SOME THOUGHTS CONCERNING THE PHYSIOLOGICAL-PSYCHOLOGICAL ASPECTS OF LIGHTING FOR WORK

QUELQUES IDÉES CONCERNANT LES ASPECTS PHYSIOLOGIQUES--PSYCHIQUES DE L'ILLUMINATION POUR LA TRAVAILLE

EINIGE GEDANKEN BEZÜGLICH DER PHYSIOLOGISCH-PSYCHISHEN ASPEKTE DER ARBEITSPLATZBELEUCHTUNG

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SUMMARY
On the basis of the Recommendation ISO 8995-1989 "Principles of visual ergonomics. The lighting of indoor working systems" a review of further, mainly subjective factors is given, which affect the individual evaluation of a lighting installation. Some of them - such as non-visual effects of optical radiation - are treated in more detail and some efforts to create UV-safe lighting are shown. As a final conclusion the question of establishing reasonable tolerances of lighting evaluation affected by subjective judgments are raised and some suggestions for further studies and education are given.

RÉSUMÉ
Sur la base de la Recommendation ISO 8995-1989 "Principes d'ergonomie visuelle - L'éclairage des systemes de travail interieur" quelques facteurs complementaires, plus ou moins subjectifs son traiteés, quels exigent un effet sur l'évaluation individuelle d'une installation d'éclairage. Quelques effets - comme les effets non-visuels du rayonnement optique - sont traité en detail et quelques efforts pour le developement des lampes sures de l'ultraviolet sont montré. Comme conclusion finale on met la question, comment on peut établir des tolerances resonables pour l'évaluation d'une installation d'éclairage, quand cette évaluation est affecté fortement par des jugements subjectifs. Finalement quelques études complementaires et élargissement du l'enseignement sont proposées.

ZUSAMMENFASSUNG
Auf der Basis der Empfehlung ISO 8995-1989 "Grundlagen der visuellen Ergonomie. Beleuchtung von Innenraum-Arbeits-plätzen" werden weitere, hauptsächlich subjektive Faktoren im Überblick behandelt, welche die individuelle Beurteilung einer Beleuchtungsanlage beeinflussen. Einige derselben - wie zum Beispiel nichtvisuelle Wirkungen der optischen Strahlung - werden ausführlich behandelt und es werden Bestrebungen um eine UV-freie Beleuchtung zu schaffen dargestellt. Als Endfolgerung wird die Frage gestellt, auf welcher Weise die Tolerazen der von subjektiven Urteilen beeinflusste Beurteilung einer Beleuchtungsanlage festgelegt werden können. Weiterhin werden weitere Untersuchungen und die Erweiterung der Bildung angeregt.

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INTRODUCTION

"Tempora mutantur et nos mutamur in illis"

We are living in a changing, even rapidly changing world. According to the proverb - even the ancient romans knew, that the changing time changes people as well. The economic and cultural development in time and space (age, and geographical location) brought fundamental changes in the behavior and needs of man. Similar thoughts of many specialists show, that the needs of man as an individual must be more frequently taken into account in the future [1].

Tasks of lighting become more and more complex "It seems necessary to spend less time on just lighting, and more time on interaction of lighting and the individual". (M.Rea)

Many scientists and specialists are dealing with illuminating engineering as an exact discipline and results of this work make it possible to create standards and recommendations, which give the technical requirements of lighting installations.

However, it raises the question whether all these exact requirements and principles, are sufficient for establishing a satisfactory lighting installation. In what proportion are objective and subjective judgments dominating in the evaluation of such an installation?

It is well known that man views the world through his feelings towards his surroundings and time; but the picture that one captures is motivated by his subjective self. Subjective judgement affected by facts relating to components are summarized in Figure 1.

At the same time the lighting technology uses other technological fields in conjunction with its own, to answer in an objective and subjective direction, which is outlined by Figure 2.

This lecture intends to evoke further thoughts drawing attention to these questions, putting emphasis on the fact that a lot of research has to be done in depth on these topics.

Division 3 of the CIE (Commission Internationale de l'Éclairage) - emphasizing the importance of similar questions - established several technical committees dealing with questions touched in our discussion, such as:

- TC 3-04 Subjective response to lighting and shading control systems - Chaired by T. McGowan(USA)
- TC 3-05 Industrial lighting and safety of work Chaired by H.J. Hentschel (D)
- TC 3-16 Psychological aspects of lighting (review committee) - Chaired by Mme M.J. Cabrol (F)
- TC 3-23 Variability in interior luminous environment Chaired by Mme P. Chauvel (F)

PARAMETERS INFLUENCING THE WORKERS PERFORMANCE

Nowadays the lighting in the work-place, - or in general lighting - incorporates in addition to the realization of adequate seeing conditions, the requirements of "seeing comfort", "well being", as well as safety in a very wide scope.

The term "comfort" means the physical and physiological equilibrium of the individual and "well being" the psychological equilibrium of the individual. Pronouncing the very subjective character of these parameters, we intend to direct the attention onto some factors, which need further investigation.

In Fig. 3. the ISO 8995-1989-10-01 Recommendation "Principles of visual ergonomy. The lighting of indoor work systems" summarizes the most important factors influencing the work efficiency in our visual environment. [2] These factors may be considered as objective ones, which may be determined definitely, calculated and controlled by measurements.

Completing this figure - some subjective aspects may be set against the objective factors acting in the same field. Fig.4. shows these subjective factors.

Because of our limited possibilities most of them can only be mentioned and only a few of them can be explained in detail.

The task attributes were considered to be objective factors, therefore we do not deal with them.

The Workers Characteristics

Among the workers characteristics, one can find some subjective factors, which may have a minor influence on the judgment of the lighting installation and the visual environment. Some of them are:

- Health conditions (hypertonia, meteorological sensitivity etc.). They can result in temporal change of the visual performance and lighting needs
- Mental conditions, mood (motivation)
- Effect of spectral distribution, correlated colour temperature of light, colours in the environment (some colours may produce nausea in pregnant women; colours affect heat impression of the environment; cool colours at low illumination levels may cause fear; warm colours raise the"good will" of workers [3]
- Economic and cultural level (welfare) Advantageous economic conditions assure the installation of higher quality lighting, but this results in the increase of demands as well. Social and cultural levels have similar results.

Lighting Characteristics

In the judgment of the lighting characteristics the "lighting climate"has an important influence.

The "lighting climate" is considered as a summarized effect of physiological and physical effects evoked by a certain lighting installation. Some further subjective judgements were made such as:

- Illuminance demands varying during the day
- Adequate choice of colour (colour temperature)
  Sodium light may raise viewing acuity [4] for small size task objects
- Adverse effects of light (line spectra, blue light hazard) [5,6]
- Beneficial effects of light (SAD, jet lag curing) [7.8]
- Adverse effects of the lighting installation

A reoccurring question is the harmfulness of the lighting installation. Mostly installations with fluorescent lamps are claimed to cause ocular complaints, hormonal disorder, skin cancer etc. Recently similar complaints arrived concerning sodium light and desk-top luminaries with halogen incandescent lamps. Most of the ocular complaints are in connection with the non-adequate outline of the lighting network (single-phase operation) or direct and indirect glare, which can be limited with correct design. Electronic ballasts will eliminate the flickering.

The adverse radiations at indoor work-illuminance levels lie below the values allowed by safety regulations [5,9,10,11,12,13,14]. The long time effects of lighting with various kinds of discharge lamps need further investigation. Until now the evidence of adverse chronic effects could no be verified nor refuted.

Work Space Variables

The work space variables may be affected mainly by the subjective judgment of the working climate [15].

Factors acting in addition may be the non-visual ones, like attention, which is one of the psychological functions determining the process of recognition.

Such a component may be fear. It is well known, that light phenomena of a tempest may be frightening for some people, while others enjoy the beauty and power of the sky. Lighting with high correlated colour temperature and low illuminance may induce fear. Light may also calm and give the feeling of safety - and it is also possible to play with light. Light is a tool which affects our mood and also has an influence on human behaviors. This influence affects on man as a system. The optical nerve conducts light not only to the visual field of the brain, but also to the central part, which controls the whole hormonal and physiological system [7]. For instance:
- lack of light may cause depression SAD
- well lit areas reduce criminality and stimulate to keep them clean.

The safety of the workspace is influenced by many factors, like contaminations in the atmosphere, heating-cooling, electrical insulation, outline of the network, mechanical factors and adequate lighting as well. One factor connected with artificial lighting is the safety of UV radiation.

UV SAFETY OF THE SOURCES

In the past century human activity affected the composition of the atmosphere and this resulted in the diminishing of the ozone layer.

That's why the importance of the reduction of the UV-content of artificial lighting is growing and the question of UV-free lamps was raised.

Only radiation absorbed by the body can have an effect on man. The affected organs are the covering layers - the skin and the eye. Some internal effects may be mediated by means of the blood circulating in the capillary blood-vessels of the skin.

Some acute effects of optical radiation are known from literature and some standards, and can be described with action spectra [5, 6, 16]. High levels of UV radiation may raise the risks of malignant tumors of the skin. The basic procedure of tumor-formation is in connection with distortion in the DNS, this effect may be studied in vitro, but the very complex procedure in vivo may be influenced by several other parameters.

A very special effect of UV-A present in indoor illuminating systems is the reduction of visual contrast caused by the fluorescence of the eye tissues [17]. A very high proportion of test persons preferred UV-free lamps for work lighting. This effect excludes even low amounts of UV-A radiation tolerated by safety regulations [18].

In general the safety regulations take into account an integrated action on the skin and on the eye.

Nowadays the safety standard established by IRPA (International Radiation Protection Association) published in 1991 [19], which agrees, mainly with the regulation of ACGIH (American Conference of Industrial Hygenists) [5.6] widely used as well - seems to be the most accepted one. The weighting function $S(\lambda)$ for spectrally composed sources may be seen on Fig.5.

The evaluation of the effective power E_{eff} of a broad band source should be calculated according to the formula

$$E_{eff} = \sum_i S(\lambda_i)\, E(\lambda_i)\Delta\lambda \qquad (1)$$

where $E(\lambda_i)$ is the radiant power of the source at the wavelength λ_i and $\Delta\lambda$ is the spectral bandwidth.

The total irradiance on the unprotected eye for 8 hours should not exceed 1.0 J/cm^2 in the wavelength range of 315-400 nm. The total effective irradiance on the unprotected skin for 8 hours should not exceed given values. 30 J/m^2 Supposing the validity of the reciprocity law, the permissible exposure time (PET) may be calculated [20]

$$PET = \frac{30\ J/m^2}{E_{eff}\ W/m^2} \quad \text{if } \lambda < 315 \text{ nm} \qquad (2)$$

These values are surpassed under geographical latitudes between 0-40° in summertime even in 5-10 minutes. Taking a sunbath, suncreening and eye protection is always necessary [21].

The standardizing body for light sources IEC-TC 34 (International Electrotechnical Committee) proposed to give PET values for 8 hour intervals and 1000 lux illuminance. For sources with high UV content, as metal halide lamps, or halogen incandescent lamps, protective filters may be used. The necessary transmittance of these filters may be calculated according to the formula

$$\tau < \frac{PET}{t} \cdot \frac{1000}{E} \qquad (3)$$

for irradiation times t in hours and illuminance E in lux [22, 23, 24].Recently the IEC proposed to characterize light sources with value E_{eff}/1000 lm [25].

The UV content of lamps can be reduced by using UV absorbing bulb materials. Some efforts were made in this direction for both glass and quartz bulb-materials. The spectral transmittances of such experimental materials may be seen on Fig. 6.

The calculated E_{eff} values using the IRPA weighting function are given in Table 1.

Table 1. E_{eff} m W/1000 lm of conventional and UV-free lamps

Lamp Type	UV free	Conventional	UV ratio
Compact fluorescent FD9W	0.14	26.0	$5.3\ 10^{-3}$
Metal halide lamp 4000K 150W	0.0253	62.202	$4.0\ 10^{-4}$

These UV-reduced lamps are useful for increasing the visual comfort, safety of the work-place and in addition they can be used in several other applications, where UV-sensitive objects are lit, like art galleries, show-cases, shop-windows etc. Similar reduction of the UV radiation of other types of light sources may be expected as well.

CONNECTIONS WITH LIGHTING TOLERANCES AND OTHER DISCIPLINES

Taking into account the previously mentioned viewpoints, some further considerations should be noted.

Lighting engineers are fighting with tooth and nail for every % increase of efficiency of their installation. The CIE is shortly going to establish a working group on tolerances for differences of calculated and measured values of illuminance levels [26]. These tolerances are intended to be international standards for indoor and outdoor design.

The goal of all efforts is definitely the satisfaction of all quantitative and qualitative requirements of visual needs. The calculating and measuring techniques nowadays are at our disposal to fulfill these requirements [27]. In spite of this, some subjective factors may have a much bigger influence on the satisfaction of individual needs, than these objective tolerances.

High accuracy in lighting with respect to efficiency and other lighting parameters is a rather relative thing. As a result the question may be raised, what amount of influence depends on objective and what on subjective factors.

In giving answers to these questions the computer simulation of lighting situations may be a valuable tool [28, 29] but previous subjective investigations cannot be avoided. Also there is a need to have more knowledge about the conformity of the subjective evaluation of real installations with their simulated model.

This raises the problem and directs thought evoking research toward looking for answers, which should help the illuminating engineers to fit their work to future needs.

These answers need further investigations - carried out together with doctors and psychologists - and depend strongly on the complex skills of illuminating engineers.

The study of viewpoints of the psychological and physiological aspects makes the lighting engineer in some extent less sure in his technical assessments. Considering the requirements, the needs and the possibilities, he has to answer some questions, which help the "humanization" of the environment.

In this field, which we have been dealing with for approximately two decades, and its main point - which is widely accepted - as one which is "considerate to man" and ensures a safe work-place. It is an accepted fact that the productivity of work is highly influenced by ones mood.

The "humanization" collective term covers a variety of questions and fields, one of which is also lighting! Another important fact , which nowadays is constantly spoken of, a "reaction" in short: the re-building of an individual`s working ability from day to day, in other words its reproduction.

Taking into consideration the above information, the following thoughts and questions were raised:

- To what extent is it possible to determine the characteristics of "lighting comfort" and how is it possible to incorporate these characteristics in the new lighting recommendations?
- Since the fulfillment of these comfort requirements needs a lot of expenses, what level of comfort should be recommended for different types of work?
- Our knowledge on the health effects of light changes, how should this knowledge be incorporated in the lighting recommendations? Is it possible in the present stage to finish the dispute around the harmfulness of certain types of lighting installations?
- What role does lighting play in the recreation in an individuals daily rebuilding of working productivity, in other words the daily work reproductability.

SUGGESTIONS

1. Considering the previous viewpoints, it seems to be reasonable to give preferences to individually adjustable lighting systems and to incorporate this into the new lighting standards, since systems of this type can give the highest level of individual satisfaction.

2. In the education of illuminating engineers it seems to be necessary to enlarge the field of their skills according to the points mentioned earlier.

3. Lighting recommendations should incorporate health regulations worked out together with doctors.

SYMBOLS USED IN THE TEXT

E_{eff}	effective power Watt
$S(\lambda_i)$	value of the spectral weighting function at wavelength
$E(\lambda_i)$	spectral radiant power of the source at wavelength Watt/nm
λ	wavelength nm
$\Delta\lambda$	bandwidth nm
PET	permissible exposure time hours
τ	transmittance of the UV-protecting filter
t	time of exposure hours
E	illuminance at the work place lux

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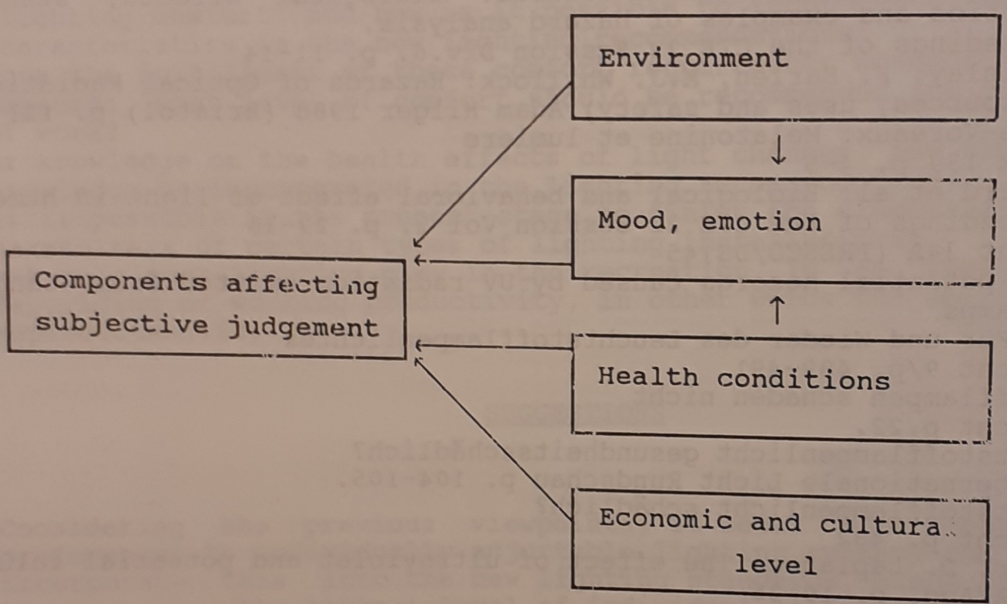

Fig.1. Components affecting subjective judgement

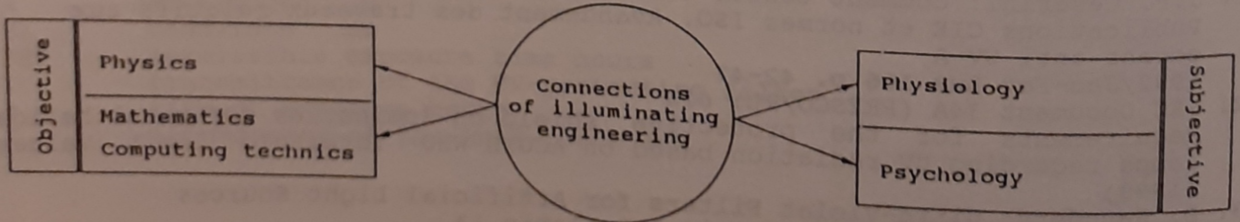

Fig.2. Connections of illuminating engineering

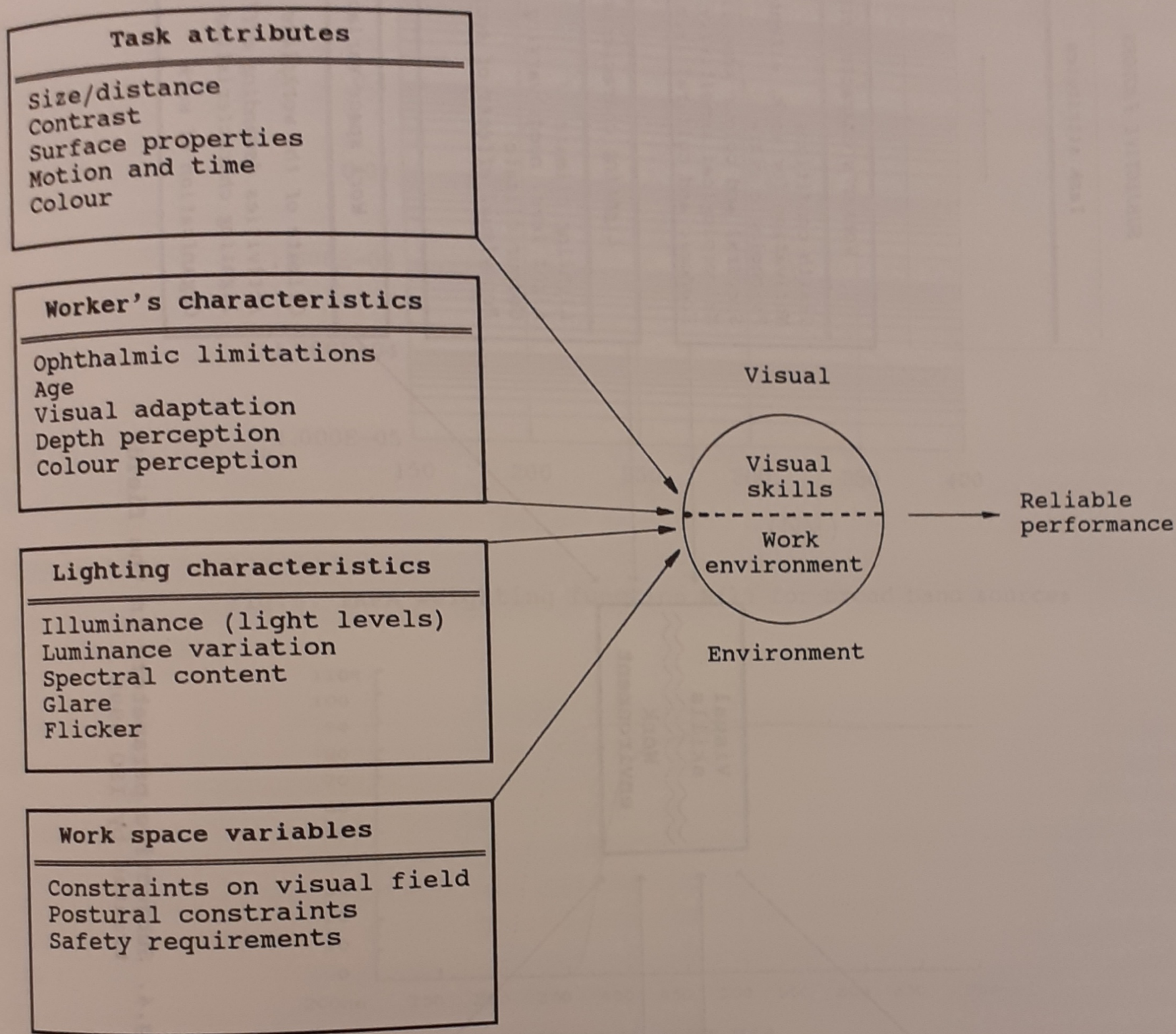

Fig.3. Major parameters influencing a worker's performance in the visual environment /From ISO 8995/

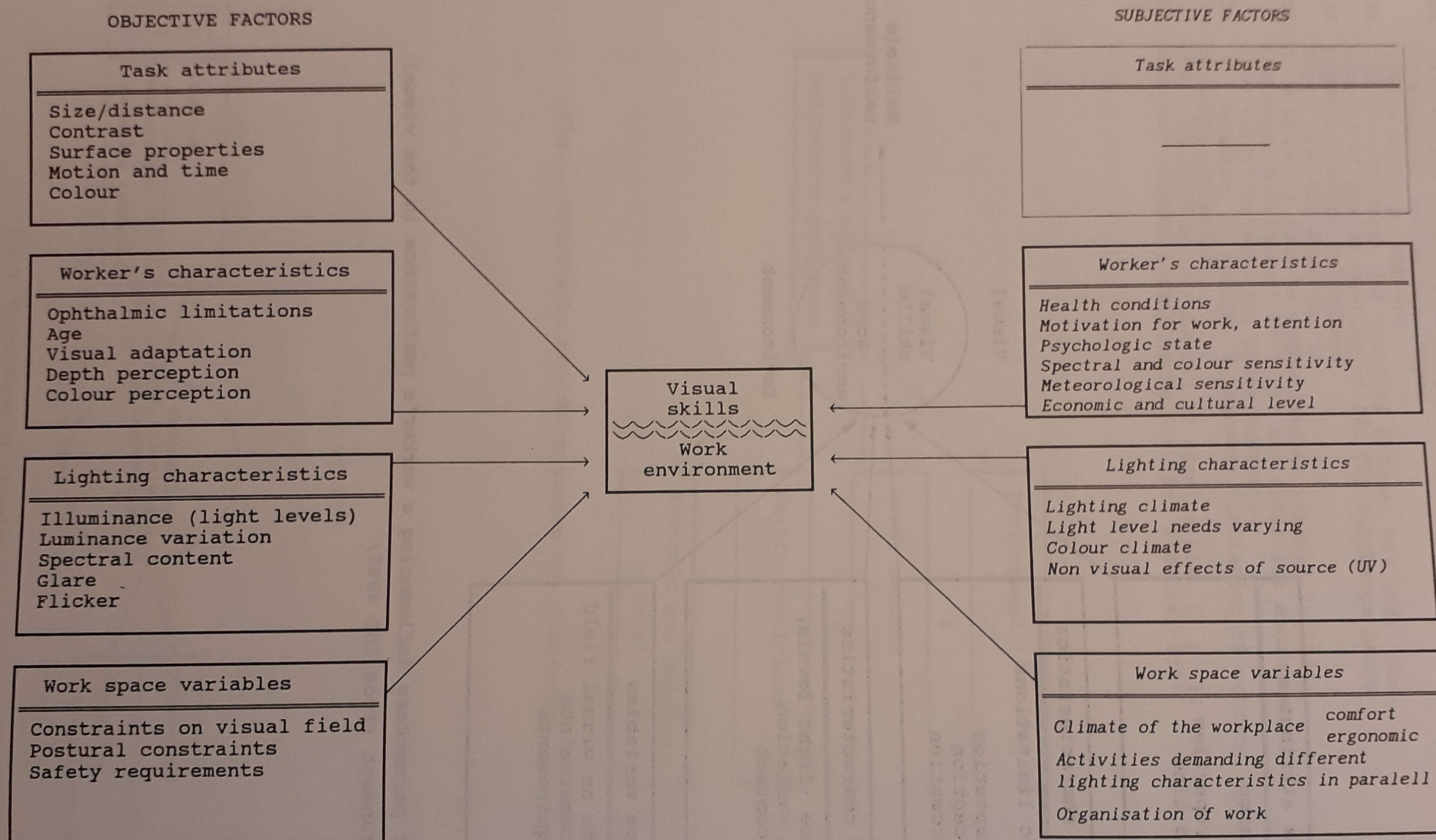

Fig.4. Subjective parameters in the fields treated by ISO 8995

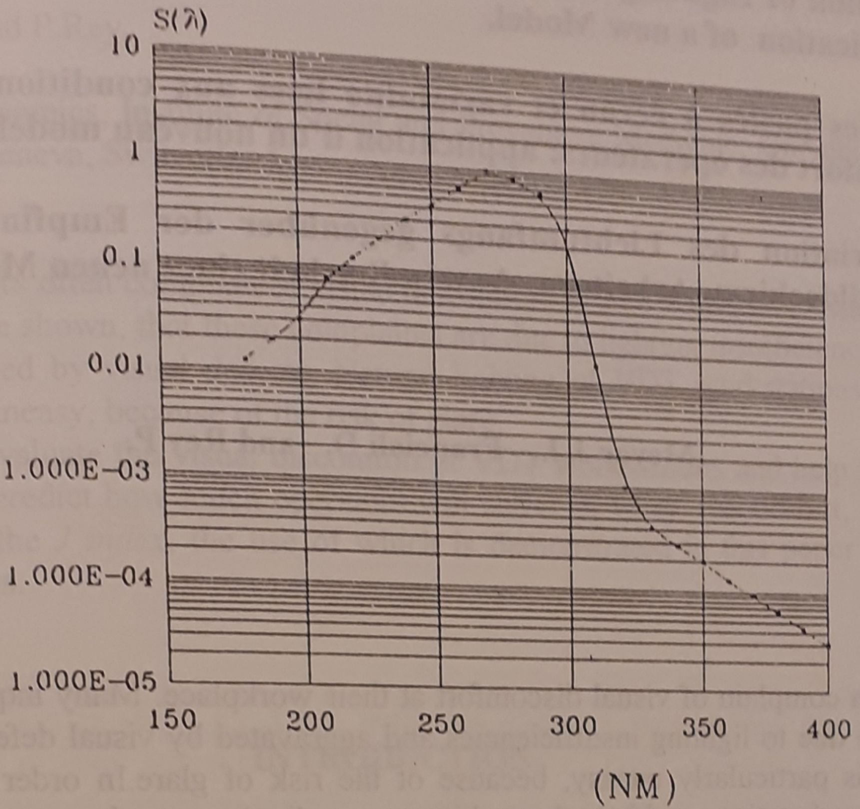

Fig.5. IRPA weighting function S(λ) for broad band sources

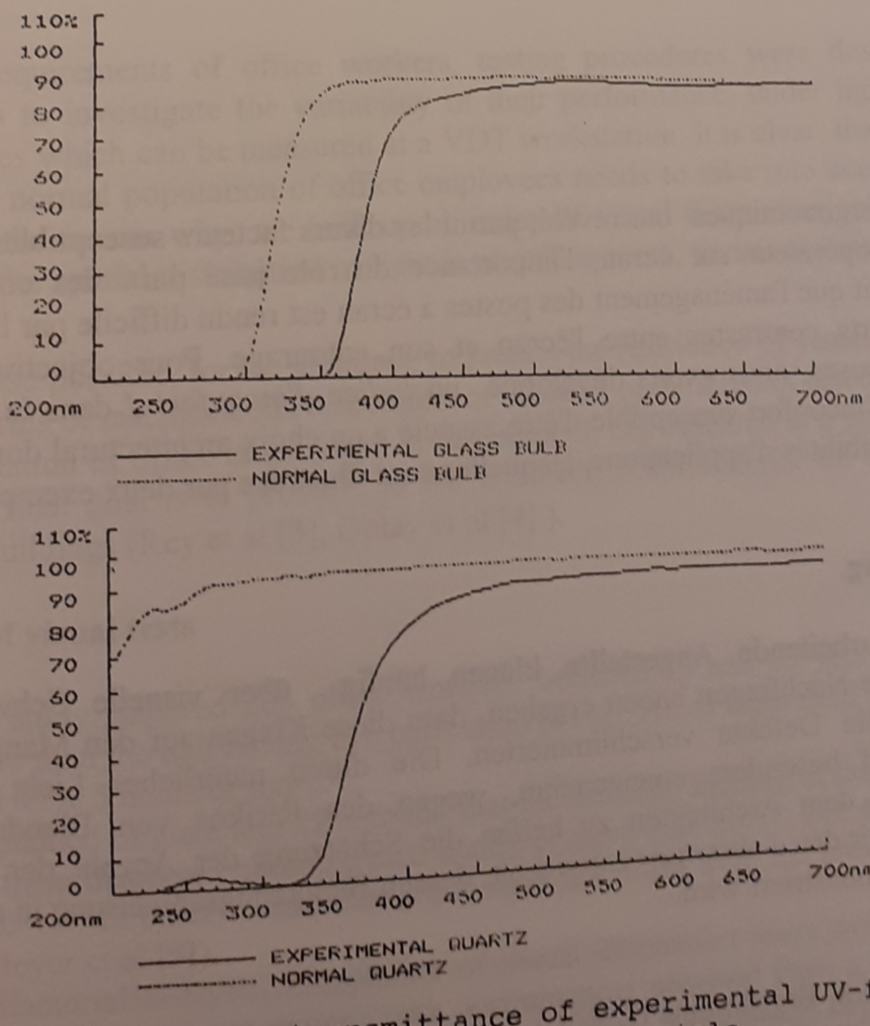

Fig.6. Spectral transmittance of experimental UV-free and conventional bulb materials