

A critical appraisal of current knowledge and future directions of ergophthalmology: consensus document of the ICOH Committee on ‘Work and Vision’

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In the past, occupational health gave scant attention to the visual apparatus. Studies on issues relating to ‘work and vision’ have predominantly addressed industrial accidents and the toxic effects of exposure to chemical and physical agents, with secondary prevention being more common than primary prevention. In recent years, the huge transformations implemented in workplaces, mainly due to computer-based technologies, demand a progressively higher efficiency of the eye and the related nervous system components that co-ordinate eye movements and accommodation. At the moment these aspects are managed by medical, psychosocial and a variety of technical disciplines, without any shared criteria, terminology and method. Objectives of the Committee are: to investigate holistically the many possible hazards associated to the occupational visual performance; to come to a consensus on terminology, risk assessment and health surveillance procedures. The present status of research and practice in ergophthalmology does not allow for clear-cut decision about health risk and nor is there a clear direction on the prevention of work-related ocular and visual disturbances and disorders. Specifically, at least three determinants must be objectively considered, namely: (a) visual effort; (b) environmental agents; (c) individual characteristics. Although criteria exist for the evaluation of some of these determinants, a greater refinement is necessary ‘for a good working life’ of the visual apparatus. The ICOH Scientific Committee on ‘Work and Vision’ is seeking to systematically develop this matter, yielding a more rational and complete approach to the relationship between work and vision.

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1. Introduction

1.1. Main messages

- (1) Occupational visual performance is progressively more important in modern technologies;
- (2) Ocular and visual disturbances and disorders (occupational asthenopia) have a high prevalence both in white and blue collar workers;
- (3) Occupational asthenopia can seriously interfere with cognitive processes, increasing the so-called 'human error', which in modern technologies can also have catastrophic effects (air traffic control, nuclear power station, etc.).

1.2. Policy implications

- (1) Risk assessment should be performed taking into consideration the specificity of the human visual apparatus;
- (2) Sanitation surveillance and job fitness cannot be carried out simply applying 'ophthalmic criteria', but need specific knowledge and competence in occupational health.

1.3. Definition of ergophthalmology

The carrying out of daily work activity has often damaged, altered or caused discomfort to workers vision (Ramazzini 1743, Hunter 1975). In the past, research was mainly concentrated on severe irritative reactions to environmental pollutants, industrial eye trauma, ocular injuries from contacts with chemicals, specific toxic effects such as retrobulbar ocular neuritis due to methanol or lead, cataract and maculopathy due to radiation, etc. (Zenz 1975, Rom 1983). More recently, in occupational health, interest has shifted from diseases with obvious and specific etiology to 'work related diseases'. Studies on 'Work and Vision' issues have followed suit, developing more up-dated research directions, where, although the risk of severe and irreversible alterations is less probable, the population exposed is much greater and progressively increasing. As all of these studies have the common aim of protecting the integrity of workers' vision, one can define a new area of research namely 'ergophthalmology'. Accordingly, the ICOH Scientific Committee on Work and Vision defines ergophthalmology as 'the scientific field aimed at analysing, evaluating and designing simple or complex working systems pertaining to the relationship between work and visual performance. Ergophthalmology makes use of established knowledge derived from ophthalmology, industrial hygiene and occupational medicine, as well as from technology (physics, engineering, architecture, etc.) and social disciplines (psychology, sociology, etc.). The purposes of ergophthalmology are mainly the prevention and management of discomfort and disease in order to obtain maximum efficiency and effectiveness of visual function in organized work'.

1.4. Literature review

Analysis of the literature (with particular reference to that produced since the 1980s), reveals three distinct areas of interest. The first, mainly bio-medical, focuses its attention on 'functional' aspects, describing the existence of 'visual inefficiencies' (transient or pseudo-myopia) and disturbances during close work (Saito *et al.* 1981, Jashinski-Kruza 1984, Ong and Ciuffreda 1997, Yamada 1998). Recently, some

authors have started to investigate the possible effects of close work on ocular motility, based on the hypothesis that very intense stimulation of convergence may cause binocularity disorders (Nyman *et al.* 1985, Gratton *et al.* 1990, Ishikawa 1990).

A second area, mainly supported by hygienists and toxicologists, explores the possible irritative actions produced by particulate and gaseous airborne contaminants on the ocular mucosa. This research (Wehshler *et al.* 1990, Molhave 1991, Berglung 1992), developed in the areas of 'Indoor Air Quality' (IAQ) and Sick Building Syndrome (SBS), has assumed a progressively greater importance in the field of ergophthalmology, given the vast number of workers involved (mainly office operators). In many cases, an exposure-response relationship has been observed. A subset of these studies has considered microbial contamination of air and surfaces. Indoor environments may provide substrates for microbial growth, playing a well-documented role in the development of certain respiratory and skin disorders (Harris *et al.* 1986, Teeuw *et al.* 1994, Hung *et al.* 1995). According to some researchers (Piccoli *et al.* 2001), the ocular surface seems directly involved, but very recent evidence needs further investigation.

A third area developed by experts of technical disciplines, mainly through investigations conducted in office environments, is concerned with lighting conditions. The irrational distribution of light sources (both natural and artificial), from which noteworthy variations in light intensity at the work site can derive, are apparently a cause of discomfort, sometimes intense ('discomfort glare' and 'disability glare') (Weston 1962, Grandjean 1987, Begemann *et al.* 1997).

Besides these three well documented areas, research continues into more limited areas such as electromagnetic field exposures and the possibility of a relationship with ocular flogosis in VDU operators (Guy 1987, Eriksson *et al.* 1995), and to microclimate, whose effect on the ocular surface can be a cause of severe disturbances (Franck 1986, Sotoyama *et al.* 1996).

In conclusion, it can be said that, according to present knowledge, the work related ocular/visual disorders and disturbances reported in the literature have a multifactorial origin, where:

- task characteristics,
- environmental conditions,
- individual ophthalmic characteristics,

constitute the essential elements to consider both for risk assessment and health surveillance.

2. Exposure evaluation

In ergophthalmology, perhaps even more so than in other sectors of occupational health and hygiene, it is necessary, for risk assessment to separately analyse task content ('*what* the operator does') and environmental conditions ('*where* the operator works'), because many variations in intensity and quantity can exist simultaneously. For example, occupational activities requiring an intense visual effort could be carried out in a good 'hygienic' environment or, on the other hand, a simple visual effort could be performed in a polluted environment. Between these two opposite extremes, each of which could contribute to the onset of ocular/visual alterations, a multitude of intermediate work situations can occur. Consequently, task duration, i.e. the time effectively spent to perform the tasks, and working time, i.e. time spent at the work place, must be separately quantified.

2.1. Task related parameters

Occupational visual performance, in either an industrial or an office environment, is characterized, especially in technologically advanced countries, by the necessity to observe, for most of the working day, image/object details with very small dimensions. Given the ubiquity of computer-based technologies, these work situations will surely become more frequent and possibly, in a not too distant future, will involve almost all workers. Ergophthalmologically, these performances can be defined as:

- near,
- prolonged,
- fixed.

Near, because the objects and instruments to be observed during work are usually placed within one metre; prolonged, because near point fixation is maintained for many hours each day, often for the entire working life; fixed, because, due to the frequent presence of structural limitations (wall, curtains, furniture, partitions, etc.), the physiological alternation between near and far vision is quite restricted (figure 1). This type of work situation has important physiological repercussions. It is well known that in near vision two important physiological functions, not stimulated in distant vision, are specifically activated: accommodation and convergence. They are controlled by psycho-optical reflexes (i.e. involuntarily and unconsciously), and their stimulation proportionally increases as the required observation distance decreases. Under these circumstances, accommodation and convergence may become overloaded, giving rise to discomfort (occupational asthenopia) (Nyman *et al.* 1985, Jashinski-Kruza 1990, Piccoli *et al.* 1996) and visual inefficiency (pseudomyopia) (Duke 1930, Jashinski-Kruza 1984, Rosenfield and Ciuffreda 1994). Consequently, to evaluate adequately the visual effort of a given operators (within their working time), two parameters must be known:

- near observation duration,
- average observation distance.

These parameters can be quantified by subjective methods (questionnaires, interviews, anamnesis, etc.), or by objective methods (direct observation, specific instrument, etc.), obviously with different degree of precision (Piccoli *et al.* 1996, 2001, Kong-King and Ming-Te 1997, Jaschinski-Kruza 1998). In both cases, these data are useful, either to reliably interpret subjectivity/symptomatology for research and health surveillance purposes, or for ergonomics rationalization of work procedure and task sequence. It is therefore essential that in ergophthalmic investigations and research, particularly if the aim is to explore cause-effect relationships, the above-mentioned parameters are carefully evaluated. Unfortunately, it is common, both in literature and in professional practice, that the occupational visual effort is unknown or simply described by adjectives such as 'intense', 'high', 'very close', etc. (sometimes derived from unverified administrative designations). This approach excludes reliable epidemiological evaluations and does not allow the appropriate data verification and comparison in relation to the conclusion drawn.



Figure 1. Common VDU working situation where the operator maintains her accommodation activated even when screen and keyboard observation is not required. Author: Bruno Piccoli *et al.*

2.2. Chemical agents

Chemical exposure is most common in industrial environments and existing exposure standards have traditionally been aimed at the prevention of adverse effects among healthy blue-collar male workers. Severe chemical eye injuries, due to alkalis, hydrocarbons, metals, etc. may occur at the work place and nearly 10% of all industrial eye injuries involve chemical agent. Among these, chemical burns account for a significant percentage of severe and disabling injuries (Pfister 1984, Karlson and Kline 1986, Morris *et al.* 1987). Despite efforts of prevention, acute chemical ocular injuries continue to occur. Nevertheless, without ignoring the evidence from these industrial situations, where a better recognition and management of the work process appear to be required, it is now appropriate to focus on non-industrial work places, where there is a large and increasing number of operators. These operators are exposed to a “chemical environment” characterized by:

- (a) low concentration of airborne substances;
- (b) mixture of chemicals, arising from a variety of indoor and outdoor sources, and possibly interacting with themselves or with other physical and biological agents;
- (c) similarity with the non-occupational (home) environment.

A significant proportion of office workers reports 'eye irritation', which is often an important feature of Sick Building Syndrome. It should also be noted that many pollutants are present in higher concentration in the indoor environment than in the outdoor environment. The literature (Chernow 1992, Grant and Schuman 1993, Menzres *et al.* 1996, Guideline for air quality 2000) suggests that the prevalence of these eye disturbances may be partly attributable to:

- (a) gaseous emission, especially formaldehyde, volatile organic compounds (VOCs) and ozone (O₃) from new interior furnishings and equipment;
- (b) airborne particles from carpets, ceiling insulation, etc., and the electrical effects from VDUs;
- (c) irritants from environmental tobacco smoke (ETS), nitrogen oxides (NO_x) and combustion products, from interior or exterior sources.

It has been found that short term effects are most common, and usually mediated by the interaction of the chemicals with the ocular surface, although effects on ocular muscle or nervous tissues (Kjaergaard *et al.* 1992, Cometto-Muniz *et al.* 1997, Hempel-Jorgensen *et al.* 1998) cannot be excluded. Also subjective (perceived irritation intensity) and psychosocial factors seem to have a role (Bachmann *et al.* 1995, Hempel-Jorgensen *et al.* 1997).

The principal mechanisms of action of this main group of chemicals, are the following:

- (1) lacrimation;
- (2) caustication;
- (3) solvent action;
- (4) surfactant action.

2.2.1. *Lacrimation*: Tear formation is caused by many substances via specific chemical mechanisms, by means of selective stimulation of the sensory nerve endings in the cornea and conjunctiva. Most of these substances produce stinging and lacrimation at low concentration (without any clinically evident injury), while at high concentration can cause severe corneal damage. Although neither the relation between the nerve endings stimulatory processes, nor damage mechanism are well understood, there is clear evidence that corneal/conjunctival injuries and nerve endings stimulatory effects are not linked. A series of biochemical studies on lacrimators confirmed that they are active inhibitors of cellular respiration, often more effective than cyanide. However, the airborne concentration of lacrimators able to produce eye discomfort was several hundred times smaller than that needed, *in vitro*, to interfere with tissue metabolism or respiration. It has been postulated that there might be an adsorbent and selective concentrating effect in the superficial layers of the corneal epithelium and nerve endings, able to produce a locally higher concentration of lacrimators than in the surrounding air (Morgan 1987, Cometto-Muniz 1995).

2.2.2. *Caustication*: Alkalis and acids produce deep penetrating injuries of cornea and conjunctiva, as well as of lens and iris. These injuries are the result of an extreme and very rapid change of the pH within the tissues. Some changes in the tissues (dissolution of the corneal epithelium and mottled clouding of the corneal stroma by

alkalis; coagulation of the corneal epithelium by acids), are immediately evident. Oedema and corneal stroma loss of mucopolysaccharide, as well as opacification and degeneration of the cornea, can develop later. In human beings, it is questionable whether chronic exposure to causticating agents in air can cause anything more than hyperaemia of conjunctiva and eyelids. Indeed, low exposure to ammonia, which has been associated with keratitis epithelialis or 'fine band-shaped corneal clouding' with slight visual impairment, did not provoke any irritation and subjective disturbance (Nielson 1991, Ronzenbaum *et al.* 1991, Ronk *et al.* 1994).

2.2.3. *Solvent action:* Eye exposure to a splash of a chemical solvent usually causes immediate stinging and smarting pain. It may also cause loss of some or all of the corneal epithelium, which normally regenerates in a few days without permanent damage. Immediately following exposure, while the epithelium is damaged, the corneal stroma may be slightly swollen and the posterior surface of the cornea appears wrinkled. Most organic solvents are used mainly for their solvent properties and have no strongly alkaline or acid contents. Their tendency to react chemically with tissue is moderate and usually causes no serious long term effects to the eye (Berglund *et al.* 1989, Molhave 1991, Kjaerjaard *et al.* 1992).

2.2.4. *Surfactant action:* Surfactants are synthetic organic compounds having a common property of lowering the surface tension of water. They are used in great quantity and variety industrially and domestically for cleaning, washing and scouring, as well as in cosmetics and ointments. These substances are classified chemically as (i) cationic, (ii) anionic, (iii) nonionic, with some related and rather complex differences in type and severity of the injuries. Some detergents that are used industrially and in the household, rarely cause serious eye injuries; some surfactants, such as ordinary soap, cause immediate stinging or burning with little or no injury, while some others produce corneal oedema and loss of corneal epithelium with no discomfort; finally, some have delayed effects after a variable latent period. Generally, it can be said that cationic surfactants are the most damaging, the anionic are less injurious and the nonionic are the least (Clayton *et al.* 1985, Morgan 1987).

It is well known that, due to its structural characteristics, the ocular surface is quite delicate and vulnerable to chemical agents, even at low concentration. The application of occupational health criteria, as promulgated by many institutional bodies such as the American Conference of Governmental Industrial Hygienists (ACGIH), the Environmental Protection Agency (EPA), the National Institute of Occupational Health and Safety (NIOSH) or the Occupational Safety and Health Administration (OSHA), appears to be problematic in ergophthalmology, since these 'recommended exposure level' or 'permissible exposure level' are usually based on non-ocular effects. The guidelines are, in fact, neither based on 'comfort criteria', nor on the evaluation of long term effects, with any specific consideration of the physiology of the eye.

2.3. *Physical agents*

Several factors are involved in this area: microclimate, electromagnetic fields, environmental lighting. While the first, and particularly the second, have a minor impact, the third is clearly the most important physical agent to consider in ergophthalmology today.

Concerning microclimate, the issues to be considered are relative humidity and air velocity (Christensen and Olensen 1984, Franck 1986, Nakaishi and Yamada 1999). The lacrimal film, which has essential functions for the protection and efficiency of the structures composing the ocular surface, can be markedly evaporated when the environmental humidity is low (particularly if below 40%). Even more problematic are situations where the operator's eyes are impacted by airflows. These are commonly produced by fans, fan-coils, air conditioners, photocopiers, etc. If any of this equipment is moving the air constantly toward the operator's eyes, gritty feeling, burning, conjunctival hyperaemia and corneal abnormalities can easily result. In addition, for VDU operators, screen height is a consideration, due to the fact that the head inclination, associated with a higher screen, increases the surface area of the eye exposed to the environment (Rolando *et al.* 1993, 1994, Sotiyama *et al.* 1995, 1996).

Regarding electromagnetic fields, the problem seems to arise only in VDU operators. The exterior surface of the screen, which has a net positive charge, can repel positively charged airborne particles in the direction of the operator's face, hence causing ocular and skin irritation (Wallach 1982, Eriksson *et al.* 1995).

Lighting is probably the most important of the physical factors to consider. Lighting represents the most common 'physical pollutant' in indoor work-places, and the major source of visual discomfort in office activities (Rea and Fies 1995a,b). However, photometry at the work place is carried out almost exclusively by use of a luxmeter. This photometer is used to measure the amount of light on work surfaces as well as to evaluate the efficiency of the lighting system. Although the validity and practicality of this instrument is well recognized for maintenance and/or redesign purposes, its use appears inappropriate when the operator's exposure has to be evaluated. To know the illuminance, for instance, on a desk or on a keyboard is of little importance in ergophthalmology, because this parameter is only very roughly correlated to the light that *actually enters the operator's eye*, which is the *exclusive* 'visible radiation' able to cause discomfort and work inefficiency. Three elements support these considerations. The first is that luxmeters, because of their intrinsic structural characteristics, follow the 'cosine law', i.e. they quantify 100% of light rays that fall perpendicularly onto the photocell ('vertical'), but progressively less the inclined ones (for instance 64% of those having an inclination of 50°), until the value becomes zero for light rays having an inclination of 90° ('horizontal'). The second is that luxmeters, normally positioned on a surface (tabletop, wall, working-surface, etc.), detect the 'incident light', but do not consider at all, the light which is reflected from the surface toward the operator eyes. The third is that luxmeters express, in an average value, the sum of all the light rays whose intensity is obviously very variable, detected over a large angle. Consequently, small areas intensely illuminated (from which marked discomfort can originate), cannot be adequately identified. It is therefore possible to affirm that 'occupational photometry', whose aim essentially consists in the evaluation of the compatibility of *that* lighting with *that* operator, cannot rely solely on illuminance measurements. In ergophthalmology an adequate photometric study must allow:

- (a) reliable measurements of the quantity of light which falls onto the operator's retina (i.e. use of an instrument which fits the anatomy and the physiology of the human visual apparatus);

- (b) detailed measurements (areas of square centimetres) of light emitted from light-sources or surfaces;
- (c) contrast ratios evaluation (for instance: VDU screen and surrounding objects);
- (d) multiple readings in order to delineate, in details, the 'lighting features' of the workstation considered.

These requirements can be met by the use of a luminance photometer (Grieco and Piccoli 1982, Sahahnavaz 1982, Halonen 1993, Campbell 1996). This photometer is similar in shape, size and mode of use to a video camera. It has an optic system with a viewfinder, which allows the area of interest to be framed during the evaluation. Moreover, it can be placed and adjusted according the estimated position of the operator, allowing a photometrical analysis which is (i) more detailed and selective, because of the features of the optical system, and (ii) more accurate and reliable, because of its structural characteristics. In conclusion, the lux meter maintains its validity if the amount of light that falls on work-planes needs to be measured (effectiveness of the lighting system and relative cost-efficiency ratios). Otherwise, if the aim is to study the compatibility of the environmental lighting with the visual system and the related operator's subjectivity, the most appropriate instrument appears to be the luminance meter.

2.4. *Microbial agents*

The risk of eye infection due to the presence of micro-organisms in work places has been poorly investigated (table 1), even though bacteria, fungi, and other infectious agents are common in industrial (table 2) and non-industrial environments (Piccoli *et al.* 2001). The number of occupational health studies on indoor microbial pollution, particularly in offices, has increased consistently in the last 10 years, and these have examined the roles that bacteria, viruses and fungi play in the development of certain respiratory and skin diseases (Zenz *et al.* 1994, Baxter and Adams 2000). The origin of microbial contamination are usually outdoor air (bacteria and fungal spores) and human occupants, sustained or worsened by poor maintenance of air conditioners, fan coils and humidifier systems (Tacket *et al.* 1982, Hay and Seal 1995, Berkowit and Fagel 1998, Flannigan 1998, Lin *et al.* 1999), as well as by the presence of carpets and office equipment such as keyboards and computer mice, etc. (Harrison *et al.* 1986, Hung 1995, Reijula 1998). Despite this, the literature, which specifically considers the risk of occupational eye infection, is scarce (Piccoli *et al.* 2001, Doyle *et al.* 1989). In everyday clinical practice, it is common to observe the presence of micro-organisms (i) on the periocular tissues, (ii) in the conjunctival sac, (iii) in the excretory part of the lacrimal system (Seal *et al.* 1998, Hodge and Smolin 1999, Marsh and Easty 1999, Tufail 1999). Moreover, ocular infectious diseases, such as conjunctivitis, keratitis, dacriocystitis, etc., seem to be quite frequent, even though well established epidemiological data on both general and working population are not reported in the literature. Risk assessment, which appears most opportune in some sectors like abattoir and livestock industry, laboratory and medical personnel, etc., should consider:

- (a) microbial contamination, i.e. magnitude and pathogenic strength (survival, growth and invasive capacity) in the work environment;

Table 1. Output of literature review concerning occupational ocular infections.

Keywords	Sources	General references	Useful references
Incidence, Prevalence, Infection, Bacteria, Virus, Fungi, Chlamydiae,	Index Medicus	10	–
Ocular Surface, Conjunctiva, Cornea, Eye Lids, Working Age	Medline (Farmila)	38	6
Eye, Eye Surface, Ocular Surface, Conjunctiva, Conjunctivitis	Medline (Knight Ridder Info)	17	7
	Occ. Safety and HTI (Knight Ridder Info)	2	2
Bacteria, Fungi, Virus, Chlamydiae	Biosis	4	3
Work, Occupation, Activity, Profession,	Embase (Elsevier Science B-V)	1	–
Risk Assessment, Indoor Air Quality and Eye,	Toxline (Knight Ridder Info)	2	–
Sick Building Syndrome and Eye, Epidemiology	Medline Query	87	19
Total = 29	Total = 8	Total = 161	Total = 37

- (b) promiscuous use (many operators on daily basis) of the same equipment and tools;
- (c) operator's habits (food consumption at the work-place, use of cosmetics, rubbing/scratching eyes);
- (d) predisposing conditions, both general (immunological deficiencies, pharmaceutical treatment, allergy, etc.), or ocular (contact lenses, degenerative pathologies, lacrimal film alterations, etc.).

The very limited data on the relationship between microbial agents and ocular infections, experienced by indoor workers, do not exclude the possibility of causal relationships. It is therefore opportune to deal with these aspects in the field of ergophthalmology.

3. Psychosocial factors

3.1. Emotional factors in asthenopia

The hypothesized relationships between asthenopia and emotional factors suggest the idea that the so called 'visual fatigue' might be multifactorial, induced and/or supported by psychological factors, as well as the intensity and duration of the visual strain, the perceived situation and the physiopathological characteristics of the individual visual apparatus (Grandjean *et al.* 1971, Cail and Petrescu 1992, Bruno *et al.* 1995). Indeed, contingent or purely subjective psychological factors might significantly influence the perceived degree of 'visual fatigue' which, accordingly, should be included in the manifold domain of the psychologically determined 'fatigue syndromes' (Petrescu 1974, Briner and Hockey 1988). Psychological fatigue can be clearly distinguished from general fatigue in that it is (i) global, i.e. physical and emotional, (ii) not relieved by rest, (iii) accompanied by relevant mood changes.

Psychological fatigue can thus become a determinant factor in a subject's actions and reactions. Whereas physical fatigue is positive, emotional fatigue can inhibit further actions and induce a variety of physical adverse reactions, such as visual discomfort. In this context, the psychological factors to be considered are either subject-related or related to the 'organizational climate'. The subject-related factors can be cognitive, motivational or conditioned by personality. Cognitive factors concern the relationships between job characteristics and personal abilities: undemanding tasks can induce habituation or attention decrease, while highly demanding tasks can cause fatigue and confusion. Motivational factors are dealing with the presence or absence of task compliance with the subject objectives: the wider the distance between tasks and objectives, the sooner psychological fatigue will appear together with 'physical discomfort' (in these situations ocular/visual discomfort is quite common). Personality factors refer to the congruity between the subjective perceptive strategy (analytical, synthetic or creative) and the visual task to be performed. The possible presence of mild to severe psychopathologies (phobic reactions, depression, even hallucinations), can further intensify the reactions to visual constraints. Visual/ocular disturbances will then become the outstanding indicator of a physical discomfort where the psychological component is predominant. With regard to the 'organizational climate', relationships between colleagues, supervisory relationships, corporate policy, supervisor support and competitive philosophy, can play an important role, similarly to the above factors, in increasing the subject's tolerance or sensitivity to the occupational visual effort (Theeuwes 1991, Tsang *et al.* 1994).

3.2. Occupational asthenopia

Duke Elder first described occupational asthenopia in 1930 (Duke-Elder 1930) and the subject later attracted the interest of many other authors (Schwartz and Sandberg 1954, Pepersack 1977, Franck *et al.* 1993, Ukai *et al.* 1997, Scullica and Rechichi 1989). Occupational asthenopia is a syndrome characterized by:

- (a) transitory and unspecific ocular/visual disturbances (redness, burning, gritty feeling, lacrimation, etc., and blurred vision, double vision, light intolerance, etc.);
- (b) multifactorial origin;
- (c) unclear association with the ophthalmic clinical picture;
- (d) positive association with near work duration.

At present, there is a need to come to a consensus on the terminology dealing with this topic. Terms such as 'eye irritation' are used by hygienists, whereas psychophysicologists might refer to 'visual fatigue' or 'visual strain', and lighting engineers relate to 'veiling/disability glare'. This diversity in terminology, due to the different disciplines involved and to the multifactorial origin of the disturbances, is cause of confusion and favours misunderstanding of the data. Moreover, considering that potentially expensive interventions, such as, for instance, health surveillance, illumination redesign, air conditioning renovations, etc., are sometimes implemented because of subjective complaints, a reliable and widely accepted definition of this syndrome is needed. In this regard it seems important to underline that a high prevalence of ocular/visual disturbances in a working population, particularly if identified by self-administered questionnaires or based upon anamnestic informa-

Table 2. Occupational infections (from Rom, modified)

Diseases and synonyms	Causative agent(s)	Occupations at risk	Mode of exposure	Site of infectious manifestations
<i>Bacterial</i>				
Anthrax	<i>Bacillus anthracis</i>	Hide processors, butchers, agricultural workers, veterinarians	Direct contact through breaks in skin; occasionally pulmonary	Skin; occasionally lungs
Brucellosis	<i>Brucella abortus</i> , <i>B. suis</i> , <i>B. melitensis</i> , <i>B. canis</i>	Abattoir and livestock industry workers, veterinarians	Direct contact with infected animals or their products	Reticuloendothelial system
Erysipelothrix	<i>Erysipelothrix rhusiopathiae</i>	Fishing industry and abattoir workers, veterinarians	Direct contact through breaks in the skin; organism present in slime layer on fish and in infected swine	Skin, usually on the hand
Leptospirosis	<i>Leptospira interrogans</i> (various serogroups)	Abattoir, agricultural, sewer and farm workers; veterinarians and miners	Contact with infected animals and their excreta deposited in soil, mud, water	Liver, meninges, kidney, muscle
Tuberculosis	<i>Mycobacterium tuberculosis</i>	Medical students, physicians, nurses, laboratory personnel	Inhalation	Lung
Tularemia	<i>Francisella tularensis</i>	Packinghouse workers, farmers, veterinarians	Exposure to infected animals	Skin ulcer, regional lymph node
<i>Chlamydial and Rickettsial infections</i>				
Ornithosis	<i>Chlamydia psittaci</i>	Poultry processing plant, pet bird industry, and laboratory workers; poultry producers, pet bird owners, and veterinarians	Inhalation of infected, dried bird feces; direct contact with infected birds	Lung
Q fever	<i>Coxiella burnetii</i>	Abattoir, livestock industry, dairy and laboratory workers, veterinarians, farmers	Airborne; direct contact with infected animals or their by-products	Lung

(continued)

Table 2. (continued)

Diseases and synonyms	Causative agent(s)	Occupations at risk	Mode of exposure	Site of infectious manifestations
<i>Fungal disease</i>				
Coccidioidomycosis	<i>Coccidioides immitis</i>	Field and construction workers in the endemic region (lower Sonoran life zone)	Inhalation	Lung
Histoplasmosis	<i>Histoplasma capsulatum</i>	Farmers, construction workers	Inhalation	Lung
Hypersensitivity pneumonitis	Various fungi, molds, thermophilic actinomycetes, animal and bird dander	Farm, sugar cane, mushroom, lumber mill, brewery, cork, cotton industry, and pet bird industry workers	Inhalation	Lung
Sporotrichosis (rose thorn fever, rose handler's disease)	<i>Sporothrix schenckii</i>	Farmers, horticulturists	Direct inoculation	Skin, lymphatics and regional lymph nodes, lung, joints, and bone
<i>Parasitic diseases</i>				
Echinococcosis	<i>Echinococcus granulosus</i> or <i>E. multilocularis</i>	Ranchers, especially sheep herders, veterinarians	Ingestion of eggs passed in canine feces	Lung, liver, central nervous system
Toxoplasmosis	<i>Toxoplasma gondii</i>	Butchers, abattoir and laboratory workers; veterinarians, pet store owners, and cat breeders	Contact with infected animals; ingestion of oocysts passed in feline feces or ingestion of cyst-infected, undercooked meat	Reticuloendothelial system. lymph nodes, and eye
<i>Viral diseases</i>				
Creutzfeldt-Jakob disease	Unknown transmissible agents	Pathologists, surgeons, phlebotomists, laboratory personnel, autopsy room dieners, morticians	Unknown, probably by direct skin contact	Central nervous system

(continued)

Table 2. (continued)

Diseases and synonyms	Causative agent(s)	Occupations at risk	Mode of exposure	Site of infectious manifestations
Hepatitis	Hepatitis B virus	Workers in haemodialysis units, physicians, surgeons, laboratory workers, dentists, hospital housekeeping staff	Direct contact with infected material by puncture, through abraded skin, or onto mucous membrane surfaces	Liver

tion, does not, in itself demonstrate the existence of an 'occupational asthenopic syndrome' (Reading 1986). To be defined as such, asthenopic disturbances must have a reasonable link with risk-assessment evidence and a clear congruity with the ophthalmic picture. In this context, subjective complaints and symptoms are strongly influenced by a vast number of variables, such as age, sex, work history and seniority, psychosocial factors, etc. Therefore, research and investigations on these aspects must be carried out in accordance with the basic criteria that social psychology has developed and has been applying for many years (Blalock and Blalock 1968, Armitage 1971, Argyle 1972). Consequently, it cannot be considered scientifically defensible that occupational cause-effect relationships are sustained regardless of objective data on task characteristics and environmental conditions, as often happens in studies carried out by ophthalmologists and optometrists. Neither can it be accepted that 'eye irritation' is examined in terms of prevalence and severity, without regard of any information on the ophthalmic issues of the population considered, as can be observed in practically all IAQ investigations. Finally, there is no justification that the possible connections between 'visual comfort' and lighting are analysed in depth, while topics such as the visual work load and chemical agents effects, are ignored.

In conclusion, it appears evident that the relationship between ocular/visual symptoms and complaints with work has not yet been thoroughly and appropriately investigated. An integrated body of knowledge is required for reliable assessment of occupational asthenopia. There appear to be three essential prerequisites for a proper definition of an 'occupational asthenopic syndrome':

- (a) scientifically appropriate collection and specific (i.e. directly related to the exposed population), analysis of symptomatology/subjectivity;
- (b) congruity of symptomatology/subjectivity reports, with the exposure conditions (task and environment);
- (c) adequate ophthalmic information on all the subjects involved.

A high prevalence or incidence of cases affected by occupational asthenopic syndrome in an exposed population, should be considered a 'warning signal' regarding the possible existence of ergophthalmic problems. Confirmation by targeted 'on site' investigations and appropriate medical check-ups is highly recommended.

4. Ophthalmic aspects

Traditionally, ophthalmic examinations are carried out on *patients* and have the aim to make a diagnosis, prognosis and treatment of suspected or apparent ophthalmic pathologies (functional, chronicle-degenerative, infectious).

Ergophthalmic examinations involve *workers* and are aimed at:

- (a) singling out any alteration, regardless of its severity, which might be linked to occupational activities (health surveillance);
- (b) evaluating the compatibility of present or future task assignment, in relation to present and future visual capacities of the worker (job fitness).

A thorough description of the ergophthalmic examination is not within the scope of this document. Nevertheless, it is appropriate to refer to the most important of its aspects.

4.1. *The ergophthalmic anamnesis*

This should have two objectives. The first is to acquire a task-description capable of highlighting risks of disease and discomfort. Specific reference must be made to:

- (a) characteristics (duration and observation distance) of near (<1 m.) visual tasks;
- (b) presence of chemical, physical and microbial agents in the environment generally and at the work station in particular.

The second objective should be directed to the analysis and interpretation of subjectivity/symptomatology, in order to evidence the possible connection with previous and present exposure.

4.2. *Refraction*

Traditionally, refraction is performed for two basic reasons: to assess the natural visual acuity (foveal visual function), and, if needed, to permit determination of optimum optical correction of a refractive error.

Three aspects appear to have a specific interest in ergophthalmology:

- (a) use of contact lenses and chemical pollution;
- (b) presbyopia correction for short/middle distance tasks (VDU work, decoration, engraving, precision mechanics, etc.);
- (c) accommodative anomalies (accommodative fatigue, accommodative spasm, accommodative insufficiency).

4.3. *Ocular motility*

Symptoms related to ocular motility disorders include visual discomfort, diplopia, dizziness, headache, etc., which are very similar to those typically described in the occupational asthenopic syndrome. In ophthalmology, while major pathologies of ocular motility (strabismus, myopathies), are well considered, minor ocular motility disorders such as heterophorias (lateral and vertical, at near and at far), are normally underestimated. Yet, 'unstable phorias' (phorias/tropias) and convergence insufficiency can be responsible for a consistent number of "visual disturbances", particularly in close-work operators (Bagolini *et al.* 1989).

4.4. *Adnexa, anterior and posterior segment examination*

Most of the degenerative and infectious ocular pathologies are diagnosed by this part of the ophthalmic examination. Nevertheless, in ergophthalmology, two aspects appear to be insufficiently studied with traditional eye examinations:

- (a) ocular surface disorders;
- (b) infectious diseases.

The ocular surface can be defined as the outermost portion of the eye, representing the interface between the eye globe and the environment. It comprises (i) lacrimal film, (ii) corneal epithelium, (iii) conjunctival epithelium. Although these structures are presented as apparently separate, they are in strict anatomical and functional continuity, and present a morpho-functional entity whose integrity is fundamental in

acting as a strong barrier against aggressive environmental agents. In this regard, the role played by the lacrimal film is essential (Dartt 1992, Norn 1992). Alterations in the lacrimal film can foster the negative actions of chemical and infectious agents, with the onset of kerato-conjunctival disorders and severe asthenopia. Specific tests like stains, Schirmer's tear test, B.U.T., Mucus test, etc., defined 'ancillary' in ophthalmology, should be regularly adopted in ergophthalmology (Sugar 1994, Rheinstrom 1994, McDermot 1994, Cook 1999).

With regard to infectious diseases, everyday clinical practice seems to show the occurrence of external eye infection as being quite common. In addition, indoor environments may well provide substrates for fungal and bacterial growth. Besides this, no clear-cut research appears in the literature, which indicates these diseases as work-related. Nevertheless, it seems opportune to remark that both occupational physicians and general practitioners could easily misinterpret the symptomatology produced by these pathologies, due to its similarity to that of the typical occupational asthenopic syndrome. For these reasons, the tendency to prescribe antibiotic treatment in cases of bacterial and fungal kerato-conjunctivitis, without performing appropriate investigations, can make the diagnosis of a possible occupational etiology of these abnormalities in an exposed population, even more problematic.

5. Conceptual framework

The fundamental aim of ergophthalmology is to guarantee the well being and the efficiency of workers' visual functions for their entire working life. According to the literature, occupational alterations, disorders and disturbances of the visual apparatus are generally very non-specific and have a multifactorial origin. The current approach to the matter is strongly monodisciplinary (eye-checks by ophthalmologists, illumination by engineers or architects, chemical pollution by occupational hygienists, etc.) and seems neither scientifically adequate nor effective in safeguarding workers' health.

It is therefore necessary to look at the topic of 'work and vision' holistically. This would foster the development of interdisciplinary investigations where environment and work tasks (exposure) and individual psychological and physiopathological characteristics are evaluated as a whole. A conceptual framework for understanding the relationships between 'work and vision' is proposed in figure 2. Even though these relationships have not been thoroughly investigated, a huge amount of data is available, which should permit reliable risk assessment to be carried out and effective primary and secondary measures to be taken.

Armed with this knowledge, rational decisions could be made and every-day practice in ergophthalmology could be substantially improved.

In this regard there must be objective consideration of the following aspects.

5.1. *Exposure evaluation*

Crude job description and lack of objective measurements are unfortunately quite common in ergophthalmology. Due to the fact that the prevalence of ophthalmic injuries/diseases in the general population is high, an accurate evaluation of their possible link with work is strongly recommended. There are three underlying determinants:

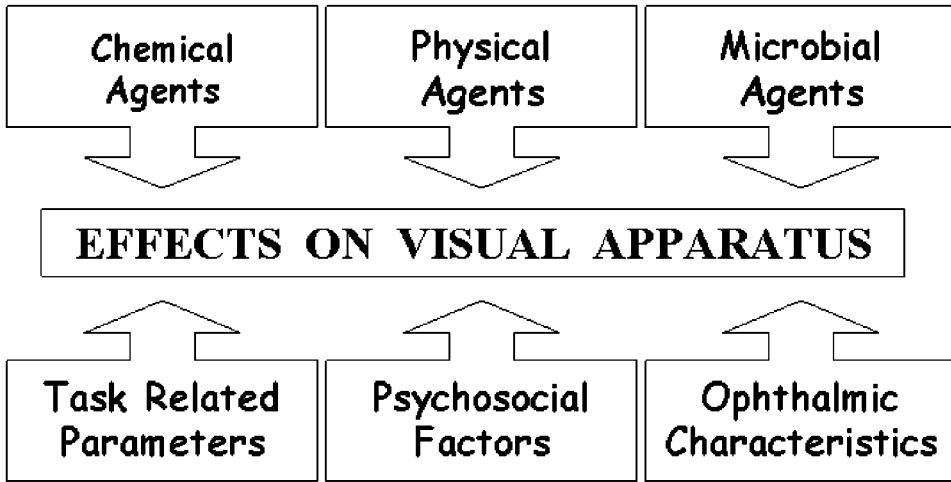


Figure 2. Relationship between work and effects on the visual apparatus: the conceptual framework. Author: Bruno Piccoli *et al.*

- (a) task duration (not merely self reported);
- (b) average observation distance (referred to a well-defined period);
- (c) environmental agents (effective to the ocular surface).

5.2. Health surveillance

This must be implemented according to the data obtained from the exposure evaluation and following ILO Guidelines recommendations (International Labour Office 1997). Among others, three prerequisites appear to be essential:

- (1) eye examination should be strictly relevant to the assessed risk;
- (2) appropriate tests should be selected in order to detect early signs and symptoms;
- (3) job-fitness should be provided.

The ICOH Scientific Committee on 'Work and Vision' is seeking to systematically develop this conceptual framework, yielding a more rational and complete approach to the relationships between work and vision. This hopefully will assist in risk assessment and to a cost-effective optimization of work situations.

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