDT screen was 1.5 V/m. The equivalent surface potential was less than 0.5 kV for 63% of the VDT screens. The computer monitors were a major source of magnetic fields in the offices. The median value for the ELF magnetic field in front of the VDT screens was 0.21 μT, and in the VLF-range we found 0.03 μT.
Skin symptoms among VDT workers and electromagnetic fields — a case referent study (Paper II)

Materials and methods

Comparisons between the EM-fields in offices used by VDT skin cases and those of the matched referents were performed.

During the same time period that the EM-field measurements were performed, extensive interviews with the representatives of the organisation were carried out by other members of the team; an extensive questionnaire addressing psychosocial and organisation factors was distributed among the selected office workers, the indoor climate factors (with focus on ventilation) were measured in the offices and all the subjects were invited to a clinical examination by a dermatologist. See Fig. 2 for a schematic overview.

Figure 2. A schematic overview of the project. The dotted lines indicate published papers from the project from which independent variables of interest are included as confounders in the expanded analysis.

All these factors might influence the results concerning the electromagnetic parameters as risk indicators and are therefore taken into account in the following extensive analysis of the results in Paper II. Table 1 shows the independent variables of interest found in other parts of the project some of
which are used as confounding factors in the following expanded analysis. The two variables "Psychosocial work load" and "Co-workers support" are used together as a measurement of "Psychosocial factors".

Table 1. Selected risk indicators for facial skin symptoms among VDT workers as seen in other parts of the Office Illness Project.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Crude OR (C.I. 95%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Amount of VDT work</td>
<td>≥ 4 hours/day</td>
<td>1.78 (0.93–3.4)</td>
<td>Stenberg et al. 1995</td>
</tr>
<tr>
<td>*Atopic dermatitis</td>
<td>-</td>
<td>2.2 (0.80–6.3)</td>
<td>Stenberg et al. 1995</td>
</tr>
<tr>
<td>*Psychosoc. work load</td>
<td>medium</td>
<td>0.98 (0.35–2.8)</td>
<td>3.3 (1.37–7.8)</td>
</tr>
<tr>
<td></td>
<td>high</td>
<td>3.0 (1.18–7.7)</td>
<td>3.5 (1.55–7.2)</td>
</tr>
<tr>
<td>*Co-workers support</td>
<td>medium</td>
<td>2.6 (1.10–6.0)</td>
<td>Stenberg et al. 1995</td>
</tr>
<tr>
<td>Fluorescent tubes</td>
<td>plastic shielding</td>
<td>2.6 (1.10–6.0)</td>
<td>Sundell et al. 1994</td>
</tr>
</tbody>
</table>

*Confounders used in the expanded analysis

Statistical evaluation

Odds ratios (OR) were used to illustrate the strength in the association between different risk factors and the outcome variable. The estimated OR is an indirect estimation of the relative risk of having facial skin symptoms (as defined on page 12). Though we have a matched data set, we used an unconditional logistic regression model in the bivariate analysis as well as in the multivariate analysis in order to reduce drop-outs. The EGRET package was used throughout the analysis (the EGRIT statistics package, computer program) and was complimented with the SPSS package in some of the expanded analyses. To test the significance of the OR, the 95% confidence intervals were calculated according to the method given by Miettinen (1977).

Results

For most of the measured parameters there was no difference between cases and referents. However, more cases than referents were found in the highest exposure group for two of the measured parameters. For the electric background field in the room the relative risk in terms of crude odds ratio (OR) was 3.0 (95% CI: 1.2–7.2) for the highly exposed group (≥ 31 V/m) compared with the lowest group (≤ 10 V/m). The same comparison for magnetic fields in the ELF-range (≥ 0.30 μT vs. ≤ 0.145 μT) in front of the VDT gave an OR of 2.7 (95% CI: 1.0–6.9). See further Paper II.
When adjusting for other risk indicators (marked in Table 1) the increased risk level for high electric background fields in the office remained at a significant level (OR = 4.0, 95% CI: 1.2–13) see Table 2. However, the same multivariate analysis for the B-field in the ELF-range in front of the VDT, adjusted for psychosocial factors, atopic dermatitis, time of VDT work and background E-fields, decreased the OR to a non-significant level (OR=1.60, 95% CI: 0.49–5.2) for the highly exposed group.

Table 2. Crude and adjusted odds ratio for skin symptoms among VDT workers with respect to the electric background fields in the offices.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Confounder</th>
<th>No. of cases/referents</th>
<th>OR (95% C.I.)</th>
<th>medium exposure</th>
<th>high exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-field</td>
<td></td>
<td>73/75</td>
<td>1.74 (0.81–3.7)</td>
<td>3.0 (1.2–7.2)*</td>
<td></td>
</tr>
<tr>
<td>Atopic dermatitis</td>
<td>73/73</td>
<td></td>
<td>1.73 (0.80–3.7)</td>
<td>3.2 (1.3–7.9)</td>
<td></td>
</tr>
<tr>
<td>Psychosoc. factors</td>
<td>64/59</td>
<td></td>
<td>1.84 (0.75–4.5)</td>
<td>4.3 (1.4–13)</td>
<td></td>
</tr>
<tr>
<td>Time of VDT work</td>
<td>73/75</td>
<td></td>
<td>1.64 (0.76–3.5)</td>
<td>3.0 (1.2–7.4)</td>
<td></td>
</tr>
<tr>
<td>B-field, ELF. rms</td>
<td>72/75</td>
<td></td>
<td>1.81 (0.84–3.9)</td>
<td>3.0 (1.2–7.3)</td>
<td></td>
</tr>
<tr>
<td>All the above</td>
<td>63/59</td>
<td></td>
<td>1.52 (0.58–4.0)</td>
<td>4.0 (1.2–13)</td>
<td></td>
</tr>
</tbody>
</table>
*From Paper II.

We cannot exclude the possibility that there is a difference between men and women with respect to the effect of high exposure. In order to investigate this we have analysed the material stratified for gender. Out of the 150 people in the total case referent study 110 were women, and thus analyses involving only men had too low of precision to allow any conclusions. The increased risk for high levels of background E-field in the rooms is further increased when adjusting for other risk indicators and only women were included in the analysis (OR = 6.6, 95% CI: 1.7–26), see Table 3. The ELF B-field in front of the VDT showed another pattern. In this case the increased risk could be assigned to men, but as mentioned before the total number of men was small, implying a low precision in the analysis.
Table 3. Crude and adjusted odds ratio for skin symptoms among female VDT workers with respect to the electric background field in the offices.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Confounder</th>
<th>No. of cases/referents</th>
<th>OR (95% C.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>medium exposure</td>
<td>high exposure</td>
</tr>
<tr>
<td>E-field</td>
<td>–</td>
<td>53/53</td>
<td>2.2 (0.88–5.0)</td>
</tr>
<tr>
<td>Atopic dermatitis</td>
<td>52/52</td>
<td>2.3 (0.92–6.0)</td>
<td>5.0 (1.7–15)</td>
</tr>
<tr>
<td>Psychosoc. factors</td>
<td>47/44</td>
<td>2.4 (0.82–6.8)</td>
<td>6.1 (1.6–23)</td>
</tr>
<tr>
<td>Time of VDT work</td>
<td>53/53</td>
<td>2.0 (0.80–5.1)</td>
<td>4.5 (1.5–13)</td>
</tr>
<tr>
<td>B-field, ELF. rms</td>
<td>53/53</td>
<td>2.2 (0.88–5.4)</td>
<td>4.5 (1.5–13)</td>
</tr>
<tr>
<td>All the above</td>
<td>47/44</td>
<td>2.1 (0.71–6.3)</td>
<td>6.6 (1.7–26)</td>
</tr>
</tbody>
</table>

*From Paper II

The indoor climate study (Sundell et al. 1994) pointed to fluorescent tubes with plastic/glass shielding compared to metallic shielding as an risk-indicator for skin symptom among VDT users, see Table 1 (page 15). If it is improperly connected to ground, a metallic shielding might lower the emission of electric fields from the fluorescent tubes. Plastic/glass shielding on the other hand does not shield the field and could thereby contribute to a higher E-field in offices. However, as shown in Figure 3, the distribution of fluorescent tubes with plastic/glass shielding in rooms with different levels of the background E-fields do not support that. The risk-level for fluorescent tubes with glass/plastic shielding even increased, OR = 5.9 (95% CI: 1.7–21) after adjusting for psychosocial factors, atopic dermatitis, time of VDT work and background E-field.

Figure 3. The distribution of fluorescent lighting in rooms divided according to background E-field levels.
The expanded analysis can thus be summarised as below.

- The inclusion of relevant confounders adjusts the OR of the result in Paper II regarding the $B_{\text{ELF}}$-field in front of the VDTs to a non-significant level. The background $E_{\text{ELF}}$-field remains a significant risk indicator. Stratifying for female gender further supported $E$-fields in rooms as a risk indicator.
- Glass/plastic shielding of fluorescent lights in offices does not necessarily result in a high $E_{\text{ELF}}$-field in the room.
External magnetic fields and VDT instabilities
(Papers III and IV)

Papers III-IV address issues of visual discomfort related to magnetic field levels at the VDT workplace.

In the survey of the electrical environment of VDT workers (Paper I) we found a number of workplaces with a visible spatial instability of the image on CRT-based VDT screens (jitter). The instabilities were not due to low technical standards of the VDT monitor. Instead, it was due to the high general level of the magnetic fields in the offices. Two studies have been conducted under controlled laboratory conditions to find how sensitive VDT screens are to external magnetic fields (Papers III-IV).

Paper III focuses mainly on how office workers in general experienced jitter when a power frequency magnetic field was applied to a number of different VDT monitors.

Due to the increased use of electronic loads, the harmonic content of the magnetic field in buildings is on the rise. It was therefore of interest to study how the harmonics (i.e. 150 Hz magnetic fields) affected the stability of monitors. It was also of special interest to study the influence of a 16.7 Hz magnetic field, the frequency used by the Swedish railways (Paper IV).

Material and methods

The experimental procedure was the same in the two studies with only some minor exceptions. In Paper III the magnetic field was generated using a pair of Helmholtz' coils with a diameter of 1.80 m. The coils were fed from a signal generator and an amplifier. Eight volunteers judged the occurrence of jitter. Both increasing and decreasing magnetic fields were used during the test procedure and the appearance and disappearance of the instabilities were recorded as well as the flux density at the point the test subjects judged the monitor as absolutely impossible to work with.

In Paper IV a double square coil (1.0 m side) was used to generate a vertical homogenous magnetic field at different frequencies in the same way as in Paper III. One well-documented monitor was used in this test. The experimental procedure in Paper IV was similar to the procedure in Paper III. However, instead of increasing and decreasing the field strength, the field strength was
randomly set to different fixed levels and the test subjects answered the question: “Can you see the instability, yes or no”.

A method based on a combination of applied DC and AC magnetic fields was used in Paper IV in order to translate the amplitude of the jitter to an apparent movement on the screen.

**Results**

Our ability to detect jitter on the VDT screen varied between people (Paper III), but also from day to day with the same person (Paper IV). When a 50 Hz sinusoidal $B$-field was applied to seven different screens the mean value of the detection limits for 8 test subjects ranged from 0.6 to 1.0 $\mu$T (rms). Some individual subjects were able follow the instabilities for a number of screens down to 0.4 $\mu$T. If the screen was watched through a magnifier the instability could be detected at much lower values; this was done with one tested screen down to 0.2 $\mu$T when a 50 Hz $B$-field was applied. If the difference between the external $B$-field and the refresh rate of the screen was about a couple of Hz, the instability was noticeable at even lower flux densities (Paper III).

Our ability to detect jitter depends on the amplitude and frequency characteristics of the jitter. When a 0.45 $\mu$T $B$-field with a frequency of 150 Hz was applied to a monitor with a 72.2 Hz refresh rate, the mean value of the percentage detected jitter for all test subjects was 88%. Corresponding values when the frequency of the applied $B$-field was 60, 16.7 and 50 Hz were 58, 47 and 11%, respectively (Paper IV).

The amplitude of the jitter could be translated into a horizontal displacement in mm if a vertical DC $B$-field was applied (Paper IV). For the tested monitor the displacement of the screen image was $0.031 \pm 0.006$ mm/$\mu$T (note DC field!).
Flickering light and perceived electrical hypersensitivity

The clinical experience from interviewing patients with EHS shows that fluorescent light and/or VDT work are the most commonly reported provocative factors for symptoms. One common physical factor emitted in our environment from both CRT-based VDT screens and artificial light is amplitude modulated light.

To gain a basic understanding of modulated light in our environment we have studied different commonly used light sources (Paper V).

It is known that the nervous system is able to respond to flickering light with frequencies well above the critical flicker fusion frequency, i.e. above which the light is perceived as continuous. It is also known that the response of individuals varies. Effects of amplitude modulated exposure might be quantitatively assessed by conventional electrophysiological methods, such as electroretinogram (ERG) and visual evoked potential (VEP). In view of this it was of interest to find out if individuals with EHS had an enhanced sensitivity to amplitude-modulated light at higher frequencies (Paper VI).

Amplitude modulation of light from various sources (Paper V)

Material and methods

The dominating component of light fluctuation in 50 Hz supplied voltage fluorescent tubes is a 100 Hz whole tube fluctuation. Each half-wave of the supply current creates a discharge cycle within the tube. The modulation of this light depends primarily on the time-constant of the phosphor and the gear. The measurements of the modulation-degree of different light sources were done under controlled laboratory conditions with a photometer directed towards the centre of the light source. The objects consisted of incandescent lamps, tungsten-halogen lamps, different commonly used fluorescent tubes and some discharge lamps.

Results

The study showed that the modulation of light varies substantially between different commonly used light sources. In general, the 100 Hz component in the flickering light was dominant.
For incandescent lights the modulation increased with decreasing power and was in the interval 10–22%. Light from the tungsten halogen lamps had 2–6% modulation. The most common light sources (single colour fluorescent light) had a modulation of about 20%. Fluorescent tubes with better colour rendering (full colour and full colour special fluorescent tubes) had a higher degree of modulation, 30–40%. One fluorescent tube showed a modulation degree of 98%, while light from high frequency (HF) fluorescent tubes had a modulation of about 1%. Light from conventional compact fluorescent tubes had a modulation degree of about 44% and for HF compact fluorescent tubes 2–7%. Modulation of light from HF compact fluorescent tubes had a tendency to decrease with increased tube size.

Neurophysiological effects of flickering light in patients with perceived electrical hypersensitivity (Paper VI)

Material and methods

Ten patients with perceived electrical hypersensitivity treated at the Dermatological or the Occupational Medicine Clinic at the University Hospital in Umeå participated in the study. The characteristics of the symptoms varied widely within the group. However, they usually had a combination of skin, eye and neurological complaints and associated their complaints with EM-fields emitted from VDTs, fluorescent tubes or TV sets. An equally large group of subjects without any problems associated with VDT work or light exposure served as a control group. The test procedure took place in a well-shielded room with very low electric and magnetic fields. Each experiment included two different kinds of stimulation: flash stimulation by a stroboscope discharge lamp in order to examine the behaviour of occipital VEPs and ERGs in the CFF-range and a sector disc stimulation providing different depth of light modulation by means of a system of two slide projectors. In the latter experiment the frequency was constant at 45 Hz, but the depth of the modulation varied, 100, 75 and 50%.

Results

Enhanced VEP amplitude at all the investigated frequencies in the range 20–70 Hz was found in the patient group in comparison with the control, whereas no difference between the groups was observed in the physiological decrement of the amplitude with increased stimulation frequency. Experiments with different modulation depths at 45 Hz stimulation showed some differences between the patients and the control group at 100% and 50% modulation depths. The VEP amplitudes were higher for the patients than for the control subjects.
One can assume that the effect of amplitude modulated light exposure has a central rather than a peripheral perceptual character, since the amplitude of the ERG did not differ between the patients and the control group in all experimental conditions.

Specific deviation of the autonomous nervous system was found in pre-test examination of this group of patients. The mean values of the Inter Beat Intervals (IBI) significantly increased during the relaxation period in the patients whereas it did not change in the control group. It should be noted that background values of IBI among the patients were significantly lower compared with control subjects.
Discussion

Technical measurements

Several EM-field measurements have been done during the last years to examine the possible link between EM-fields and cancer. The measurements have mainly focused on $B$-fields in homes, but lately occupational exposure has also been reported. In the cancer epidemiological studies the exposure assessments have focused on long-term averaged values since this is considered more likely to be associated with the disease.

In Paper I we have only used spot-measurements of the $E$- and $B$-fields in each office as the purpose was to obtain an estimate of the level in the workplace of interest. We chose not to take an estimate of duration time into account because of lack of such clinical experience and no questions about “relation to” or “hours or days before symptoms appear” were put forward (Stenberg et al. 1992).

A certain degree of caution must be exercised when comparing measurements because of different measuring procedures and the selection of offices in this study. The workplaces studied were not randomly selected. Instead, the selection was based on the symptoms or lack of symptoms of the office workers.

It is known that, for instance, the grounding of the $E$-field instrument strongly influences the results of the $E$-field measurements. A comparison between measurements with grounded, ungrounded and handheld instrument revealed differences up to a factor of three (Sandström et al. 1993a). The source of electric field levels in offices can often be found in the room and is mainly ungrounded electrical equipment. As long as the equipment is connected to the main and not safety grounded, the contribution depends not only on if the equipment is switched on, but also if the switch is placed on phase or neutral.

The $B$-field level in a room depends not only on if the electrical equipment in the room is on or off, but also on the use of current in the whole building, which in turn depends on the time of year and time of day the measurements are performed. This has not fully been taken into consideration as the measurements have only been done once in each office. In spite of this, differences in measuring procedures and difficulties in comparing results from different studies (Bracken 1990), the measurements of the magnetic fields in the offices
show results of the same magnitude as other studies (Silva et al. 1989; Floderus et al. 1996).

The measurements in Paper I were done in early 1989. At that time recommendations were published regarding electrostatic fields and the line frequency B-field emitted from VDT screens (SWEDAC 1987). As the debate about “radiation from VDTs” had been going on for a few years in Sweden we found many monitors that met these guidelines. Today the guidelines have taken into account the other field components (SWEDAC 1990b; TCO 1995). Our experience from recent measurements in offices is that the fields from VDTs are now also low on these other parameters (i.e. ELF and VLF electric fields and ELF B-fields). Thus, today monitors do not substantially increase the total EM environment.

On the other hand the harmonic content of fields has increased with the use of more electrical equipment with electronic loads (Hansson Mild and Sandström 1994a; Redl et al. 1997). It is now not uncommon to find offices were the harmonic content of fields exceeds that of the fundamental frequency.

**Skin symptoms among VDT workers**

Work-related illness often demands an interdisciplinary approach to find the cause of the illness and to help the patient. This was the overall object of *The Office Illness Project in Northern Sweden*. Constitutional factors (Stenberg 1994), psychosocial factors (Eriksson 1996) and indoor climate factors (Sundell 1994) were found as risk indicators for VDT workers with skin symptoms and, thus, support the need for an interdisciplinary approach. Paper II shows that the electrical environment is also a risk indicator. This is the first study where the total electrical environment has been measured and taken into account concerning VDT work and skin symptoms. Because of this there are some questions that need to be addressed.

The cross-sectional design used in the questionnaire study as a basis for the case referent investigations resulted in a lack of information when the symptoms first appeared. For instance, actions may have been taken at the workplace because of symptoms and, thus, may have hidden or changed the values of important parameters of interest. The application of filters on VDT screens is one such example. In 1989 when the study was done there were no or very few discussions in public about the total electromagnetic environment and skin symptoms and, therefore, we can assume that no action to reduce fields was
taken, except for filters mentioned above. If, on the other hand, a filter with high conductivity was applied, both the electrostatic field and the alternating electric fields in front of the VDTs would have been reduced (Anger 1990). If that measure did not decrease the skin symptoms of the operator, we have a situation with very low electric fields in front of the VDT, but the operator is still classified as a case. However, stratifying for filter did not change the result.

The definition of a skin symptom case was based exclusively on the clinical experience that such patients almost always report marked sensory symptoms in facial skin and that clinical signs can be very sparse. If the duration time for symptoms is short — the time between the reply period and the measurements was 2–4 month — “borderline persons” with fluctuation symptoms might move from one group to another during the period. However, clinical investigation of the selected subjects in the case referent study showed that both signs and symptoms were more prevalent in cases than in referents (Stenberg et al. 1995). Furthermore, dry facial skin, facial erythema and rosacea signs used for separating cases from referents corresponded well with findings in earlier studies (Nielsen 1982; Rycroft and Calnan 1984; Fisher 1986; Stenberg 1986).

The fact that there were few dropouts in the questionnaire study as well as the results of the interviews with non-respondents indicate no selection bias (Stenberg 1993).

Most of the measured parameters assigned to the electrical environment showed no demonstrable association with prevalence of skin symptoms. However, an increased risk for skin symptoms in terms of crude OR were found for two of the measured electrical parameters, the general $E$-field in the room and the $B$-field in the ELF-range in front of VDT screens. The risk level for the latter did not remain significant after adjusting for different confounders supporting that psychosocial factors and time of VDT work were the main reasons for the detected increase in risk. Furthermore, the increased risk was related to men and thereby difficult to explore further as that group was too small. The demonstrable increased risk found for high $E$-fields in the room remained and even increased when taking confounders of interest into account.

There was no correlation between $E$-fields in rooms and the type of fluorescent lights in the office. Furthermore, the association found for the prevalence of skin symptoms and plastic shielding of the fluorescent tubes could not be explained by the $E$-fields in the room or vice versa. But we have to take into
consideration that the measurements of $E$-fields were done about 1.2 m above the floor and at that position other sources might dominate the contribution to high $E$-fields. As discussed in other parts of this thesis, quality of light is found to be of great importance when discussing symptoms or discomfort in not only among VDT users, but also office workers in general (Küller and Wetterberg 1993). However, the collected data of the office environment did not include such information.

No other study has measured the total electrical environment in the offices of VDT users. Bergqvist and Wahlberg (1992, 1994) measured the VDT-related EM-fields with a different procedure than used by us. The questionnaires used in the two studies were also different. In agreement with our results Bergqvist and Wahlberg did not find any association between VDT-related fields and the prevalence of skin symptoms. The general EM-field was not considered in their study. The study design used by Bergqvist and Wahlberg (1992, 1994) made it possible to study diagnosed skin diseases in relation to physical factors. They found an association between high prevalence of diagnosed Seborrhoeic dermatitis and low relative humidity. The study design used in the Office Illness Project as well as the low number of diagnosed Seborrhoeic dermatitis made this comparison impossible. Only 16 persons among cases and 10 among referents were found with diagnosed Seborrhoeic dermatitis (Stenberg 1994). In spite of this it is of interest to note that these persons were overrepresented in rooms with low relative humidity and high personal charge and this might therefore be of interest for further studies in view of the particle deposit hypothesis (Wedberg 1986; Skulberg et al. 1996).

This study indicates that $E$-fields in rooms or unknown factors associated to $E$-fields might be a factor of interest for the prevalence of skin symptoms. There is currently little knowledge of how weak electric fields can initiate or promote adverse health effects. It is known that ELF electric fields induce time-varying electric charges on the surface of the body and this in turn leads to electric fields and currents in the body. All standard settings in the area have as a base for the limit an induced current on the order of a few mA/m², and this is translated into limits for the field strengths in air. In the European prenorm (CENELEC 1995) the limits are given as 10 kV/m for the whole working day. For shorter times it may reach 30 kV/m. Valberg et al (1997) have analysed the physics of several mechanisms by which electric and magnetic fields can interact with living systems. So far there is no consensus about a mechanism for adverse effects from the weak $E$-fields encountered in the office environment.
Image quality of VDT screens and external magnetic fields

Physical visual ergonomic factors associated with eye discomfort, symptoms and reading performances (Bergqvist 1984; Wilkins 1986; Collins et al. 1990; Sheedy and Bailey 1994) have so far been discussed in terms of performance characteristics of the screen, environmental light conditions and software performance. In this study we have shown that external $B$-fields also influence the image quality of the VDT screen by causing an apparent jitter and our ability to detect this instability depends on the differences in frequency between the refresh rate of the screen and the external $B$-field. Furthermore, with the increasing content of electronic loads in our environment, the harmonic content of the general $B$-field will also increase and the risk for instabilities in CRT-based VDT screens might increase.

If we are going to be able to meet the international accepted criteria that stipulates that VDT screens “shall be free from disturbing flicker and other forms of instability” (Council-Directive 1990; AFS 1992; ISO 1992), either monitor product standards (CISPR 1997) have to be more demanding or there has to be a limit for general $B$-fields in offices which includes both fundamental and harmonic frequencies.

It seems reasonable from visual ergonomic as well as financial reasons to take this into account when planning for new offices. It is often difficult and cost consuming to deal with the problem afterwards (Hansson Mild et al. 1991; Hasselgren et al. 1994; Munderloh et al. 1995; Carrns 1997). It should also be noted that the magnetic fields in offices may have a rather large variation in amplitude over time, both from day to day and during the same day, (Nair and Zhang 1995; ESAA 1996) causing fluctuations in the amount of VDT interference. Another factor to consider is that depending on software installation different programmes use different refresh rates, which could result that with one programme the instability is visible but not with another.

EHS and flickering light

Questionnaire studies and interviews with EHS persons have shown a large variety of symptoms (Knave et al. 1989; Bergdahl et al. 1994) that have much in common with other environmental illnesses: MCS (Multiple Chemical Sensitivity), which has symptoms attributed to low levels of various chemicals (Sparks et al. 1994), SBS, which has symptoms mainly attributed to indoor climate factors (Stenberg et al. 1994), and “oral galvanism”, which has
symptoms mainly attributed to tooth fillings (Bergdahl 1995). The described symptoms are not unique for environmental illnesses and are rather common among the general population (Tibblin et al. 1990).

Bergdahl (1995) made a comparison between persons with VDT-related skin symptoms and EHS persons and found that they differed from each other psychologically and therefore should be handled in different ways by the health care system. The 5 year follow-up study of VDT workers who participated in the original case referent study (Paper II) showed that persons with only skin symptoms had a better prognosis compared to those with a more complex collection of symptoms and that a poor psychosocial work environment made the prognosis worse (Eriksson et al. 1997a). A common conclusion in these studies of environmental illnesses, VDT workers skin symptoms and EHS patient, is that even if many symptoms are common within and between the groups, the groups themselves are heterogeneous and a multidisciplinary approach is needed to develop a successful plan for rehabilitation for each individual within the group (Hillert and Kolmodin-Hedman 1997).

But the question remains: do physical environmental factors play a role in the appearance of symptoms in EHS persons, and do we have an established method of measuring the response in humans? Paper VI focused on the fact that persons with EHS consider VDTs and fluorescent light as the most common provoking factor in their environment. Furthermore, both VDT screens and fluorescent light produce flicker at frequencies in the CFF frequency range and this light modulation has been suggested not only to have an impact on visual comfort and performance, but also on symptoms, such as headaches and eyestrain (Brundrett 1974; Wilkins 1986; Wilkins et al. 1989; Lindner and Kropf 1993). Kölle and Laike (1997) found in a recently performed study that persons with high CFF responded with a pronounced attenuation of Alfa waves as well as decreased accuracy of performance when exposed to conventional fluorescent light compared to fluorescent light powered by electronic high-frequency ballast.

In Paper VI we used a modified method previously used by Brundrett (1974) to see a synchronised response to a given light signal in EEG. Paper VI is the first part of a more extensive program and only included the specific VEP responses to given light signals in different frequencies and degrees of modulation. However, the higher amplitude responses found in the patient group compared with controls for both different frequencies and degrees of modulation of the
light exposure indicated a hyperreactivity in the nervous system. Furthermore, Wibom et al. (1995) exposed EHS persons to fluorescent tubes with different degrees of light modulation and found significantly lower scores of well-being and experience of light as well as higher Alfa activity in the EEG with high degrees of modulation of the light compared with controls.
General discussion

Current facts indicate a multifactorial aetiology for facial skin symptoms among VDT workers as well as for EHS. This in turn motivates a multidisciplinary approach to the problem. The Office Illness Project in Northern Sweden, where VDT workers with skin symptoms were studied epidemiologically, supports this view. It further shows that physical factors should be incorporated in this multifactorial approach to viewing at the problem. A demonstrable statistical association between $E$-field in rooms and the occurrence of such symptoms was found, but today it can not be determined whether this association also demonstrates a causal relation between the $E$-field (or unknown factor associated with $E$-field) and the genesis of the symptoms. Furthermore, the hyperresponsitivity found in EHS persons when exposed to flickering light does not necessary indicate a causal association between flickering light and the occurrence of symptoms in EHS persons. The results from the studies, however, indicate that physical factors cannot be discarded as provoking factors and therefore they should be subject to further study.
Conclusions

• In 1989, when our measurements in the offices were performed, the general levels of the 50 Hz magnetic fields in the offices were found to be low, but in 5% of the measured offices the flux density exceeded 0.5 μT. At this level it was shown that VDT monitors displayed visible instabilities (jitter). Furthermore, the ability of test subjects to detect jitter depended on the amplitude and frequency characteristics of the jitter. The study indicates that the instability of computer monitors and thereby the visual image of VDT screens might be an increasing problem since it is known that the harmonic content of the general magnetic field in offices is on the rise.

• The measurements in the offices showed that VDT monitors contributed to the magnetic field level at VDT workplaces in both extremely low and very low frequency ranges. The dominant source of electric fields was ungrounded electrical equipment, not VDT screens.

• High electric fields in the extremely low frequency range or undetected factors related to such exposure in the office were associated with skin symptoms among VDT workers. This association was further strengthened when stratifying for female gender. Such association was not found, however, for any of the VDT-related electromagnetic fields.

• Commonly used fluorescent tubes in our office environment have a modulation degree of the light (flicker) that varies widely from less than 1% (fluorescent tubes with high frequency gear) up to nearly 100%.

• Exposure to flickering light at frequencies in the CFF frequency range led to a higher amplitude of brain responses (Visual Evoked Potential) in patients with perceived electrical hypersensitivity in comparison with control subjects.
General conclusion

It seems prudent at this present time to regard electromagnetic and light conditions as physical factors that should be considered when planning office workplaces. Furthermore, this thesis indicates that these factors might be included as a part of a multidisciplinary investigation of persons with VDT-related symptoms and/or discomfort, but further investigations are required in order to establish a possible relationship.
Further research

• There is a need to look at the problem of skin symptoms among VDT workers and “electrical hypersensitivity” in a broader perspective and include other “environmental illnesses”. We also need to examine the occurrence of such symptoms in the general population.

• It is important to conduct follow-up studies on the thousands of patients that have visited occupational dermatological and occupational medical clinics during the last 10–15 years. Of special interest are those patients who have been cured and what measures have been applied.

• It is important to explore the role of flickering light further (by using VDT screens with different refresh rates), as well as other physical factors such as sound and EM-fields, by using and further developing the method previously used to record neurophysiological responses. It is also of importance in this context to involve more parameters for examine of the autonomic nervous system reactions and comparing different constellations within the “environmental illness” group with these methods.

• It is important to further explore the role of low level $E$-fields in our daily environment.

• Further investigations concerning perception of jitter on VDT screens exposed to external magnetic fields are also called for. Of particular interest is the use of fields with a high harmonic content and fields with different polarisations.
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