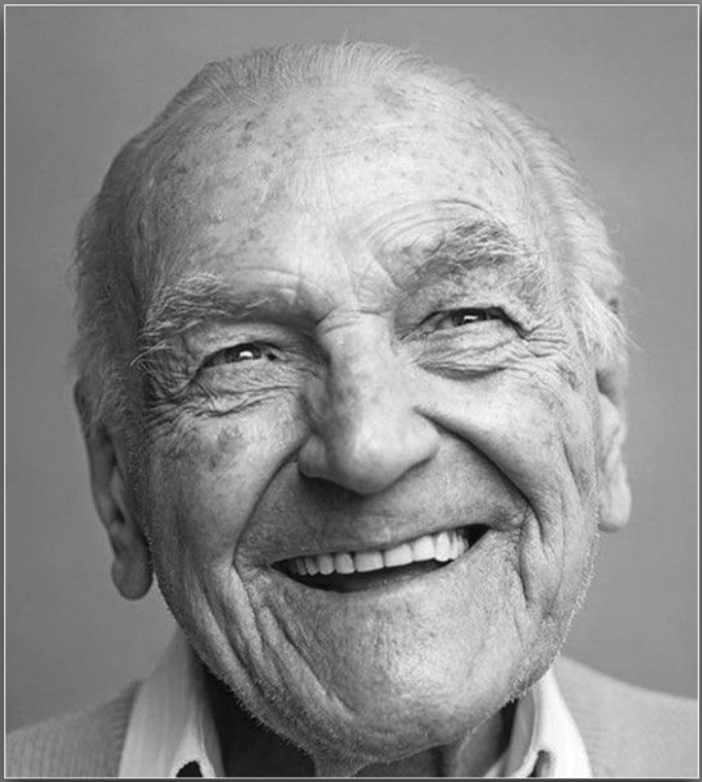


THROUGH THEIR EYES

Have you ever wondered
how older people see things?

Politecnico di Torino

Facoltà di Architettura

Corso di Laurea Magistrale: Costruzione Città

TESI DI LAUREA MAGISTRALE
MASTER THESIS

Relatori/Supervisor:

Prof.ssa/Prefessor: Pellegrino Anna

Prof.ssa/Professor Matusiak Barbara Szybinska

Candidati/Candidate:

Stud.ssa/ Student: Borra Francesca

Stud.ssa/ Student: Cane Laura

23 Dicembre 2015

Accessible and Lighting Design for Elderly and Visually Impaired People

Preface

When, a year and a half ago, we completed the class in : "*Physical and Technical Building Planning: Lighting Design*" at the Politecnico of Turin, we would never expect to succeed in fulfilling an experience as exciting and rich with emotions as the one recently completed.
Above all, what caught our attention was the lecturer's will in deepening the theme of daylight and its strong connection with the human being: the first step towards the decision for our master's thesis topic.
The second step came in talking with the Ophthalmologist Monica Dogliani, who made us aware about the existence of recent interdisciplinary cooperation between ophthalmologists, opticians and architects to find out methods able to support the development of a new design, (*mainly from a Lighting Design point of view*) aimed at improving the accessibility in both private and public environments for visually impaired people.
Soon after this conversation we got informed and, last October in Milan, we took part in the Eyecare Workshop and in the National Congress of Low Vision where there were also, in addition to doctors working in that specific field, Francesco Iannone and Serena Tellini, Architects from their *Consuline Study*. Thanks to their enormous enthusiasm showed about that topic during the Convention, the development of our thesis concept came almost naturally.
The topic reached a turning point when we decided to focus our attention more specifically on the elderly visually impaired people and not on visually impaired people in general; the choice was partly driven by the current European situation: given the increasing size of the older adult population (*over 60*) in many countries, there is a pressing need to identify the nature of age-related vision impairments, their underlying mechanisms and how they impact on older adults performance of everyday visual tasks. The design that takes care for those people with special needs is called Accessible Design or "Accessibility".
Thanks to our lecturer, we had also the chance to develop our topic at the Norwegian University of Science and Technology in Trondheim (*Norway*) between March and August 2015. To deal with a deeply different reality than the Italian one and having access to previous studies in this specific field combined with a wide bibliography, increased our personal interest and enthusiasm even more.
This search ranges from theoretical fundamentals to applications. There have been a large number of interesting developments in our understanding of how lighting and people interact.
We started from an analysis of this new social class and of the visual degenerative diseases that may be affected; it was crucial to know more about the needs of elderly visually impaired people and in which ways solutions could be reached in a different social and spatial milieu and at the same time the European Legislation with its standards and different Guidelines on these issues were taken into account.
The Theory of Color was subsequently analyzed, some visual functions such as the color

discrimination, daylighting devices, different artificial light sources to then conclude with our experimental part. In application, it had been possible to develop full-scale prototypes of the residential environment and to test the different daylighting and artificial light devices designed in our experiments.
The readers who expect to find exceptional design projects in this search, or ready-made technical solutions to be easily applied, will surely be disappointed; the results reached match that precise lighting and climate condition in that specific year's period. Unfortunately it was not possible to investigate, from an experimental point of view, even the LED technology, not being available in the laboratory.
The central purpose of this study is to contribute to our knowledge of this Accessible Design in a way that can be supported by the knowledge of the situation and by the experience and expectations of those who are affected by visual impairments. To fully achieve this aim and to help them to better perform their home daily tasks it is necessary to understand their particular needs and problems arising from the reduction or absence of vision.

Index

SECTION I *The Aging Eye*

"The design of every environment, private and public, is affected by the aging population."

[Giovanna Borasi e Mirko Zardini, Imperfect Health, CCA Montreal, 2012]

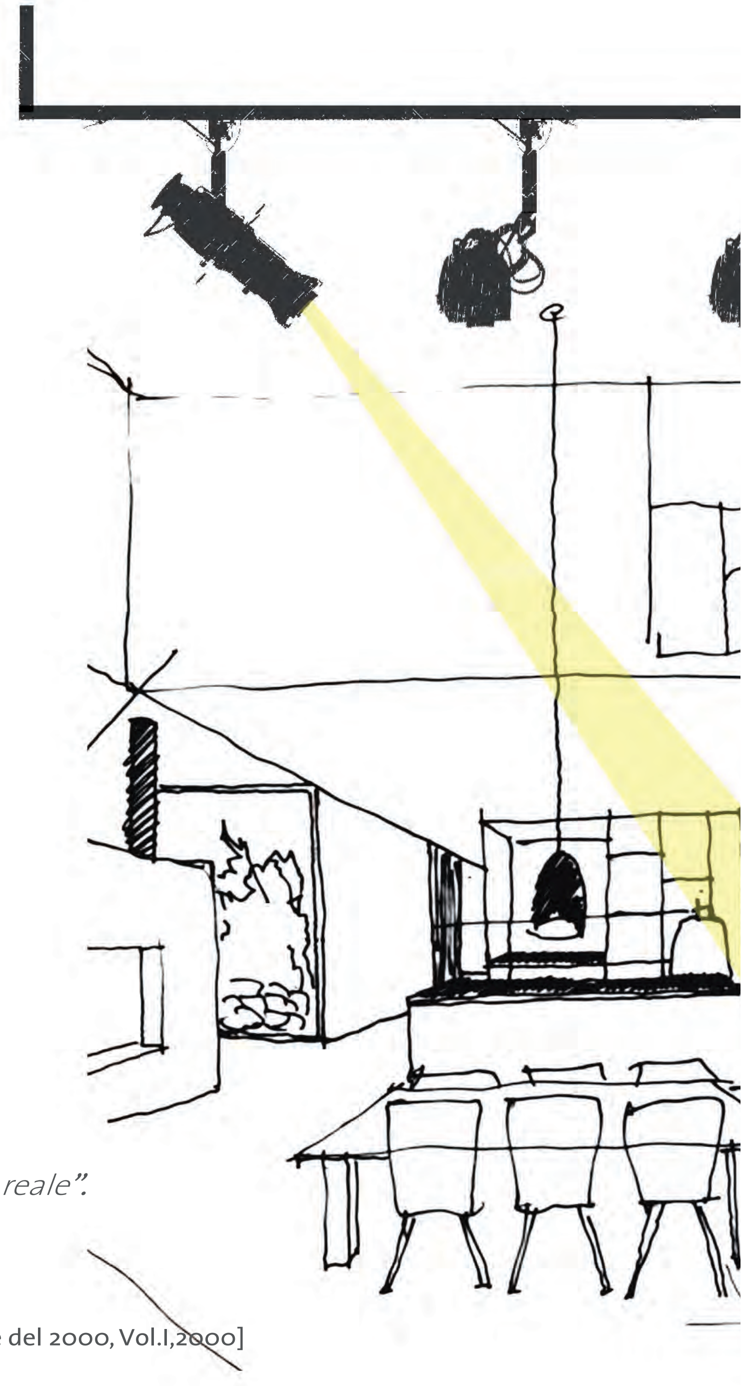
SECTION 2 *Understanding Light and its interaction with Humans*

"Not just see, you have to see well"
[Lucia R.Ronchi, Visione e Illuminazione alle soglie del 2000, Vol.I,2000]

SECTION 3 *Full-Scale Study in a Room Laboratory*

"If I can't see it's not just my eye fault"
[Lucia Baracco et al, Questione di Leggibilità, Progetto lettura Agevolata, Venezia, 2005]

Chapter 7



“Si tratta di considerare come una scenografia anche il mondo reale”.
“It comes to considered as a scenic design also the real world”.

[Lucia R.Ronchi, Visione e Illuminazione alle soglie del 2000, Vol.I,2000]

Introduction

Often, it is only when we cannot do something that we realize how important all the elements involved in our actions are. Since we strive to attain a very high level of control of our environment in accordance with our human needs, we tend to assume that environmental factors would not restrict our individual abilities and actions. In order to obtain this purpose, today we are getting more and more relevant systems capable of providing variable lighting scenarios according to the physical design, use and function and to the natural light contribution in it. While the computerization of the scenic lighting design has by now reached an advanced level, the indoor lighting unfortunately still requires serious in depth search. What should still be done:

- to understand how lighting, comfort, pleasantness, productivity are related to each other;
- to understand how we could go beyond the prescription given by the standards;
- to point out the visual performance standards.

However, if on one side Lucia R. Ronchi says we should take into consideration also the real world as a stage set, where each single light source is carefully calibrated and oriented to give the right value to the actors and to the scene's setting at that specific moment on the stage. On the other side, there are those who, in lighting planning, choose to limit themselves by indicating the base illuminance level with reference to the engineering and energy codes[1].

1 Lucia R.Ronchi , Visione e Illuminazione alle soglie, Vol. I, 2000

Today what arises with vehemence is the need to relate, in terms of lighting, how the individual reacts and behaves outside the laboratory, in the real world. The average observer seems to have run its course, now the human being is no longer a passive receiver of lighting technologies but is the integral part of the illumination system. Individual variability creates inconvenience, especially in aging population, but exists and it does not seem that can be removed by mere statistical procedures.

As regard the topic of the thesis, to design a quality lighting environment, researches on vision and aging are essential for several reasons: the percentage of the population over 60 is increasing in the U.S. and many other European countries; thus eye conditions, diseases, and vision impairments associated with aging represent a larger segment of our societal health challenge on a population basis than in previous decades. Thus, there is a pressing need to identify the prevalence and incidence of various age-related vision impairments in populations, the mechanisms underlying these impairments, and how they impact on older adults performance of everyday visual tasks.
It is known that as people age, a number of changes in the eye occur. With increasing years, the ability to focus close up is diminished; the amount of light reaching the retina is reduced and more scattered. These changes start in early adulthood and increase in form and magnitude with increasing age. The consequences of these changes with age for the capabilities of the visual system are many and varied: reduced sensitivity to light, reduced visual acuity, reduced contrast sensitivity, reduced color discrimination and greater sensitivity to glare. Thus, outside the laboratory the elderly have difficulty with seeing in dim light, moving from bright to dark conditions suddenly, reading small print and distinguishing dark colors. It can be inferred that a subject age 65 benefits more from higher illuminance than does a younger person and a subject age 80 benefits even more than does a subject age 65. Vision loss in old age can be defined as a state that falls between normal vision and blindness. Globally, the five most common causes of vision loss are: cataracts, macular degeneration, glaucoma, diabetic retinopathy and refractive errors.
From the designer's point of view, a quality lighting environment should be planned to optimize the person-in-environment system; understanding the effects of illumination on people can assist him/her in fulfilling the purpose of the environment itself.

The study carried out at NTNU (*Norges teknisk-naturvitenskapelige universitet, Trondheim(Norway)*)started from fairly wide international literature that deals with this topic in several aspects; it should be stressed that given the recent development of this subject, the literature consists of a wide number of specific scientific papers while there are very few publications dealing with the topic in a comprehensive way and from the lighting design point of view.
As regard the scientific papers, The International Commission on Illumination - also known as the CIE from its French title, the Commission Internationale de l´Eclairage[2] - articles are

2 With strong technical, scientific and cultural foundations, the CIE is an independent, non-profit organization which, in 1913, has become a professional organization and has been accepted as representing the best authority on the subject and as such is recognized by ISO as an international standardization body.

devoted to a worldwide cooperation and to the exchange of information on all matters relating to the science and art of light and lighting, colour and vision, setting great significance on the notion of lighting quality, as well as visual performance and including among the designer's duties those to satisfy human, architectonic and energy saving needs.
These articles were crucial to acquire more awareness and sensitivity on issues such as: user satisfaction with different lighting concepts, discomfort glare, measurement of naturalness, quantification of age effects on contrast and glare perception under daylight conditions, brightness perception, etc.
As regard the application, the projects: *Assisted Reading* of the City of Venice and two experiments previously carried out at NTNU under the guide of Barbara Matusiak: *Daylighting/lighting preferences for subjects with visual impairments and for subjects with normal vision and Aesthetic perception of a small office with different daylighting systems*, were essential in helping us to understand how to plan an experiment from the beginning to the end and to see how far they had gone to try to go even further and make new discoveries.
In all the sources examined (theoretical and experimental) were very clear issues to be investigated for Accessible Design in light and lighting field: Visible contrast, conspicuous colour combination, legible font size, useful visual field, avoidance of glare, care for low vision, etc.

However, the studies listed above, also in line to what happens in the legislative field, are mainly addressed for the work environment. Hence our question is: *Is it possible, through a careful natural and artificial lighting design, safeguard the same accessibility both for normal and visually impaired people in daily home tasks performance(cooking, reading, take medicines, watching tv, etc.)*?

We tried to answer this question in a whole and comprehensive way to organizing our study into three main sections:

Section I- Puts the problem in a more general context of design, European legislation and disability; It also introduces the visual diseases and the daily barriers encountered by visually impaired people in private environments;

Section II- Tries to explains how an understanding of a complex problem can be reached by working with concrete design situations, discussing the relations between design cases and Design Theory. It also introduces the studied knowledge about spatial perception from various fields, which was necessary to support the understanding of the problem.

Section III- The section starts with a detailed description of the location, situating the main needs and problems related to the accessibility of visually impaired individuals. Conclusions are reached through the reflection and interweaving of the theoretical knowledge (*in depth in Section I and II*) with the results obtained in the experimental part. The research consists of four experiments carefully designed and described one by one:

-Experiment 1: Pick out a book from the library.
Main topics analyzed: user satisfaction with different lighting concepts, Visible contrast, conspicuous colour combination;

-Experiment 2: Reading
Main topics analyzed: measurement of naturalness, quantification of age effects on contrast and glare perception under daylight conditions, legible font size;

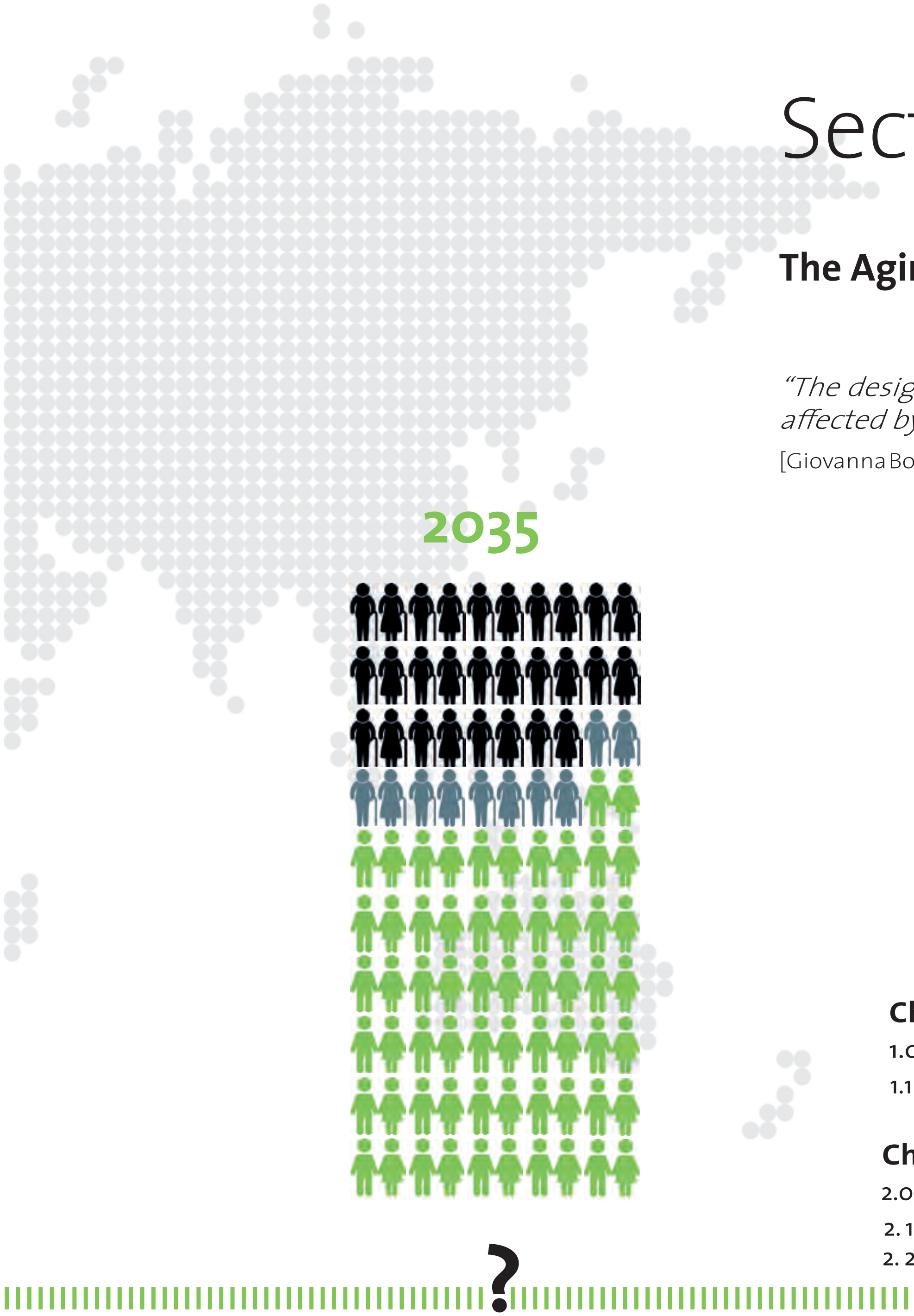
-Experiment 3: Object Recognition
Main topics analyzed: avoidance of glare, accessibility in home daily tasks performance, users satisfaction with different lighting concepts;

-Experiment 4: Watching TV
Main topics analyzed: users satisfaction with different lighting concepts, visual comfort, brightness perception.

To conclude, to the question: what is quality lighting? It stand out from the study that **Quality Lighting** allows users to simultaneously function comfortably in a space, feel safe and appreciate the aesthetic components of the interior. Environments with quality lighting are specifically designed for the client, users, architectural features, site and location. These environments reflect a skillful application of the principles of design by integrating and layering light into the entire composition. Layered lighting includes natural light and multiple electrical light sources and has to be provided in such a way that both disability and discomfort glare are carefully controlled and veiling reflections are avoided. Following this advices should lead to improvements in visual function for the elderly and for many people with vision loss without causing problems for young people.

Europeans
over 65

17.4% **28%**

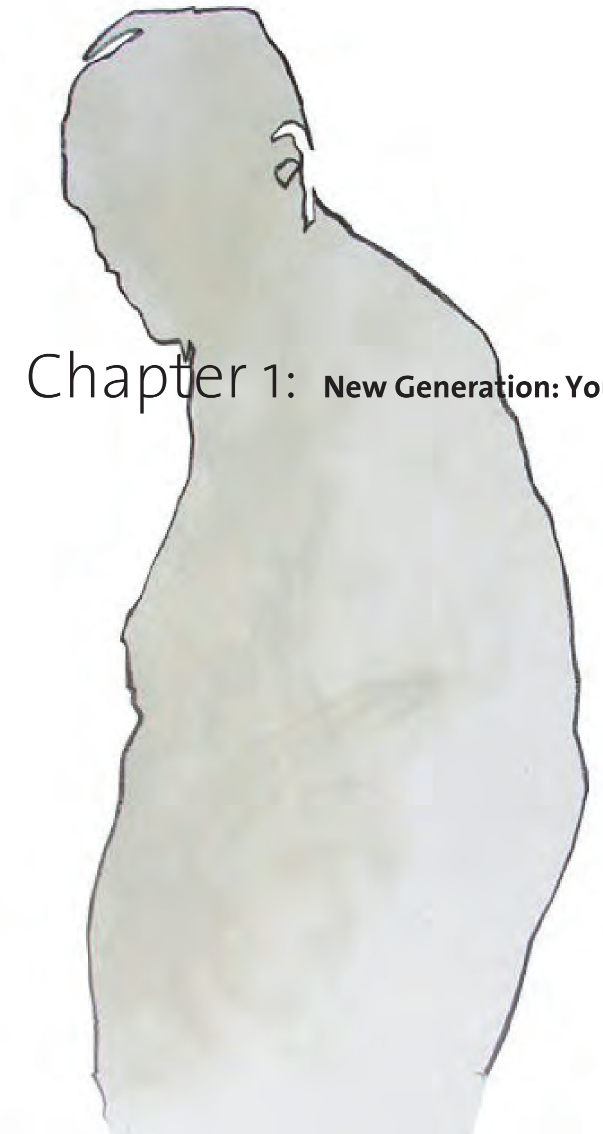


Section I

The Aging Eye

"The design of every environment, private and public, is affected by the aging population."

[Giovanna Borasi e Mirko Zardini, Imperfect Health, CCA Montreal, 2012]



Chapter 1: **New Generation: Young Old**

The second half of the twentieth century witnessed the unprecedented rise of the socio-demographic group known as "Third Age" or "Young Old"[3] .
In 1974, the American gerontologist *Bernice Neugarten*[4] coined the term Young Old to describe a theory of differentiated old age. The Third Age refers both to a historical moment and a phase of life. As a historical moment, it is characterized by the coincidence of the demographics extended longevity and the domination of retirement as an institution. As a phase of life, the category Third Age distinguishes between at least two different types of older persons that emerged in the post-war period: the traditional notion of "old-age" bifurcated into the ailing and dependent Old-Old (*Fourth-Age*) and a new and rapidly expanding population of healthy and independent

3 Giovanna Borasi, Mirko Zardini, Imperfect Health, CCA Montreal, 2012
4 Bernice Neugarten (born Bernice Levin; February 11, 1916 – July 22, 2001) was an American psychologist who specialised in adult development and the psychology of ageing. She was president of The Gerontological Society of America starting in 1969.
http://www.nytimes.com/2001/07/30/us/dr-bernice-l-neugarten-85-early-authority-on-the-elderly.html

Young-Old (*Third Age*).
At present, 17.4% of all Europeans are aged 65 and older. In 2020, the share of those over age 65 will rise to 28% (*COM 2011*)[5] . Accordingly, within the European Member States, a growing number of older people stand in contrast to a declining number of younger people who are able to care for the elderly to a lesser extent. Furthermore, the number of single elderly persons and single-person households will increase even more.
In the ten-year growth strategy Europe 2020 approved in June 2010 (*COM 2010$_a$*)[6] , ageing population is described both as a challenge and an opportunity for smart, sustainable and inclusive growth.
In fact the Third Age, as it has been defined before, is also characterized as a period of "*late freedom*", the "*golden years*" *of adulthood*: generally defined as the span of time between retirement and the beginning of age-imposed physical, emotional, and cognitive limitations; today would roughly fall between the ages of 65 and 80+. This is a period of adulthood when typically there are fewer responsibilities (*e.g., career and family-rearing*) than before and, when coupled with adequate financial resources and good physical and psychological health, offers rich possibilities for self-fulfillment, purposeful engagement, and completion.
For some adults, indeed an increasing number of single elderly persons and single-person households, there can be many positive outcomes related to aging, many of which are explicit during the Third Age: these include relative good health and social engagement. At the same time, declines in effortful and resource-intensive cognitive processing are clearly detectable for nearly all adults, despite being launched much earlier in the lifespan.
Moreover, Third Age is relatively new to human history and as a result there is little social understanding about it. It could be said that it looks like a paradox [7]: a point in chronological time when adults experience life and self more positively while some basic cognitive functions continue to undergo slow deterioration. It is a period of divergent trajectories: life management, and improvement in the areas of identity, self-esteem, emotional stability and regulation, emotional experience and subjective well-being; on the other side, declines in effortful and resource-intensive cognitive processing, vision loss, stabilization of autonomic cognitive processes (*e.g., attention and some types of memory function*), word knowledge, expert knowledge.

5 European Commission, COM(2011) 594 final, Brussels, 28.9.2011
6 European Commission, COM(2010) 748 final, Brussels, 14.12.2010
7 Neugarten, B. L. (1986). Our Aging Society: paradox and promise. (pp. 33–53). New York: Carnegie Corporation.

Current Living situation of the elderly in Europe

In the last decades, these processes have begun to change the housing market, requiring new forms of house to be developed: today design in general, seems to be affected by such anxieties and diseases too. In addition, aging at home has become viable thanks to the assistance of technologies including communications systems, home safety and security; as a consequence, the integration of services and structures for the elderly has become a major concern for architects and planners, especially in Europe. In recent years in fact, an increasing number of elderly intend to purchase a new home for retirement: this is because the majority of the elderly people want to remain in their familiar environment and to live as independently as possible – even in the case they need assistance and care[8].
In general, the willingness to leave familiar surroundings declines significantly in old age and, as a consequence, while older people spend more time in their homes with increasing age and health limitations, the age appropriateness (*location, furnishing*) of the living situation and age-appropriate design of the residential environment become more and more unsuitable in maintaining independence and quality of life.
The living situation of elderly people in the EU in 2006/2007, as reported by the *Statistical Office of the European Union (Eurostat)* and of the international survey project SHARE[9] , highlighted that the majority

8 Sabrina Stula, Living in Old Age in Europe - Current Developments and Challenges, Working Paper No. 7 of the Observatory for Sociopolitical Developments in Europe, June 2012.
9 Survey of Health, Ageing and Retirement in Europe (SHARE) is a repre-

of people aged 65 and older lived alone (31.1%) or as a couple (48.3%). In 2009, approximately nine of ten persons aged 65 and above in *Germany, France, Finland and the United Kingdom* lived independently in their own home. By contrast, this share was especially low in *Cyprus, Spain, Portugal and Estonia* where elderly people more often lived in common households together with their children. Today the situation is even more alarming.

A study[10] of the development of age-appropriate forms of housing in 13 European countries from 2007 reached the conclusion that only one percent of all residences in Europe are barrier-free or have been adapted to the needs of elderly people. According to this study, the greatest successes in the adaptation of individual living space may be observed in the Netherlands, the United Kingdom and Belgium with shares of between two and five percent.

sentative study of the population aged 55 and older, by means of which changes in the economic, health and social situation are monitored for more than 55,000 elderly residents in 20 European countries. The results used here are from the second round of the survey 2006/2007 in 14 European countries and Israel (Angelini/Laferrère 2008, Kohli et al. 2008).

10 Sabrina Stula, Living in Old Age in Europe - Current Developments and Challenges, Working Paper No. 7 of the Observatory for Sociopolitical Developments in Europe, June 2012.

Universal Design/Design for All	Belgium	Denmark	Germany	Hungary	Ireland	Luxembourg	Netherlands	Norway	Poland	Portugal	Spain
Primary policy headline	Universal Design	Accessibility for All	Barrier-free design	Universal Design	Universal Design	Accessible design	Design for All	Universal Design	Design for All	Design for All	Universal Access, Accessibility
Other policy headlines		Design for All, Universal Design			Accessibility for All		Inclusive Policy, Accessibility, Usability		Accessibility for All		Equal Opportunities, Non-discrimination
UD/DFA on the political agenda	Yes	Yes	Yes*	Yes	Yes	Yes*	Partly	Yes	Yes	Yes	Yes*
National UD/DFA plan	No	No	Yes*	Partly	Yes	Yes*	No	Yes	Yes	No	Yes*
Legislation on UD/DFA	No	Partly	Yes*	No	Yes	Yes*	No	Yes	Yes	Yes	Yes*
Disability Discrimination Act	No	No	Yes	Yes	Yes	No	Yes	No	No	No	Yes
National monitoring system on UD	No	Yes	Yes*	No	No	No	No	Partly	No	No	No
Awareness programmes on UD/DFA	No	Yes*	Yes*	Yes	No	Yes	Yes	Yes	Yes	No	Yes*
Public procurement policies include UD/DFA	No	Partly	Yes*	Yes	Yes*	No	No	Yes	Yes	No	Partly
Disability organisations take part via a structured dialogue	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry participation via a structured dialogue	No	No	Yes*	No	No	No	Yes*	Yes	Yes	No	Partly
UD in built environment education curricula	Yes	Partly	No	Yes	No	Partly	Partly	Yes	Yes	Yes	Yes*
Research programmes on UD/DFA	No	Partly	Yes*	Yes	Partly	Partly	Yes*	Yes	Yes	No	Yes*
Labelling system on UD/DFA	No	Yes*	No	Yes*	Yes*	Yes	Yes*	Yes*	Yes	No	Partly

UD/DFA: Universal Design/Design for All Yes*: yes, but under different headline

Table 1.1: European position on Universal Design, Overview of Universal Design in selected European countries

Vision and Age

Changes in vision, with increasing of age, have to be examined in depth in order to better understand elderly and visually impaired people lighting needs in residential environment.

Perceptual and cognitive systems start to change after about 60 years of age. As regard vision, old eyes reduce visual acuity because of yellowing of the lens, they require more time for adaptation at higher illumination level and an optimum contrast of the visual task to achieve the best visual performance *(Figure 1.1)*. In addition, human visual sensitivity to the spectra, which is called spectral luminous efficiency (SLE), it makes visual appearance of older people different from that of the younger due to the yellowing of the eye lens with aging *(Figure 1.2)*.

The aging eye is virtually a fixed focus optical system, the maximum pupil area decreases much more than the minimum and this means that elderly are much less able to compensate for low light levels than young people. With regard to this topic, eye health is sometimes put forward as a justification for high levels of illumination, with the implication that low levels of illumination will damage the eye. It is necessary to bear in mind that the need for wearing glasses arises only from organic causes, not from inadequate illumination level.

For the sake of greater clarity, age-related declines in vision can be categorized into three general levels[11]:

- changes in the optics of the aging eye;
- sensory changes *(from retina to early visual cortex)* and
- perceptual changes *(mid and high level visual cortex)*.

These declines have a direct impact on the ability of older observers to perceive spatial changes in luminance or contrast and are usually assessed in studies of orientation discrimination or objects detentions.

Over the past 25 years, researches on aging and vision[12] have made

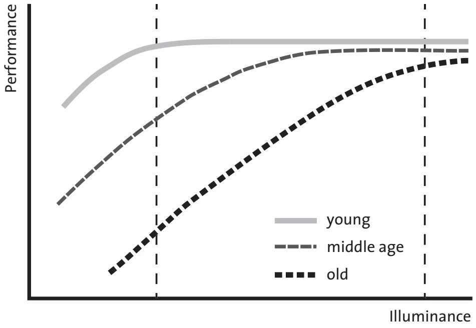


Figure 1.1: Model of general relatioship between visual performance and illuminance for three age groups: young, middle age and old. At high levels of illuminance the visual performance of the three groups is very similar. At low illuminances there are very large differences in performance.

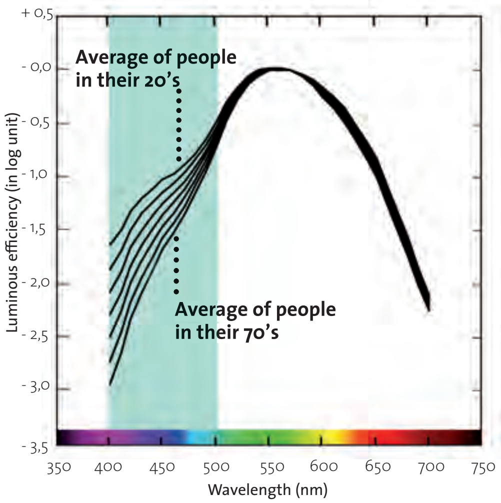


Figure 1.2: Luminous efficiency functions for difference age groups from those in their 10s to those in their 70s measured by flicker photometry.

11 Nick V. Baker et al, Daylighting in Architecture: A European Reference Book, Routledg,; 1 edition ,December3, 1993

12 K. Sagawa, Vision of the elderly and visually impaired -for Accessible Design in Light and Lighting, 26th Session of the CIE Beijing, 2007;
G.K. Cook, Innovation in light reflectance value - measurement and application, 26th Session of the CIE Beijing, 2007;
Y. Zhang, Experiments and researches of reading lighting for the elderly, 26th Session of the CIE Beijing, 2007;
I. Youko, Emergency lighting with considering adaptation of eyes, 26th Session of the CIE Beijing, 2007;
C. Chain, Public Lighting specification for visually impaired people: results from an experiment, 26th Session of the CIE Beijing, 2007;
J. Wienold, Quantification of age effects on contrast and glare perceprtion under daylight conditions,Session of CIE, 2012;
A. Lewis- J. Torrington, Extra-care housing for people with sight loss: Lighting and design, Lighting Res. Technol. 2013, 45: 345-361;
A. Lewis, Daylighting in older people's housing: Barriers to compliance with current UK guidan-

significant steps forward focusing on spatial contrast sensitivity, vision under low luminance, temporal sensitivity, motion perception and visual processing speed. However, it is important to keep in mind that just because one can demonstrate an aging-related deficit or difference in some task in the psychophysics laboratory, this does not necessarily mean that this deficit is relevant to understanding older adults' everyday visual performance or behavior difficulties.

In general, there is an underappreciation of individual differences in the aging of visual function. Most popular studies design in the field of lighting[13] involve the comparison of young versus old group differences without taking into account that there are undoubtedly "general principles" in the aging of visual older adults, such as different lifestyle, genetic, and environmental exposures during the life-course, that can theoretically impact ocular and brain structure and function in later life in different ways.

Anyway there are many types of visual problems that increased in difficulty with age: reading small print, distinguishing dark colors, distinguishing luminance contrast, dislike a great amount of scattered light and benefit from a good distribution of light.

It is reasonable to assume that increasing size or contrast of the task, will produce an improvement in visual performance for the elderly and for people with vision loss. The size of the retinal image of a task can be increased either by making the task bigger, for example, large print books, or by bringing the task closer or by using some form of magnification. The greater is the magnification, the smaller is the field of view. One situation where magnification might be thought to be of great value is for people who have lost foveal vision, for example, people with macular degeneration. Unfortunately, the benefit of magnification is not as great as expected. The improvements that does occur with magnification occurs because the effect is to enlarge the retinal image so that it extends over the near periphery of the retina, an area that is unaffected by macular degeneration. Unfortunately, visual acuity decreases with retinal eccentricity.

But size is just one dimension that can be used to make the task easier to do. Another is luminance contrast and as a consequence, still another factor that need to be considered when seeking to maximize luminance contrast is the amount of scattered light produced in the eye. Scattered light will tend to reduce luminance contrast of the retinal image of the task; one simple means to reduce the amount of scatter is to reduce the luminance of the area immediately surrounding the task.

A dimension that might be also used to enhance visual performance is surface colour which can be used in three different ways[14]:

- to identify objects. Colour does improve the recognition of images of familiar foods by people with normal vision and vision loss.
- to make items more conspicuous which improves visual search.
- as a substitute for luminance contrast.

Last, but not the least, aspect of lighting that can be important in determining the ability of the elderly and those with vision loss to function is the distribution of light. This can be considered in two locations: the surrounding space and the task area. The tasks elderly have difficulty with can be redesigned to make them visually easier; this usually involves increasing the luminance contrast of the task details, making the task details bigger and using more saturated colors *(See Chapter 7.3.3.4 and 7.3.4.3)*.

Only being careful with these changes, it may have a profound impact on the quality of life, health and wellbeing of an older population.

ce, Lighting Res. Technol. 2015, 47: 976-992;
Hans-Werner Wahl,*1 Frank Oswald,2 and Daniel Zimprich, Everyday Competence in Visually Impaired Older Adults: A Case for Person-Environment Perspectives, The Gerontologist, Vol. 39, No. 2, 140-149, 1999;*
Lucia Baracco et al, *Questione di Leggibilità, Progetto lettura Agevolata, Venezia, 2005.*

13 See reference number 12.

14 P. Boyce, Human factor in Lighting, CRC Press, 3 Edition, April 2014

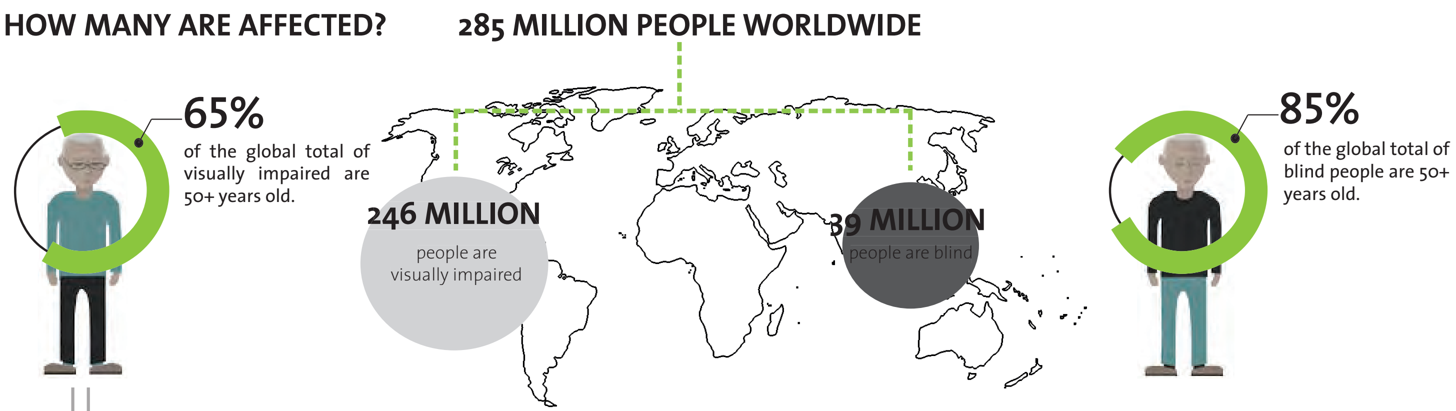
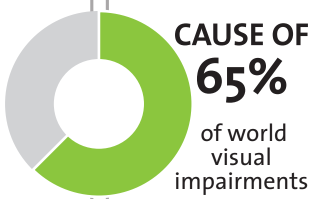


Figure 1.3: Number (%) of people with visual impairments.

Refractive error



153 MILLION

people suffer from visual impairments due to Refractive Errors

It is now necessary to consider the nature of each of the more common causes of blindness and vision loss in old age and are respectively: refractive error, cataract, macular degeneration, glaucoma and diabetic retinopathy.

- Refractive error is a very common eye disorder. It occurs when the eye cannot clearly focus the images from the outside world. The result of refractive errors is blurred vision, which is sometimes so severe that it causes visual impairment. Refractive errors cannot be prevented, but they can be diagnosed by an eye examination and treated with corrective glasses, contact lenses or refractive surgery. If corrected in time and by eye-care professionals, they do not impede the full development of good visual function.

The four most common refractive errors are[15]:

Presbyopia: during the ageing process, an individual loses the ability to focus clearly at the normal reading distance. Such a situation is referred to as presbyopia. There is no precise age at which this occurs, it differs from individual to individual, but in general terms it often starts to occur between the age of forty and fifty. It is thought to be caused by two factors: hardening of the crystalline lens and weakening of the ciliary muscle. Presbyopia occurs in addition to any existing vision defects; it is not possible to prevent it but it can be compensated for with reading spectacles or bifocal contact lenses *(Figure 1.4)*;

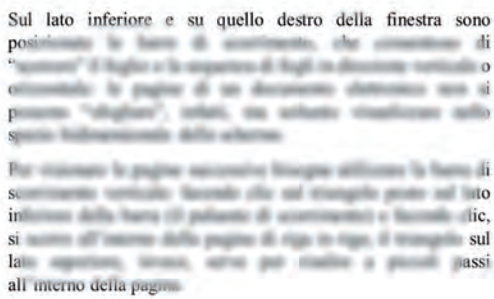
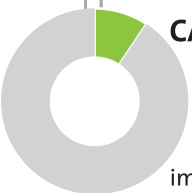


Figure 1.4: View damaged because of presbyopia.

15 N.A.Smith, Lighting for health and safety, Routledge, 1 Edition, March 2000.

CATARACT



CAUSE OF
8%
of world visual impairments

20 MILLION

people suffer from visual impairments due to Cataract.

Myopia: or near-sightedness, is a type of visual defect where seeing at closer distances is easier than seeing at far distances. Simple myopia does not always result in discomfort since the eye is not called upon to make changes in adaptation as is the case with hypermetropia. In near-sightedness, the image of the visual target falls in front of the retina and is therefore out of focus *(Figure 1.5)*;

Figure 1.5: View damaged because of myopia.

Astigmatism: is the condition where an individual will simultaneously interpret equal length radials lines as having different lengths. It is often as a consequence of unequal curvatures of the cornea or lens in different planes *(Figure 1.6)*.

Figure 1.6: View damaged because of astigmatism.

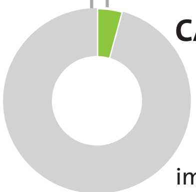
Hypermetropia: is a visual defect where seeing is clearer at greater distances. When the eye is relaxed, the total powers of its optical elements is insufficient to bring visual targets into focus hence light focused behind the plane of the retina *(Figure 1.7)*;

Figure 1.7: View damaged because of hypermetropia.

- <u>Cataract</u> is an opacity developing in the lens *(Figure 1.8)*. The effect of cataract is to absorb and scatter more light as it passes through the lens. This increased absorption and scattering results in reduced visual acuity and reduced contrast sensitivity over

Look through the circle to experience the impact of vision loss.

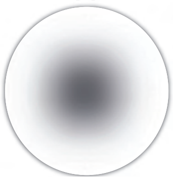
MACULAR DEGENERATION



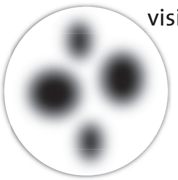
CAUSE OF
3,5%
of world visual impairments

8 MILLION

people suffer from visual impairments due to Macular Degeneration.



Look through the circle to experience the impact of vision loss.



the entire visual field, as well as the diminished colour discrimination, especially colors in the cool spectrum, and greater sensitivity to glare. The extent to which more light can help a person with cataract depends on the balance between absorption and scattering. More light will help overcome the increased absorption but if scattering is high, the consequent deterioration in the luminance contrasts in the retinal image will reduce visual capabilities.
Cataract cause blurring and increase sensitivity to bright lights and glare but the extent of vision loss resulting from cataracts ranges does not affect to blindness. *(See also Chapter 7, paragraph 2.1)*

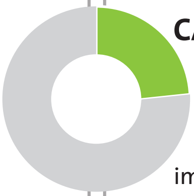
- Macular Degeneration. There are two forms of macular degeneration related to age, wet and dry *(Figure 1.9-10)*. Wet macular degeneration is shown by the growth of small, leaking blood vessels in the retina. Dry macular degeneration involves the accumulation of cellular waste under the retinal pigment epithelium leading to deterioration of parts of the retina. Both wet and dry macular degeneration cause damage in and around the fovea which implies a serious decline in foveal vision; ultimately making everyday activities such as reading and seeing faces impossible. However, peripheral vision outside the macular is unaffected so the ability to orient oneself in space is little changed *(See also Chapter 7.2.1);*

Figure 1.8: View damaged because of cataract.

Figure 1.9: View damaged because of wet macular degeneration.

Figure 1.10: View damaged because of dry macular degeneration.

GLAUCOMA



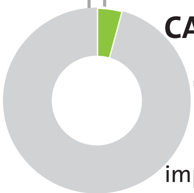
CAUSE OF
24%
of world visual impairments

60 MILLION

people suffer from visual impairments due to Glaucoma.

Look through the circle to experience the impact of vision loss.

DIABETIC RETINOPATHY



CAUSE OF
2,5%
of world visual impairments

5 MILLION

people suffer from visual impairments due to Glaucoma.

- Glaucoma is best thought of as the ultimate outcome of a number of diseases that affect the eye, that outcome being progressive visual field loss. Glaucoma is actually several disease that are caused by the lack of fluid draining from the eye *(Figure 1.11)*. The pressure created from the lack of drainage damages the optic nerve. Without proper treatment, blindness can occur. Glaucoma can cause blind spots, blurred vision and a loss of peripheral vision followed by central vision;

- Diabetes is common in the elderly, and it affects vision by contributing to cataracts and diabetic retinopathy. High levels of sugar in the bloodstream cause diabetic retinopathy. Eyesight can be affected by a change in the central field of vision and color identification *(Figure 1.12)*.

Although refractive error, cataract, macular degeneration, glaucoma and diabetic retinopathy have been discussed separately, it is important to appreciate that having any one on them does not confer immunity to the others. In fact, the older the individual, the more likely it is that more than one of these causes of vision loss will occur.

Figure 1.11: View damaged because of glaucoma.

Look through the circle to experience the impact of vision loss.

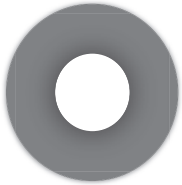


Figure 1.12: View damaged because of diabetic retinopathy.

Look through the circle to experience the impact of vision loss.

To conclude, a frequent asked question on Lighting is:

Do people with low vision need higher levels of lighting than people with normal vision?

Vision specialists offer general guidelines on the amount of light a person needs, depending on the type and severity of vision loss. General guidelines[16]:

- People with macular degeneration almost always require much higher light levels, especially for reading and close-up work.
- People with glaucoma usually benefit from higher light levels.
- Less light may work better for those with central cataracts *(cortical or subcapsular).*

People with the same type of low vision, however, can respond differently to varying light levels, so different types of bulbs, wattages, and lamps should be experimented to find out what is the most comfortable. The quality of light is just as important as the quantity. An overly bright room, a bright light in a dark room, or exposed bulbs in a chandelier will cause discomfort for most people with low vision. That is why just replacing low wattage bulbs with higher wattage bulbs will not work if it also increases glare.

16 Rosemary Bakker, Household Tips for People with Low Vision, Cornell University, 2011

1.1 New Design Needed

Historical connections between health, design and environment need to be investigated after becoming aware of all the main types of visual impairments in elderly people. Architects should develop specialized spatial typologies to characterize housing requirements *(See the following Paragraph: Cases Studies)* which correspond to different phases of life and aging: daytime help, assisted living, retirement home and hospice.
This suggests an evolving perception of the Third Age necessitates, not only the transformation of one's lifestyle *(from work to leisure)* but also the transformation of one's spatial environment to support the lifestyle transition. The design that takes care for those with special needs is called Accessible Design or simply "Accessibility" and is no longer an option. It's a necessity.

What is Accessible Design?

The aim of the Accessible Design concept is to simplify life for everyone by making the built environment, communication, products and services equally accessible, usable and understandable. Mainstreaming is a keyword in this process, implying that all policies and solutions have to be carefully designed to accommodate all users. The aim is to achieve this to the greatest extent possible, diminishing the need for segregated solutions and special services.
For example, if the letters in visual signs or product labels are too small for people with low vision to read them, Accessible Design means to design letters in an appropriate size or to design lighting so that letters are legible to older people and people with visually impairments as well without using any assistive tool, such as a magnifier. As regard individuals with visual disabilities, they have an increased need for lighting to compensate for poor vision or other spatial navigation difficulties: in accessibly designed homes this often translates to in-

stalling ground track lighting along hallways and outdoor pathways. LED lighting is ideal for this purpose *(See Chapter 6: Artificial Lighting)*.

The difference between assistive technology and accessible design can be briefly described as follows: *The assistive technology is a design to increase human ability concerning with the best fitting of devices to the individuals, while accessible design is a design in products that can be used many people with a focus on the best fitting to majority of users taking accounts of distribution of users' abilities*[17].

A truly accessible design changes the way we integrate even the most common aspects of a home, such as lighting. In the field of light and lighting the term "all people" includes people with visual impairments such as low vision, or partially sighted, and older people as well; visibility of those people cannot be improved simply by wearing glasses but also with cares in designing visual signs and lighting design have to be taken to make their visual environment more visible and safe. For this consideration, visual property of low vision and their requirements for better lighting are necessary.
But it does not end here, there are some other factors to consider along with the fundamentals of accessible design, for example glare is another popular problems of which older people suffer in their everyday life.

The most important thing is being mindful of a range of physical challenges and abilities, which means reconsidering how every aspect of the home comes together for diverse users, who are the basic concept of accessible design. Smart home management techniques such as new lighting, bright contrasting colors, and specialty products such as magnifiers and talking devices, can help a person function better and remain independent.
It can be concluded that there is a definition of Universal Design in Europe and a clear belief in the need for Accessible Design to enable people with disabilities to reach full democracy and economic advantages. To offer technical information on ageing or limits of visual abilities of people with disabilities is one of the key issues in promoting accessible design.

17 K. Sagawa, Vision of the elderly and visually impaired -for Accessible Design in Light and Lighting, 26th Session of the CIE Beijing, 2007;

European Contribution and Projects

Europe now is facing the adoption of an increasing number of national disability action plans and intends to give them their proper place, acknowledging that concrete actions are needed because good intentions are not enough.
Legislation can be subdivided into rights, acts, provisions and local regulations, backed by methods to enforce legislative measures, and, in some cases, standards on accessibility. The ISO/IEC Guide 71 *(See Chapter 2.2)* addresses some of those critical factors, the European Standardization Organizations (CEN, CENELEC and ETSI)[18] are also including the principle of accessibility in the development of the standards, and the CIE[19], as one of the international standards developing organization, published a technical report to summarize the knowledge of low vision[20]. It is also responsible, through its sessions, international conferences, seminars, expertise workshops, for implementing and promoting this con-

18 The European Committee for Standardization (CEN, French: Comité Européen de Normalisation) is a nonprofit standards organization whose mission is to foster the European economy in global trading, the welfare of European citizens and the environment by providing an efficient infrastructure to interested parties for the development, maintenance and distribution of coherent sets of standards and specifications. The CEN was founded in 1961. Its thirty three national members work together to develop European Standards (ENs) in various sectors to build a European internal market for goods and services and to position Europe in the global economy. CEN is officially recognized as a European standards body by the European Union;
19 CIE: The International Commission on Illumination - also known as the CIE from its French title, the Commission Internationale de l´Eclairage - is devoted to worldwide cooperation and the exchange of information on all matters relating to the science and art of light and lighting, colour and vision, photobiology and image technology. With strong technical, scientific and cultural foundations, the CIE is an independent, non-profit organization that serves member countries on a voluntary basis. Since its inception in 1913, the CIE has become a professional organization and has been accepted as representing the best authority on the subject and as such is recognized by ISO as an international standardization body.
20 The CIE Board of Administration, TC 1-54 "Age-Related Change in Visual Response". TC 3-44 "Lighting for Older People and People with Visual Impairment in Buildings" are the groups currently working on this issue.

cept in the field of light and lighting even if much more data on various visual functions of low vision are still required.

To understand the current position on Universal Design, a number of significant international events which play an important role are here listed:

1950: European Convention for the Protection of Human Rights and Fundamental Freedoms.

1990: The Americans with Disabilities Act (ADA) with its set of regulations banning discrimination against people with disabilities in almost every aspect of society. The ADA has been a worldwide inspiration on equal rights for people with disabilities. The Department has also compiled **Guidance on the 2010 Standards** from the revised regulations: the **2010 ADA Standards for Accessible Design.**

1999: Accessibility Guidelines first established in the International Organization for Standardization (ISO)

2002: ISO Guide 71: "*Guidelines for standards developers to address the needs of older persons and persons with disabilities*", forming the basis of CEN/CENELEC Guide 6 *(See Chapter 2.2)*.

2006:The Council of Europe Disability Action Plan 2006-2015 *(See the following Paragraph: Case Studies)* seeks to translate the aims of the Council of Europe with regard to human rights, non-discrimination, equal opportunities, full citizenship and participation of people with disabilities into a European policy framework on disability. The intention is to assist policy makers in designing, adjusting, refocusing and implementing appropriate plans, programmes and innovative strategies.

Many European states, however, are not taking full advantage of the potential of Universal Design, and to cope with ageing and the increasing number of people with disabilities new measures are clearly needed.
Progress in the enjoyment of human rights at international, European, national or regional level depends on governments and elective bodies as driving forces. Implementing and enforcing Universal Design strategies can facilitate the promotion of equal rights of all citizens in all aspects of society.

Case Studies[21]

Linked to the action lines of the Council of Europe Action Plan to promote the rights and full participation of people with disabilities in society: improving the quality of life of people with disabilities in Europe 2006-2015 *(Council of Europe Disability Action Plan 2006-2015)*, a selection of examples of good practice in Universal Design is presented together with additional issues. Universal Design features and limitations of the examples are brought forward as an inspiration to national and local initiatives[22].

1. The Government Action Plan for increased accessibility for persons with disabilities. Plan for Universal Design in key areas of society, Norway.

Description: The Government Action Plan for increased accessibility for persons with disabilities aims to enhance accessibility for all, and directs a special focus towards persons with functional impairments. These include disabilities affecting **vision**, hearing, cognition and sensitivity to environmental factors.
Purposes:The action plan is designed to unify and strengthen efforts to increase accessibility to buildings, outdoor environments, products and other important areas of society. **The plan includes more than 100 concrete actions with an annual budget of more than €35 million. €2.5 million is used each year to stimulate innovation and new actions**.

21 Søren Ginnerup, Achieving full participation through Universal Design, April 2009.
22 Mr Søren Ginnerup, Achieving full participation through Universal Design, Committee on the Rehabilitation and Integration of People with disabilities, 2009.

Universal Design features: The action plan emphasis the importance of embedding the Universal Design strategy into government policies and administration, as has already been done in several acts relating to universities, colleges, and vocational school education.

2. Design for All – a Nordic program for action, the Nordic countries

Description: The action plan, which is based on the principle of mainstreaming, announces Universal Design/ Design for All as a crucial strategy for improving accessibility within the Nordic Council of Ministers and offers 17 measures, which are divided into three parts: an overall strategy; information strategy; and accessibility to the institutions of the Nordic Council of Ministers.
Purposes: The action plan is aimed at developing awareness within the area of Design for All and promoting systematic work towards full accessibility within the Nordic Council of Ministers, its institutions and, in the long run, of society in the Nordic countries for all citizens.
Universal Design features: it underlines the importance of incorporating a Design for All perspective into existing and new programmes and action plans.

3. Vision of the elderly and visually impaired for accessible design in light and lighting[23]

Description: To implement the concept of accessible design in light and lighting field fundamental data on human vision of the elderly and visually impaired are necessary to correctly address the needs of them.
Purposes: to implement the concept of accessible design into the light and lighting fields.
Universal Design features: In this paper, some basic visual functions such as spectral luminous efficiency function, span of categorical colours, visual acuity, and useful field of view, are shown as a function of age together with its implication to designing visual signs and lighting. Data on low vision are also presented with regards to contrast sensitivity function and span of categorical colours.

23 K. Sagawa, Vision of the elderly and visually impaired -for Accessible Design in Light and Lighting, 26th Session of the CIE Beijing, 2007;

4. Extra-care housing for people with sight loss: Lighting and design[24]

Description: The study investigated whether United Kingdom-based extra-care housing, which provides older people with individual dwellings, communal facilities and care support, complies with current guidance on design for people with visual impairment and satisfies the needs of residents with sight loss.
Purposes: This study aimed to investigate whether existing extra-care housing schemes:
(a) comply with current guidance on design for people with visual impairment and
(b) satisfy the needs of those extra-care scheme residents with sight loss
Universal Design features: It is difficult to prescribe ideal illuminance levels for people with sight loss not least because there is no strong correlation between optimum light levels and specific pathologies of the eye. This study draws recommendations for minimum average illuminance at floor level with all lighting, excluding task lighting and portable lighting, were used in evaluating general lighting.

5. Daylighting in older people's housing: Barriers to compliance with current UK guidance[25]

Description: this work identifies barriers to compliance with current UK guidance on daylighting in the design of extra-care housing which provides older occupants with self-contained dwellings and access to communal facilities and care.
Purposes: this study aimed to identify barriers to compliance with current guidance on daylighting in the design of extra-care housing.
Universal Design features: comparison between qualitative and quantitative data, enabling the qualitative

24 A. Lewis- J. Torrington, Extra-care housing for people with sight loss: Lighting and design, Lighting Res. Technol. 2013, 45: 345-361;
25 A. Lewis, Daylighting in older people's housing: Barriers to compliance with current UK guidance, Lighting Res. Technol. 2015, 47: 976-992;

data to be used to explore possible explanations for the findings of the quantitative study. Through the analysis process, themes were further refined to reflect the order in which building features, which affect daylighting, are normally considered in the design process.

6. Evaluation of Older People's Living Environments (EVOLVE)[26]

Description: Study of emerging forms of extra care housing, Produce a building evaluation tool, Carry out a quality of life study of people living in extra care housing, Pilot and test the tool in 23 extra care schemes and Produce a final version for wide dissemination.
Purposes: Do extra-care schemes meet current design guidance on lighting? Do extra-care schemes satisfy the needs of residents with visual impairments?
Universal Design features: Use of many different tools:
-Specialist Design Guidance, Housing for People with Sight Loss
-Building Sight
-General Design Guidance
-Lighting Guide 9: Lighting for communal residential buildings *(See Chapter 2.2)*

26 A. Lewis, Evaluation of Older People's Living Environments (EVOLVE), University of Manchester, Housing LIN Extra Care Housing Conference, 2011

A New Design in different Climates

In the previous paragraph, a wide sets of complementary measures are mentioned but the more robust Accessible Design plans described seem to be national and local programmed. Each country has its history, customs, legislations, climate etc, new housing forms which vary by size, form of organization, mutual commitment, homogeneity of age or generational composition are gaining more and more importance but all these factors need a deepen examination.
However, as in the lighting design field, between 1950-1970 in Europe, research into indoor climate has led to standardizing the optimum level of indoor climate comfort making it objectively measurable. This standardized indoor climate template implies that the appearance of buildings may also be standardized, leading to a tendency to standardize architecture from the tropics to the arctic[27].
The highly developed human adaptability mechanism, which in its original form has ensured man's survival, good health, comfort and pleasure, is not paid any particular attention by the regulations, design and construction practices that constitute the framework of modern architecture. As a result, the indoor climates and design that they create exclude the outside world rather than respond and adapt to external conditions in a dynamic way *(Figure 1.13)*. It is therefore important to design the building envelope so as to enable the interaction between the user and the indoor environment: not only in the perspective of being able to turn the heating on and down, control the incident sunlight and open

27 Dahl Torben, The architectural potential of climate in: Climate and Architecture, Routledge, November 2009.

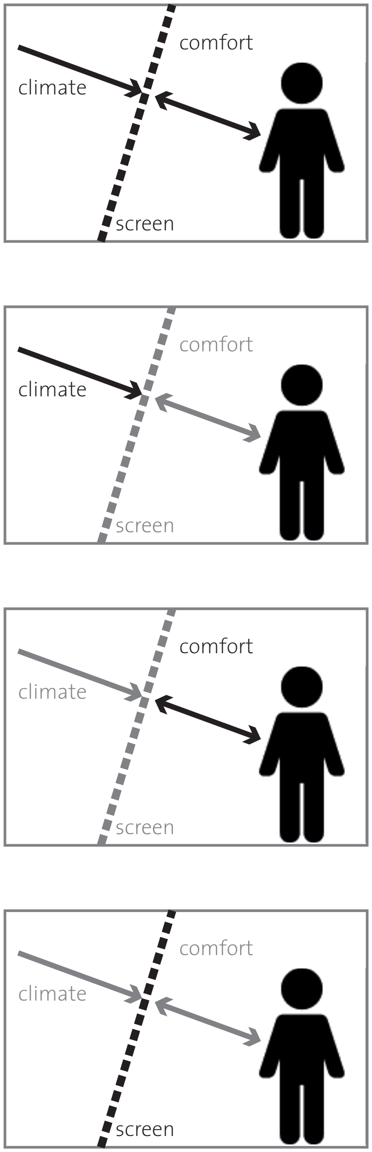


Figure 1.13: CLIMATE AND COMFORT
This sample climate scrren divides the world into an outside, where you are unprotected and exposed to climatic changes, and an inside, where you are protected and able to influence and adjust the circumstances that provide human comfort.

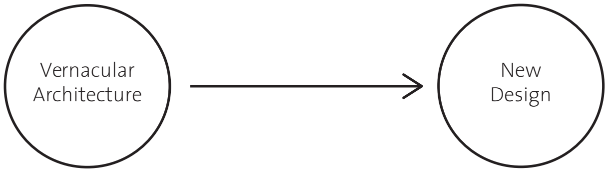


Figure 1.14: Vernacular design as a model system

a window to let in fresh air, but also to enable subjects such as older people and people with disabilities to take care of themselves.
It is known that architecture is a whole and in detail designed through the experience gained from a long development process based on the resources of the specific place and its particular climatic and cultural conditions. By studying traditional architecture and the principles of climate adaptation and control found in vernacular buildings, it is possible to understand and exploit the hidden knowledge and experience behind the design as an inspiration for contemporary architecture and new forms of design *(Figure 1.14)*.

The designer's task therefore consists of choosing the controllable causes and adjusting them in such a way that, under circumstances defined by the uncontrollable causes, desired effects are obtained. To clarify the fundamental design it is necessary to talk of measures of the system, which is what an architect does when using terms such as luminance or brightness:
- design variables as measures of the controllable causes, the design configurations or the architectural types;
- independent variables as measures of the uncontrollable causes *(the skies site)* and effects *(the eye's responses to light stimuli)*;
- dependent variables as measures of the controllable effects (the luminous environment).

Independent Variables: Skies and their Light Variables

Over millions of years the only principal source of light has been daylight. The illumination produced by the sky depends on its luminance while the intensity of illumination from direct sunlight on a clear day varies with the thickness of the air mass it passes through: it is less intense at sunrise and sunset at any latitude; and at noon it is less intense at high latitudes because the sun is lower.
The masters of architectures through history have demonstrated a very good understanding of sky conditions but the advent of electric lighting has distracted designers from considering the sky under which they have to build. Sky luminance varies according to a series of meteorological, seasonal and geometrical parameters that are difficult to codify. In view of this problem some models of standard skies have been worked out, and simplified references can made to some other limited conditions.
The simplest model is the Uniform Luminance Sky Distribution, which represents a sky of constant luminance. Another model is called the

CIE Standard Overcast Sky Distribution, where the luminance is not uniform bur varies in accordance with geometrical parameters, and which pertains to a meteorological situation that correspond to a sky covered with light cloud in a clear atmosphere, where the sun is not visible.
The third sky is the Clear Blue Sky Distribution that represents a sky of variable luminance and which pertains to a meteorological situation that correspond to a sky with clear atmosphere. This model takes into account the effects of the varying position of the sun but direct sunlight is not considered.
In as much as the absolute values of luminance vary according to latitude, season and the time of day, all these models express luminance in relative terms with respect to the zenith value.
A good architect should attempt to relate the design to the moods of daylight found in different seasons and at specific places[28].

Light and shadows

Light describes the surroundings on the basis of the variation of light intensities that reach our eyes. Designing buildings means to work with architectural form and light. To work with the light aperture is to design not only the room's lighting, but its appearance and mood. The facade works as a light filter, which controls incident light and determines the outward view by means of the apertures; this means that the facade's apertures contributes to the creation of variations in light and shadows. Architectural choices are often made in relation to the local light and sky conditions (see above), so that the facade not only creates the room behind but also constitutes an important element in the control of the room's climate and light level. Over millions of years, man has developed to function optimally in relation to different light conditions on Earth and has had to adapt to the specific conditions of life under the different altitudes of the Sun, both in relation to buildings and to clothing. Such adaptability has helped to create a comfortable environment around the body in an interaction between three levels: building, clothing, skin.

Light behaves in a predictable way, and if you know how to work with it consciously, it is possible to create functional and beautiful architecture.
As the Earth is hit by parallel rays from the Sun, the solar rays' angle in relation to the Earth's surface will differ according to the latitude, and

28 B.H. Evans, Daylight in architecture, McGraw-Hill Inc.,US, First Edition, August 1981 thus the strength of the light will vary between one region to another *(See Figure 15-16)*. The solar rays that hit Earth perpendicularly have the highest intensity, and as the ray's path through the atmosphere is relatively short, the diffusion in the atmosphere is quite limited. When the Sun is low in the sky, the intensity lessens, and as the rays have to travel a long distance through the atmosphere, the diffusion of light is equally greater. When more light is spread out into the atmosphere, the sky will appear brighter. As a result, the clear sky closest to the poles is much brighter than the areas around the equator.

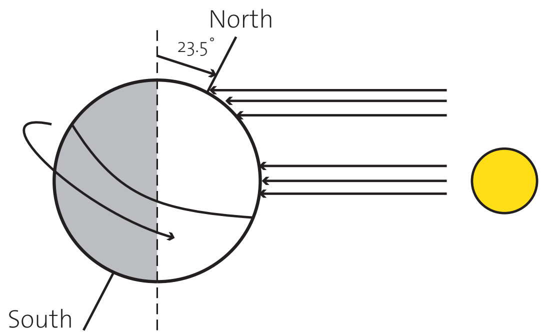


Figure 1.15: Angle of incoming solar radiation

Light is also an important part of the internal climate and a prerequisite for many functions in the building. The optimum solution depending on latitude, thus the character of light and hence the most appropriate design will differ from one location to another. Through knowledge of a place's climate and light types, coupled with careful design will ensure optimum use of light within the building for different function and location because each particular place has its light, especially when we have lived in a place, we know its rhythms of light and dark, clear and cloudy, and bright and dull.

Particular sky conditions are repeated around the world, but in different times of the day and year. In northern countries, architecture's response to this light is transparency in buildings, or skylight bathing walls with a gentle introspective light, or water reflection to bring the sky's brightness onto the earth's dark surfaces. On the other side, forests provide an ever-changing palette of colours and textures in light, and each one is particular in its own part of the world.

Depending on where on Earth you are, either sunlight, skylight or reflected light (which will be analyzed in depth in Chapter 5) can be the predominant type of light. Normally, daylight is a combination of the three but its intensity and proportion varies through the day and over the year between the types.

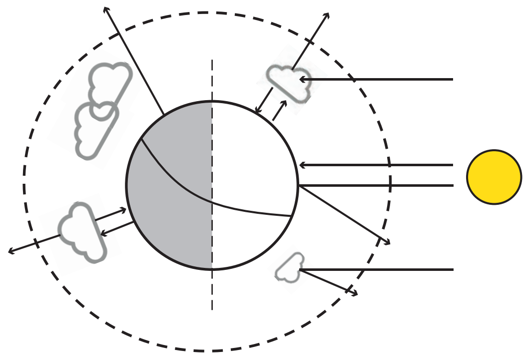


Figure 1.16: EARTH'S RADIATION BALANCE
The amount of clouds in the atmosphere is of great significance to the Earth's radiation balance. If there are a lot of clouds, a considerable amount of incoming solar radiation will be reflected or absorbed and therefore not reach the Earth's surface. At the same time, a large proportion of the outgoing radiation from Earth will be sent back towards the Earth's surface as atmospheric counter radiation, contributing to the heating of the atmosphere.

Place and Climate

All architecture is affected by climate, architecture is a connecting link between place, climate and human life. Attention to climate can be studied in any building in major or minor detail, but climate-adapted architecture is primarily found in traditional architecture.

On the other hand, the interaction between light and climate is multidimensional: it has to do with the spirit of place, with thermal comfort, and also with culture, since climate affects people, their habits, and their rituals. Light is often shunned in hot climates, while it is welcomed in cool climates. Where it becomes bitterly cold, a battle is waged between the dual necessities of excluding the cold and admitting the light. Light can also convey a visual message that transform the uncomfortable realities of a particular climate condition; for example, the admission of even a small beam of sunlight into a building in a northern climate on a cold winter day can add a sense of vitality and sparkle to the interior. In Scandinavian countries, the reddish tones of the wood lend their warmth to the light that spills past them onto the floor and the structure. The wood feels warm to the touch because, having a high thermal resistance, it does not wick heat away from the body. We have associations built up from the experience of wood that contribute to our perception of it as warm. Similarly to representing the sound of water to create psychological cooling in hot climates, light can be presented in ways that alleviate unpleasant visual conditions, whether too dull or too bright.

Climate characteristics

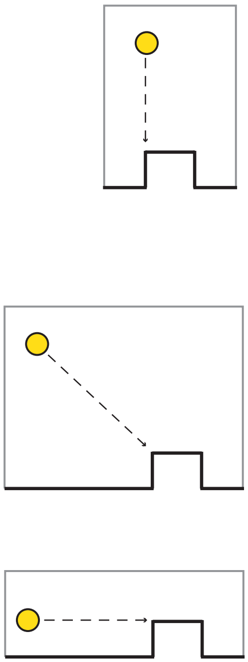


Figure 1.17: The altitude of the Sun characterises the climate zones hot, moderate and cold.

Taking a look at traditional architecture, one dominant characteristic in the planning of light apertures is consideration of the climate. It is often possible to determine the latitude by looking at the design of a building's light apertures. Knowing a place's latitude, it is also possible to determine the altitude of the Sun for the different seasons *(Figure 1.17)*. On the basis of the global weather systems indeed, it is possible to define a number of characteristics climate situations that are of great principle significance to regional climate-adapted architecture, because in the interplay between climate and building design it is important to know both normal and potential, more extreme climate conditions. Most commonly, traditional buildings are designed according to the climatically worst time of the year, whether this be summer heat or winter cold, in terms of thermal climate. However, it may be also be the rainy season or predominant wind directions that determines the design of a house.
Following, a number of characteristics climate types are described with examples of how traditional architecture is inspired by and designed according to the climate. The grouping has been made primarily according to temperature into a cold, hot and moderate climate[29].

29 B.H. Evans, Daylight in architecture, McGraw-Hill Inc.,US, First Edition, August 1981

Cold Humid (Subartic)

Cool summers, bright nights with short, intense growth periods, cold, dark winters, long snow-covered periods. Changing between quiet, dry periods and humid periods and very windy weather. The large continuous Scandinavian, Siberian and Canadian coniferous forest areas have a continental climate with long cold and windy periods. Here there is sufficient timber for building massive walls around the heavy, brick chimney core at the centre of the house, which retain heat for a long time. Internal wood panels of floors, ceiling and walls reduce heat radiation, thereby increasing the room's surface temperature and breaking thermal bridges which tend to occur.
Closer to the poles, where the altitude of the Sun and the weather conditions change a lot in the course of a year and even over a day, the light intensity will vary a great deal. Low sunlight spreads considerably more on its way through the atmosphere, so that the clear blue sky becomes relatively much brighter. Other climatic conditions mean that closer to the poles there is a great frequency of cloud sky, so that for a large part of the time the sky is the most dominant light source. Here the utilization of skylight is very important, and the need for well lit rooms is great as the climate causes people to stay indoor much of the time. Windows will often be large in order to draw the sparse daylight into the rooms. The diffuse skylight fades into the room, giving a soft and light shadow. As the Sun is a rare visitor, it is often welcome as a contribution to the life of the room *(Figure 1.18-19)*.

Figure 1.18: Architect Torbjørn Tryti, Norway. Example of cold humid house desing

Figure 1.19: Architect Unknown. Example of cold humid house desing

Hot dry - around the Equator

In dry areas around the Equator where the Sun is almost vertically above Earth all year round, the sunlight intensity is the greatest possible. The sky is relatively dark and very blue because of the limited dispersion of light through the atmosphere. Here, the Sun and the reflected light are the most dominant light source. For the sake of the indoor climate it is appropriate in this environment to keep out light and thus heat. Unscreened sunlight can heat a room to an extent where it is not comfortable to stay in it. This means that buildings are often designed with loggias, peristyles or something similar, which create shaded areas at the building perimeter. Windows are often small, and if not, it is possible to close them off completely, against direct sunlight. The sunlit ground reflected sufficient light to serve as the primary light source in such regions. This means that although the room is screened efficiently against the Sun, it can still be illuminated by reflected light from outside *(Figure 1.20-21)*.

Moderate - Southern European climate

It is a pleasant climate characterized by mild winters and warm summers. In the design should be taken into account the variation of the altitude of the Sun in the course of the Year. Balconies, which serve as a permanent integrated sun screen, have a key role in the buildings' planning: They screen out most of the sunlight when the Sun is high in the sky during summer, but allows the warmly toned reflected light to enter the room in winter. Thanks to the screening the area right behind the facade is a bright and comfortable place to stay without direct sunlight during summertime.
A system composed of these three parts: a facade element that screens out direct sunlight, a glass area that facilitates a view and makes it possible to get skylight into the room and aperture for ventilation, is highly efficient in relation to the Southern European climate as it screens out the high Sun that provides too much heat and at the same time allows in a large amount of the controlled skylight. The system ensures a pleasant indoor climate and provides a varied architectural expres-

Figure 1.20-21: Tarifa, Spain. Example of hot dry climate architecture.

sion of the facade.
Following this advices, given by both international and national lighting authorities and by organizations devoted to the welfare of the elderly, the architect should lead to improvements in visual function for the elderly and for many people with vision loss without causing problems for young people *(Figure 1.22-23)*.

Figure 1.22: Architects Unknown. Example of moderate Southern Europe architecture.

Figure 1.23: Oiseau des Iles social housing,Nantes,Antonini Darmon Architect,2014. Example of moderate Southern Europe architecture.

Chapter 2 **European legislation: Lighting Standards**

Since 2003 EU member countries have had a common standard *(EN 12464-1:2002)* for light planning in interior spaces, specifically workplaces. Based on new research, this document has now been revised and it has been superseded by the European Standard ***(EN 12464-1:2011),*** prepared from the Technical Committee CEN/TC 169 "Light and lighting". As a consequence, the national standards organizations of the following countries are bound to implement this technical changes: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

This European Standard specifies lighting requirements for humans in indoor work places, which meet the needs for visual comfort and performance of people having normal ophthalmic *(visual)* ca

pacity. The document defines requirements for

lighting solution for most indoor work places and their associated areas in term of illumination's quantity and quality; however it doesn't provide specific solutions, nor restricts the designers' freedom from exploring new techniques nor restricts the use of innovative equipment. The illumination can be provide by daylight, artificial lighting or a combination of both.
Even if the Standard EN 12464-1:2011 has been prepared specifically for lighting of work places, the Document gives fundamental concepts useful for each designer who are going to plan an indoor space.

EN 12464-1:2011

"*Adequate and appropriate lighting enables people to perform visual task efficiently and accurately. The degree of visibility and comfort required in a wide range of work places is governed by the type and duration of the activity*"[30]

30 EN 12464-1: 2011 "The Lighting of Workplaces"

The **lighting design criteria** is described in the *Clause 4* of the document: for good lighting practice it is essential, as well as the required illuminances, that additional qualitative and quantitative needs are satisfied.
The lighting requirements are determined by the satisfaction of three basic human needs: visual comfort, visual performance and safety. The main parameters determining the luminous environment with respect to artificial light and daylight are precisely:

- *luminance distribution;*
- *illuminance;*
- *directionality of light;*
- *variability of light(level and colour);*
- *colour rendering and the colour appear ance of light;*
- *glare;*
- *flicker.*

Values for illuminance ***(Em)*** and its uniformity ***(Uo)***, discomfort glare *(**UGR_L**)* and colour rendering index *(**Ra**)* are tabulated in **the schedule of lighting requirements** *(Clause 5)* based on the kind of areas, tasks and activities. If the particular task area or activity area is not listed, the values given for a similar, comparable situation should be adopted.

The Standard highlights that in addition to the lighting there are **other visual ergonomic parameters** which influence visual performance, such as*:*

-the intrinsic task properties *(size, shape, position, colour and reflectance properties of detail and background);*

-ophthalmic capacity of the person *(visual acuity, depth perception, colour perception);*

-intentionality improved and designed luminous environment, glare-free illumination, good colour rendering, high contrast marking and optical and tactile guiding system can improve visibility and sense of direction and locality.

These factors can enhance visual performance without the need for higher illuminance.

Luminance distribution

The luminance distribution in the visual field controls the adaptation level of the eyes which affects task visibility. A well balanced luminance adaptation is needed to increase: visual acuity *(sharpness of vision)*; contrast sensitivity *(discrimination of small relative luminance differences)* and efficiency of the ocular functions *(such as accommodation, convergence, etc..)*. It should be therefore avoided:

_too high luminance which can give rise to glare;
_too high luminance contrasts which will cause fatigue because of constant re-adaptation of the eyes;
_too low luminance and too low luminance contrasts which result in a dull and non-stimulating working environment.

To create a well balanced luminance distribution the luminance of all surfaces shall be taken into consideration and will be determined by the reflectance and the illuminance on the surfaces. Recommended reflectances for the major interior diffusely reflecting surface are 0.7 to 0.9 for ceiling, 0.5 to 0.8 for walls and 0.2 to 0.4 for floor; the maintained illuminances shall have the following values: Em > 50 lx with Uo > 0.10 on the wall and Em > 30 lx with Uo > 0.10 on the ceiling.

Illuminance

The illuminance and its distribution on the task area and its surroundings have a great impact on how quickly, safety and comfortably a person perceives and carries out the visual task.

The values given *in Clause 5* are maintained illuminances over <u>the task area</u> on the reference surface which can be horizontal, vertical or inclined. The values are valid for normal vision conditions and they should be increased when:

_visual work is critical;
_errors are costly to rectify;
_accuracy, higher productivity or increased concentration is of great importance;
_*task details* are of unusually *small size or low contrast;*
_the task is undertaken for an unusually long time;
_*the visual capacity* of the worker is *below norma*

As opposite, the required illuminance may be decreased when:

_task details are of unusually large size or high contrast;
_the task is undertaken for an unusually short time.

The Standard point out that ***for visually impaired people special requirements can be necessary with regard to illuminance and contrast.***

Large spatial variations in illuminances around the task area can lead to visual stress and discomfort. The illuminance of the immediate surrounding area shall be related to the illuminance of the task area and should provide a well-balance luminance

distribution in the visual field. The immediate surrounding area should be a band with a width of at least 0.5 m and it may be lower than the illuminance on the task area but shall be not less than the values given in Table 1.2.
In indoor work places, particularly those devoid of daylight, a large part of the area surrounding an

Illuminance on the task area	Illuminance on immediate surrounding areas
E_{TASK}	**E_{TASK}**
[lx]	[lx]
>750	500
500	300
300	200
200	150
150	E_{TASK}
100	E_{TASK}
<50	E_{TASK}

Table 1.2 Relationship of illuminances on immediate surrounding to the illuminance on the task area.

active and occupied task area needs to be illuminated. This area known as the "background area" should be a band at least 3 m wide adjacent to the immediate surrounding area within the limits of the space and shall be illuminated with a maintained illuminance of 1/3 of the value of the immediate surrounding area.
About *uniformity of luminance(Uo)*, task area's values shall be not less than the minimum given in the Tables of the *Clause 5*; while the luminance uniformity shall be Uo > 0.40 in the immediate surrounding area and Uo > 0.10 on the background area, considering artificial light solutions. For natural lighting, in large areas, the available daylight decrease rapidly with the distance from the window.

Glare

Glare is the sensation produced by bright areas within the visual field, such as lit surfaces, part of the luminaires, windows and/or roof lights. Glare should be limited to avoid errors, fatigue and accidents.
Direct glare can be experienced either as Disability Glare or as Discomfort Glare. The first reduces the ability to perceive the visual information needed for a particular activities. It is caused by lights that shine directly into one's eyes, causing a veiling luminance which decreases contrast and reduces visibility; the second one does not significantly reduce the ability to see information needed for activities, but it produces a sensation of discomfort. *In interior places disability is not usually a major problem if discomfort glare limits are met.*
For the rating of discomfort glare from windows there is currently no standardized method; whereas the rating of discomfort glare caused directly from the luminaires of an indoor lighting installation shall be determined using the CIE United Glare Rating *(UGR)* tabular method. The UGR value shall not exceed the values given in Clause 5.
Glare caused instead by reflection in specular surfaces is usually known as veiling reflections or Reflected Glare. High brightness reflections in the visual task can alter task visibility, usually detrimentally. Reflected glare can be prevented or minimised by the following measured:

-arrangement of work stations with respect to luminaires, windows and roof lights;
-surface finish(matt surfaces);
-luminance restriction of luminaires, windows and roof lights;
-bright ceiling and bright walls.

About work station with Display Screen Equipment *(DSE)*; in some case, reflections in the DSE and, in some circumstances, reflections from the keyboard can cause disability and discomfort glare. Light can lower the contrast of the presentation on a DSE by veiling reflection caused by the illuminance on the displays' surface and luminances from luminaires and bright surfaces reflecting in the display. It is therefore necessary to select, locate and arrange the luminaires to avoid high brightness reflections. The designer shall determine the offending mounting zone and shall choose equipment and plan mounting positions which will cause no disturbing reflections. **EN ISO 9241-307** gives requirements for the visual qualities of displays concerning unwanted reflections.

Directional lighting

The general appearance of an interior is enhanced when its structural features, the people and objects within it are lit so that form and texture are revealed clearly and pleasingly. The lighting should not be too directional or it will produce harsh shadows, neither should it be too diffuse or the modelling effect(balance between diffuse and direct light) will be lost entirely, resulting in a very dull luminous environment.
Multiple shadows caused by directional lighting from more than one position should be avoided as this can result in a confused visual effect. As opposed lighting from a specific direction can reveal details within a visual task, increasing their visibility and making the task easier to perform. Unintended veiling reflections and reflected glare should be avoided. Harsh shadows interfere with the visual task, but **some shadows help to increase the visibility of the task.**

Chromaticity and colour rendering index

The colour qualities of a near-white lamp or transmitted daylight are characterised by two attributes:

-the colour appearance of the light; it refers to the apparent colour***(Chromaticity)*** of the light emitted. It is quantified by its correlated colour temperature. Colour appearance of daylight varies throughout the day.
The choice of colour appearance is a matter of psychology, aesthetics and what is considered to be natural. The choice will depend on illuminance level, colours of the room and furniture, surrounding climate and the application. *In warm climates generally a cooler light colour appearance is preferred, whereas in cold climates a warmer light colour appearance is preferred.*

-its colour rendering capabilities. To provide an objective of the colour rendering properties of a light source the general **Colour Rendering Index*(Ra)*** is used. The maximum value of Ra is 100.
For visual performance and the feeling of comfort and well being colours in the environment, of objects and of human skin, shall be rendered naturally, correctly and in a way that makes people look attractive and healthy. The minimum value of colour rendering index for distinct types of interiors, tasks or activities are given in *Clause 5*.

Finally, the last part of *Clause 4* talks about how to reduce energy consumption without to compromise the visual aspects of a lighting installation. Lighting should be designed to meet the lighting requirements of a particular task or space in an energy efficient manner.
Energy saving can be made *by harvesting daylight*, responding to occupancy patterns, *improving maintenance characteristics of the installation, and making full use of controls.*
The amount of daylight varies throughout the day depending on climate conditions. In addition, in interiors with side windows the available daylight decreases rapidly with the distance from the window. Supplementary lighting may be needed to ensure the required illuminance levels at the work station are achieved and to balance the luminance distribution within the

room. *Automatic or manual switching and/or dimming* can be used to ensure appropriate *integration between artificial lighting and daylight.*

Daylight can supply all or part of the lighting for visual tasks, and therefore offers potential energy savings. Additionally, it varies in level, direction and spectral composition with time and provides variable modelling and luminance patterns, which is perceived as being beneficial for people in indoor working environments. Windows are strongly favoured in work places for the daylight they deliver, and for the visual contact they provide with the outside environment. However, it is also important to ensure windows do not cause visual or thermal discomfort.

Based on illuminance performance that are concordant with EN 12464-1:2011, the Technical Committee is working on the additional document **prEN Doc 9:2015** which should specify minimum recommendations for achieving, b*y means of natural light*, an adequate subjective impression of lighting indoors, and for proving an adequate view out. The working document would give information on how to use daylighting to provide lighting within interiors, and how to limit glare. The purpose is to define metrics used for the evaluation of daylighting conditions and to givemethods of calculation*(and verification)*.

2.1 UK Lighting Guideline for Residential Building

For field of light and lighting, quantitative data on visual abilities and lighting quality for older people and people with disabilities are vitally important. As people age they become more dependent on their environment to compensate for increasing frailty and sensory loss. Typical residential home lighting is inadequate to meet the lighting needs of their residents; it is clear that the physical environment does not often meet the needs of the people they are built to serve. The goal for all new construction and renovation of existing homes must go beyond shelter and provide for lighting to meet both the visual and the photobiological needs of older people. It is important to include the needs of older adults and for governments to expand their standards and regulations to address normal age-related changes, and provide appropriate environments to meet their needs. However, any national Standards do not provide quality and quantity lighting requirements to meet the visual needs of older people in their residential homes specifically. The UK States made an attempt to define lighting recommendations about this issue in the Lighting Guide 9:2013, *"Lighting for communal residential buildings".*

UK LIGHTING GUIDE 9:2013

The new edition of **UK Lighting Guide 9:2013** *"Lighting for communal residential buildings"(UK)* tries to provide a suitable general standard of illumination and a pleasant ambience for residents.

Communal residential buildings need not look institutional: well-planned lighting and decor can achieve a welcoming atmosphere and as healthy as possible.

This Guide provides information about *lighting for most constituent areas of communal residential buildings.* These may include student residences at a university, hostels, children's homes, residential homes for the elderly, nursing homes, hospices, NHS staff accommodation or school boarding houses. The document is for use by facilities managers, estate managers, school bursars and the site managers of communal residential buildings, as well as architects and building services engineers working on this type of project.

In specific chapters, the Guide deals with lighting need in residential building:
-*Chapter 2* explains needs about daylight.
-*Chapter 3* covers those areas found in almost all communal residential buildings.
-*Chapter 4* deals with requirements specific to certain types of institutions.

Daylight

Daylight makes an enormous contribution to the amenity and atmosphere of residential buildings. Adequate daylighting is essential, *both to provide light to enable occupants of the building to undertake visual tasks and to provide them with a view of the outside world.* On the other hand, windows are a source of heat loss in winter, and glare and solar heat gain in the summer, so the provision of daylight has to be balanced with heating and ventilation requirements.
Initial decisions on sitting and orientation of buildings play a vital part in daylighting, so it is important to consider daylight provision at the building concept design stage.

Indoor sunlight can be a friend or foe. In a residential building, winter sunlight is generally welcomed, *except* in administrative offices and *homes for visually impaired people, where minimization of glare is important*. Summer sunlight frequently results in complaints of glare and/or solar overheating.

In a residential building, curtains and blinds can be used to control solar glare. An ideal arrangement is to provide both, so that blinds or curtains can be drawn to control solar glare during the day.

Blinds are useful:
-for study bedrooms where people are using computers
-for people with visual impairments who are very sensitive to solar glare
-because they can be part drawn to exclude sun whilst retaining a view out.

Heat-rejecting and tinted glazing are not effective in preventing solar glare. They also have the disadvantage of distorting colours and reducing daylight during the winter months.
The quantity of daylight at a given point indoors depends to a large extent on how much sky is visible from that point. The solid angle of visible sky diminishes as one moves away from a window, so daylighting is inevitably uneven. In practice, one is often unaware of this defect in a domestic scale room; daylighting can be judged as a whole, quoting an average daylight factor accordingly.
It is important to balance the daylighting in sequences of spaces, e.g. to avoid moving from a highly glazed corridor directly to a relatively dark lounge.

Daylight Factor - The average daylight factor provides a measure of the daylight appearance of a room. Where this average is about 5%, a room looks brightly daylit; where it is significantly less than 2%, any electric lighting will appear to be the main source of light, with windows serving only to provide a view. Rooms with intermediate values will usually appear to have adequate daylight, but electric lighting may be required for activities such as reading in areas away from the window. *(Table 1.3)*

Table 1.3 Daylighting schedule

Entrance hall, reception area	
Lounge, common room	
Study bedroom, bed-sitting room	
Kitchen	

General aspects of lighting in communal buildings

Communal areas will generally have lighting in regular, if not constant, operation, so these are a high priority for some degree of automatic lighting control. Likewise, it makes sense to select high-efficiency light fittings for these areas, typically using T5 linear fluorescents, compact fluorescents *(CFL)* or LED modules. The colour temperature of the lamps is important: warm white is generally recommended in residential buildings—this gives a more domestic and less institutional atmosphere. Lamps should also have good colour rendering.

The chapter 3 of this Lighting Guidelines considers areas found in most residential accommodation buildings, indicating specifically the ***Em recommended*** *for each rooms.*

-Entrances - Em: 200lx

The entrance gives visitors and residents their first impression of a building; lighting is one of the most important factors in creating that impression. It is essential to light entrances adequately: not only is a dingy vestibule unattractive and unwelcoming, but it also creates a feeling of insecurity.

Location daylight factor (per cent)

	Standard	Best practice
	2.0	4.0
	1.5	5.0
	1.5	2.0
	2.0	3.0

-Corridors - Em: 100 lux - Night time: 20 lx

-Stairs - Em: 100 lux on the treads

-Toilets - Em: 100 lux; Bathrooms - Em: 150 lux

-Bedrooms - Em: 100 lux

-Lounges - Em: 100 lux; TV Lounges: Em: 50 lux

Lighting has more effect on the atmosphere of a large communal lounge than any other aspect of its design. Such areas benefit greatly from the interest and flexibility provided by a combination of different types of lighting. Wall bracket lights, cove strip lighting, decorative pendants, wall uplights, picture lights, recessed ceiling lights and floor standard lights can all be used, depending on the size, shape and ceiling height of the room.

-Combine at least two lighting types with separate switches, so residents can select between two lighting levels.

-Consider the daylight benefit in large rooms, e.g. where one wall has several windows, arrange lights so that they can be switched in rows parallel to the windows.

-Use dimmable lamps in one type of lighting so that some of the lights can be dimmed.

-Most of the seating should be provided with 100 lux so that people can read comfortably *(this figure **will need to be higher if residents are elderly**).*

-Some accent lighting *(e.g. of a decorative feature)* is desirable; halogen lamps or LED equivalents add sparkle.

-It is important to light the ceiling and the walls, which can be done with circular ceiling luminaires or pendants; recessed downlights on their own do not achieve this effect, whilst linear fluorescents should be avoided because of their institutional appearance.

-Lighting and decor complement one another, so selecting lighting for a lounge is more effective if it takes into account the anticipated colour and style of decor and furniture.

-The TV should not be installed such that sunlight shines through adjacent windows directly onto the screen. To avoid unwanted reflections, bright directional light sources should not be used near or directly opposite the TV screen.

-Lights should be provided near chairs and tables that may be used for reading*(Em: 200+ lux)* or close work, such as crafts in a residential home.

-Kitchen area - Em: 200 lux; Dining area: Em: 150 lux

Different lighting's type should be available to allow for different activities to take place; Activities include cooking, food preparation, eating meals, washing up, ironing and socializing etc..

Suggestions for lighting:

on the size, shape and ceiling height of the room.

-The kitchen area requires low-glare, uniform illuminance, best provided by enclosed ceiling luminaires.

-It is important to avoid people working in their own shadow, so ceiling luminaires should be sited with this in mind.

-Lamps should have good colour rendering; the recommended colour temperature is 3000–4000 K.

-The dining area is distinct from the kitchen and the lighting should reflect this, as well as being switched separately from the kitchen area. Decorative lighting on walls or ceiling, such as wall brackets or pendants, creates a pleasant atmosphere. Warm white lamps *(2700 K)* with good colour rendering are recommended.

Lighting particular to certain types of communal building: Homes for the elderly

Many elderly people have poor eyesight. The human eye loses sensitivity during life and the cornea yellows. As a result, the 60-year-old eye can require up to three times as much light as the 20-year-old eye to achieve the same retinal illumination. In addition, the eye loses flexibility, which means that adaptation to changes in lighting level or illuminance takes longer. Hence sudden changes in illuminance, e.g. when passing from one space into an adjacent area, should be avoided. The light transmission qualities of the eye also deteriorate with age. More light is scattered within the eye, particularly where a cataract forms, reducing contrast. It is therefore very important to minimize glare. Light sources should always be shielded from view at normal viewing directions.

The incidence of visual impairments also increases with age. Central vision may be poor, leading to difficulties in detailed work, such as reading or rec ognition of faces, as well as difficulty locating door handles or light switches. Peripheral vision loss *('tunnel vision')* may cause difficulties in orientation and navigation. Consequently, good use of contrast, e.g. between door handle and door, and between door and doorframe is likely to be helpful.

While most elderly people will benefit from increased lighting, this may cause difficulties for others. A cataract, for example, is progressive and causes cloudiness of the lens of the eye. If the cataract is located centrally within the lens, excessively high levels of lighting will close the pupil to the extent that it will prevent light entering the eye. Less light will allow the pupil to dilate and may allow objects to be distinguished better.

Lighting should be designed to produce a generally domestic atmosphere. In lounges, dining rooms and bedrooms an average illuminance of about 200 lux should be provided at table level *(approximately 0.7 m above the floor)* by decorative types of luminaire. Selective switching or dimming should be available to allow for different activities to take place; e.g. the same room where meals are eaten may be used to watch tv, when a lower lighting level may be preferable

Local areas of higher illumination can be introduced by floor-standing luminaires or table lamps; this will allow for further variation and assist partially sighted residents by enabling them to suit the lighting to their own eye conditions and to carry out the activities of their choice. More area-focused forms of task light can be provided on desks or work tables where craft or writing/reading tasks are carried out.

The lighting of ramps, stairs, doorways and corridors is important; white nosing on stairs can be helpful, as can contrasting colours on handrails, doors and frames. The aim is to provide good lighting without glare to enable elderly people to move around from their bedrooms to dining rooms, lounges and toilets as easily as possible.

Incidence of dementia increases with age. The lighting should help to provide a reassuring atmosphere.

Lighting should be designed to give simple information about the space and avoid producing distorted shadows or random areas of highlighting that might be perceived as confusing or threatening.

However, *the Lighting Guide is too general to provide for the special needs associated with normal age-related changes to the eyes*. For example, all areas shall be well lighted for the safety and comfort of the residents according to the nature of activities. Without specific minimum target illuminance values to guide code officials, lighting designers and inspectors, the desired intent is not achieved. *What may be judged by a younger person to be "safe and comfortable" will not be adequate for an older adult.*

2.2 Accessible Design Guideline for elderly and visually impaired people

It is an important goal for the whole of society that all people have access to products, services, workplaces and environments. The issue of accessibility to and usability of products and services has become more critical with the increasing percentage of older persons in the world's population. While not all older persons have disabilities, the prevalence of disability or limitations is highest among this demographic group.
For many years, standards bodies at the national and international level have addressed the needs of persons with disabilities in the development of specific standards in the area of assistive technology and accessible building design. However, the needs of older persons and persons with disabilities are not being adequately addressed when other relevant standards for everyday products and services are written or revised. Standards bodies are starting to address ageing and disability issues and will, increasingly, develop and implement policies and programmes in their products and services to include the needs of older persons and persons with disabilities. It is important to ensure the representation of interests of older persons and persons with disabilities in the development of these solutions.
This global movement has therefore reflected on international standards organizations such as ISO, IEC and the CIE developing and writing appropriate accessibility requirements and recommendations in their standard.
To spread this excellent concept among standards developers, ISO and IEC jointly published a general guide ***(ISO/IEC Guide 71)*** on **Accessible Design** in 2001, titled *"Guidelines for standards developers to address the needs of older persons and persons with disabilities"*, which was replaced by the second edition in 2014, retitled *"Guide for addressing accessibility in standards"*. This Guide, like its predecessor, is intended to be part of the overall framework that standards bodies can use in their efforts to support the development of systems that suit the needs of diverse users. The purpose is to assist standards developers (e.g. technical committees or working groups) to address accessibility in standards that focus, whether directly or indirectly, on any type of system that people use. However, while its intended audience are standards developers, *this Guide contains information that can also be useful to other people, such as manufacturers, designers, service providers and educators.*

ISO/IEC Guide 71
It is necessary to increase understanding and raise awareness about how human abilities impact on the usability of products, services and environments encoun-

tered in all aspects of daily life. Based on their individual abilities and characteristics, people's accessibility needs vary substantially and change throughout the course of their lives *(i.e. as they advance from childhood to adulthood and on into old age).* Impairments can be permanent, temporary or vary on a daily basis, and sometimes they are not fully recognized or acknowledged. In addition, although some limitations can be minor in nature, combinations of limitations can pose significant problems for individuals attempting to interact with systems. This is the case particularly where user accessibility needs and accessibility requirements were not recognized during development of those systems. Standards that include accessibility requirements can support development of systems that can be used by more users.

Accessible systems are particularly helpful when environmental context of use conditions *(such as light intensity, noise or busy activity of nearby people)* are unfavourable. Activity limitations and participation restrictions can be experienced by all people and can be the result of unsuccessful interaction between individuals with impairments or health conditions and barriers such as personal and environmental factors. Health conditions *(e.g. circulatory, respiratory, neurological)*, impairments in body functions and structures and related limitations can be temporary or permanent, not visible and generally increase with age. It is important to recognize that sensory, physical and cognitive limitations vary from comparatively minor *(such as mild hearing loss, mild seeing impairment, mild mobility impairment or mild memory loss)* to significant limitations *(such as deafness, blindness, paralysis or significant memory loss). Clause 7* of this Guide provides information on human abilities and characteristics and the consequences of impairments, including respective design considerations that should maximize accessibility for users. *The Guide talks specifically about seeing function in the Clause 7.2.2.*

Seeing Functions(Clause 7.2.2.)

Seeing functions relate to sensing the presence of light and sensing the form, size, shape, contrast and colour of visual stimuli, as well as discriminating the location, distance and speed of objects. The seeing function comprises a variety of aspects *such as visual acuity, near and distant vision, accommodation to changes in focus, field of vision, perception of colour and distance(or depth), adaptation to changes in light levels and sensitivity to light.*

Impairments and Limitations

Impairments and limitations can range from slight seeing impairments to complete blindness. Effects of impairments and limitations *include:*

-reduced ability to see images distinctly;
-reduced ability to change focus from near to distant objects, and vice versa;
-reduced ability to see things in one part of the field of vision *(i.e. to the side, top, bottom or centre);*
-reduced ability to distinguish colours, including effects due to age-related yellowing of the lens of the eye;
-increased sensitivity to glare;
-increased sensitivity to flashing lights or flickers;
-reduced ability to see contrast;
-reduced ability to judge distances and speed;
-reduced ability to see while the eye adjusts to different lighting levels;
-reduced sensitivity to light so that more light is needed to see.

Persons with blindness are considered to have very limited or no useful visual abilities and can rely on other sensory functions, such as hearing and touch, to obtain information.

Persons with seeing impairments can receive insufficient or distorted visual information and rely on auditory and tactile stimuli. Factors such as size, clarity *(per se as well as in relation to surrounding factors including positioning and prominence in relation to field of vision)*, luminance and colour contrast can affect perception. Persons with significant seeing impairments*(low vision)* often require a higher contrast. They use other sensory functions such as hearing and touch functions to supplement visual information.

Adverse environmental conditions, such as poor lighting, smoke and fog, can reduce visibility and present many of the same types of effects listed above for many persons.

Design considerations

Design considerations that can facilitate accessibility include the following:

-*Provision of lighting* - Appropriate lighting ensure that those with a visual impairment are better able to see instructions and controls.

-*Consideration of ambient lighting* - The likely lighting levels in typical use should be considered, for example television controls may be operated in a darkened room, installation of a product may be in a dark space.

-*Buildings* - Adjustability of lighting levels in a building is desirable to suit different needs but sudden changes in lighting levels should be avoided.

-*Avoidance of glare* - Too high light levels and strong directional light can result in deep shadows or glare. Reflecting surfaces on information panels and glossy paper in instruction books or on packaging containing warnings should be avoided, to reduce the possibility of glare.

-*Appropriate size, contrast, form, luminance, lighting and viewing distance* in relation to context of use.

-*Colour and contrast* - Choice of colour is important for ease of recognition and ease of seeing. Some colour combinations are also more effective. For example some colours, such as red/green, are not distinguishable by a significant minority of the population *(those with colour blindness)*. The best colour combinations depend on the purpose of information, whether it is for guidance or a hazard warning, and the lighting conditions under which it is most likely to be viewed. For example, black on yellow or light grey are general purpose combinations which provide strong definition without too much glare, pastel shades on pastel backgrounds or red lettering or symbols on light grey are difficult to see and should normally be avoided.

-*Information, warnings and labelling* - Appropriate physical construction and properties of fonts such as size, spacing, with or without serif, upright form or italics, and light, medium or bold appearance within a specific context of use. The required size of font for information, warnings and labelling of controls, relates to the probable viewing distance, level of illumination and colour contrast of the text against its background. The choice of font, whether with or without serif, in upright form or italics and light, medium or bold appearance also has a significant impact on legibility. Standards developers should also be aware that text written in CAPITAL letters is more difficult to read. This is significant for those with a visual impairment. Consideration should be given to specifying size and style of font and symbols for warnings.

*The guidelines are an informative document and can be useful for lighting designers who try t**o implement accessible design**.* Various factors for better lighting and visual environment for older people and people with low vision are considered on the bases of vision data of them. Those information can be effectively used for accessible design in lighting *in terms of illuminance, colour combination, and size and location of visual signs in order to respond to ISO/IEC Guide 71*[31]*.*

31 K. Sagawa, Vision of the elderly and visually impaired -for Accessible Design in Light and Lighting, 26th Session of the CIE Beijing, 2007. Chapter 1.1 Case Study.

“Not just see, you have to see well”
[Lucia R. Ronchi, Visione e illuminazione alle soglie del 2000, Vol. 1, 2000]

Section II

Understanding Light and its interaction with Humans

Chapter 3 **Lighting Design Role**

Light has always been recognized as one of the most powerful formgivers available to the designer, and great architects have always understood its importance as the principal medium which puts man in touch with his environment. In 1927, for instance, Le Corbusier stated that "Architecture is the masterly, correct and magnificent play of masses brought together in light".

After centuries of painstakingly and often ingeniously manipulating our buildings to suit the vagaries of natural light, we find, paradoxically, that we have very little aptitude for manipulating our new wealth of artificial light to suit the vagaries of our buildings.

When all buildings were designed around a single, fixed light source – the sun – the difference between great architecture and mere building could be measured to a large degree by the skill with which that sources was used. The shapes and sizes of rooms, and the materials and details in them, were determined largely by the appearance the room would take on when rendered by daylight. Light was not always simply applied to struc-

tural innovations; more often, the structures themselves were developed to make possible desired lighting and spatial effects.
Now, finally, we have artificial sources which are not only easier to control than daylight, but can also light interior spaces far more brightly. Theoretically, the possibilities for imaginative lighting are limitless. And, in theory, our ability to create great architecture should have increased in proportion to the availability of more, and more versatile, artificial sources. Designers, faced with an extraordinarily rapid turnover of products and a fast, fragmented process of design and construction which has taken root in this electronic age, have yielded the control which they once exercised over the luminous environment to other. This abdication of design responsibility – conscious or unconscious – by the designer must be reversed. Lacking an understanding of the basic principles involved, *the technicians who now control our luminous environments have reduced the criteria for illumination to simple numbers, which are basically unrelated to vision, perception, comfort, or pleasure.* This blind worship of specific levels of illumination is all too often directly responsible for the defeat and compromise of good designs. If the initial design concept is stated correctly in perceptual terms, so that the type, configuration, and placement of light sources reinforce and facilitate an awareness of information required to satisfy biological needs while proving appropriate qualities of illumination for activities needs, then the actual level of light delivered becomes far less critical. *Illumination levels should be a matter of design intent and budget availability and priorities, not merely a response to unjustifiable and often misconceived legal and programmatic requirements.* A verbal statement of ***the design concept*** as it *relates to user needs will be more complete and more likely to produce a good luminous environment than an a priori prescription of numbers.* Once one understands that the brain analyzes and perceives the entire visual field, and not its individual aspects, the irrelevance of single-parameter numerical criteria is immediately apparent.

Once minimal levels of illumination have been achieved, additional light is generally not the most effective means of increasing visibility and visual comfort. In those circumstances where further increasing the quantity of light will produce significant benefits the increase must be substantial. Absolute luminance levels do have a relationship to sensations of glare and distraction, but it is the *patters of light sources* and the nature of *their relationship to other elements in the visual field* which largely *determine* ***the overall quality of the luminous environment***.
Calculation of specific levels of illumination is much less important in lighting design than consideration of the quality of illumination in terms of its distribution and characteristics, the information conveyed by the pattern of the sources, and the degree to which they reinforce or contradict the relationships established by the architecture and the planned activities. Today our most comfortable, pleasant spaces are those in which the designer and users retained control over the layout and fine-tuning of the lighting: spaces such as churches and museums, stores and restaurants, in which objects of interest are appropriately emphasized by the luminous environment and set against background free from visual noise. The lighting in private homes is generally satisfactory and pleasant for the same reason – it has usually been designed and adjusted by the users to suit their specific needs for visual information, not to achieve some mandatory prescribed light levels.
All spaces *should be designed and lighted to satisfy specific needs, not just engineered to meet code requirements – different lights, as it were, for different sites.*
If the perception process, the nature of people's needs for visual information, and the characteristics of a good luminous environment are clearly understood, the need for new design criteria and a new design process becomes equally clear. ***"Lighting design"*** *is one of the architect's most useful and potent design tools; the design of human environment is, in effect, the design of human sensory experience; all visual design is de facto also lighting design.*

3.1 The Function of Illumination

"Light performs these basic functions: decorative, accent, task and ambient(general) – the well integrated layering of the four within each space will create a unified design."

[Winchip S. M., Designing a Quality Lighting Environment, Fairchild Books, 2004]

The new developments in lighting have created opportunities for approaches to ways of creating illumination that have only been dreamed of in the past. Lighting technology has greatly evolved from the times of table lamps and track lights, yet many homeowners have not updated their thinking much beyond that stage. We can now achieve lighting effects that are as flexible as our lifestyles, energy-efficient, and less intrusive in remodel situations. Plus we can do it within a reasonable budget, without dramatically changing the way we live. At the same time we can increase the comfort and convenience level in our living spaces.

Lighting can be a tremendous force in architectural, interior, and landscape design. It is the one factor that helps blend all the elements together. Yet, it has for too long been the second-class citizen of the design world. The results have left many homes drab, uncomfortable, and dark. Often the blame goes elsewhere when improper lighting is the culprit causing the discomfort. *Helping people become aware of what lighting can do is the first step. Most of us simply accept what light there is within a given space instead of realizing that we can change and improve the situation.*

Quality lighting can allow users to simultaneously function comfortably in a space, feel safe, and appreciate the aesthetic components of the interior. *Achieving **a quality lighting environment** requires complete control over the lighting system.* Environments with quality lighting are specifically designed for the client, users, architectural features, site, and location. This environments reflect a skillful application of the principles of design by integrating and layering light into the entire composition. ***Layered Lighting** includes natural light and multiple electrical light sources.*

Light in a space has four specific duties: to provide decorative, accent, task, and general illumination.[1] *No single light source can perform all the functions of lighting required for a given space.* Understanding these differences will help you create cohesive designs that better integrate illumination into your overall plan.

1 Randall Whitehead, Residential Lighting. A Practical Guide, John Wiley & Sons Inc, 2004

Winchip S. M., Designing a Quality Lighting Environment, Fairchild Books, 2004

Decorative Light

"Luminaires that provide illumination and are also artistic piece"

[Winchip S. M., Designing a Quality Lighting Environment, Fairchild Books, 2004]

Luminaires such as chandeliers, candlestick-type wall sconces, and table lamps work best when they are used to create the sparkle for a room. They alone cannot adequately provide usable illumination for other functions without overpowering the other design aspects of the space. Think of them as the "supermodel" of illumination. Their one and only job is to look fantastic. Another way to visualize them is as architectural jewelry.

For example, a dining room illuminated only by the chandelier over the table can create a glare-bomb situation. *(Figure 2.1)*. As you turn up the dimmer to provide enough illumination to see, the intensity of the light from the decorative fixture causes every other object to fall into secondary importance. The wall colour, the art, the carpeting, and especially the people are eclipsed by the supernova of uncomfortably bright light. No one will able to see any of the other elements in the room, no matter how beautiful or expertly designed.

By its very nature, any bright light source in a room or space immediately draws people's attention. In the best designs, the decorative light sources only create the illusion of providing a room's illumination. In reality, it's the other three functions of light that are actually doing the real work of lighting up the space.

Filling a room with only table lamps to provide the main source of illumination is bad lighting design, as it uses only one available light source. The other three functions of illumination must come into play. This is called "light layering", where a number of light sources are blended together to create a comfortable, inviting environment.

Figure 2.1 Decorative Lamp Drawing Concept.

Accent Light

"Illumination designed to highlight an object or area in a space"

[Winchip S. M., Designing a Quality Lighting Environment, Fairchild Books, 2004]

Figure 2.2 Accent Lamp Drawing Concept.

Accent light is directed illumination that highlights objects within an environment. Luminaires such as track and recessed adjustable fixtures are used to bring attention to art, sculpture, tabletops, plants etc..*(Figure 2.2)*. When considering lighting a space, the human eye is attracted to bright objects. By contrast, dark areas are of limited attraction but we need of them to accentuate(through the contrast) the brighter objects of interest.

Just like any of the other three functions, accent light should not be the only source of illumination in a room.

If you use only accent light, you get

the museum effect, where the art visually takes over the room while guests fall into darkness. You may compromise on a more layered design that provides some ambient light. People can get really exhausted when looking at illuminated art next to non-illuminated walls. Even museums are now additional illumination beyond accent light to help reduce eye fatigue, thus cutting the contrast in the overall environment.
Remember that accent lighting thrives on subtlety. A focused beam of light – directed at an orchid or highlighting an abstract painting above an ornate chest of drawers – can create a wondrous effect. People will not notice the light itself. They will see only the object being illuminated.
We want to see the effects of light, but the method needs to remain unseen. This subtlety is what will create a cohesive wholeness, allowing the design, the architecture, the furnishings, and the landscaping to become the focus of a space, not the luminaires or the lamps glaring out from within them.

Task Light

"Illumination that is specific for each task that is performed in a space"

[Winchip S. M., Designing a Quality Lighting Environment, Fairchild Books, 2004]

Task light is illumination for performing work-related activities, such as reading, cooking, sorting laundry ect.. the optimal task light is located between your head and the work surface. That's why lighting from above is not a good source of task light, because your head casts a shadow onto your book, computer keyboard, or ransom note.
Overhead lighting or incorrectly placed task lighting often contributes to what is called veiling reflection. It occurs when your eyes try to accommodate the contrast between black print on white paper. This happens when light comes down from the ceiling, hitting the paper at such an angle that the glare is reflected directly into your eyes, causing eye fatigue. Think of it as the mirror-like reflection of a light source on a shiny surface. The plane may be a glossy magazine page or any matte surface that has marking or shiny ink, pencil lead, or other glossy substance. Veiling reflection is a way of describing the resulting brightness that washes out the contrast of the print or picture. The term comes from an uncomfortable situation where you are trying to read something while wearing a veil.
Another related term is photo-pigment bleaching. When you try to read a book or a magazine outside, sometimes the brightness of the sunlight on the page makes it difficult to read. You end up moving to a shaded spot or tilting the magazine until the sun isn't hitting it directly.
A reflective surface is always a reflective surface, which means you can not eliminate glare if you are focusing light onto a mirror-like finish. What you can do is redirect the glare away from the normal viewing angle. That's why a light coming in from one side or both sides, instead of directly overhead, is more effective. It directs the glare away from your eyes. The best task light comes from a light source that is located between your head and your work surface. *(Figure 2.3)*.

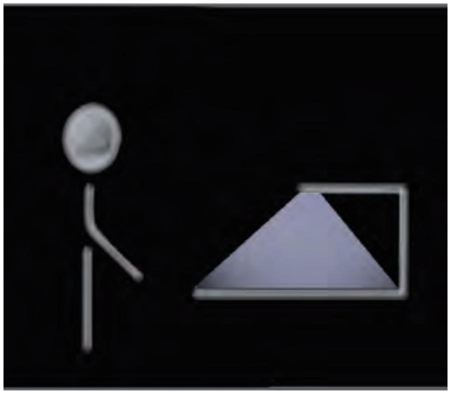


Figure 2.3 Task Lamp Drawing Concept.

Ambient Light

"Overall illumination in a space, including lighting that allows people to walk safely through a room and sets the mood or character of the interior"

[Winchip S. M., Designing a Quality Lighting Environment, Fairchild Books, 2004]

Ambient light is the soft, general illumination that fills the volume of a room with a glow of light and softens the shadows on people's faces. It is the most important of the four functions of light, but it is often the one element that is left out of the design of a room or space.

The best general light comes from sources that bounce illumination off the ceiling and walls. Such omni-directional lamps as pendants, chandeliers, ceiling or wall-mounted fixture can provide a subtle general illumination without drawing attention to them. Keep in mind that filling a room with table lamps does not ensure adequate ambient illumination. These are decorative fixture that can double as task lights when needed, but they cannot provide ambient light. Utilizing other sources to give the necessary ambient light lets decorative luminaires create the illusion of illuminating the room without dominating the design. There are many ways of getting ambient light into a room. General light, just like the other three functions, should not be used by itself, because you end up with what is known as the cloudy day effect, where everything in a given space appears to have the same value, without any depth or dimension. *(Figure 2.4)*. Here again, ambient illumination is only one component of well-designed lighting.

Figure 2.4 Task Lamp Drawing Concept.

Identifying light sources for each purpose provides the users of the space with the flexibility of selecting and adjusting the lighting for the specific activities, <u>especially for the areas where take place more than one task</u>(e.g. relaxed entertaining, media viewing, reading/writing, general activity). There is no 'best' lamp for all applications. Of the many alternatives, each has advantages and disadvantages: ***good design*** *uses an appropriate lamp/light fixture for each application.* Once you have a good understanding of the functions of light, you can decide which are need for a specific area, and for people who will live it. ***With the focus on quality****, lighting is no longer an afterthought that is added to a design plan.*

Chapter 4 Light, Colour and Perception

***Color** was identified as an important element in integrating and controlling daylight and electrical lights.* Generally, people perceive daylight to reveal an object's "true" colour. However, weather conditions, reflections, and the time of the day can affect colour. Changes in colour resulting from a light source greatly affect the work of an interior designer. This is especially challenging with electrical light sources.

Specifying a lighting system that will enhance the desired colour scheme of an environment requires a basic understanding of *the physics of the eye* and *the physics and the theory of the colour*. Knowing these basic concepts provides the foundation for understanding the technical and aesthetic attributes associated with specifying light and colour.

The human eye

From a strictly physical point of view, the human eye is a complex sensory organ which convert the light energy it receives from the spatial and temporal relationships of objects in visual space into electrical signals for processing by the brain.
The human eye system can be considered as being structured into two specialized interacting sets of components*(Figure 2.5)*:

- the optic components*(cornea, crystalline lens, pupil and intra-ocular humours);*
- the neutral components*(retina and optic nerve).*

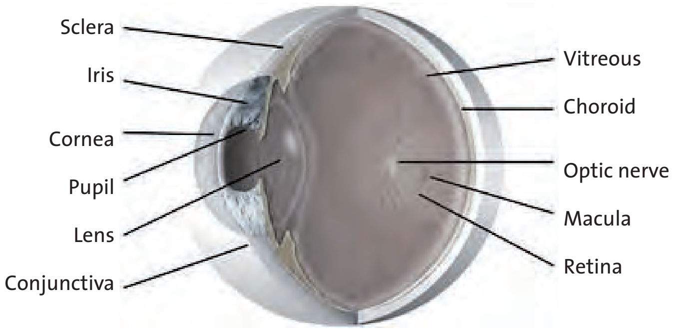


Figure 2.5 Human eye.

When light rays from an object pass through the cornea, the lens, and the vitreous body, they are reflected so that an inverted image is formed on the retina, which is a light-sensitive film. The rays are focused on the macula lutea, the retinal region where cones are numerous. **Cone photoreceptors** contain pigments which make them sensitive to colour. In dim light, we depend more on **rod photoreceptors** vision. These cylindrically-shape receptors are distributed throughout most of the retina. Both rods and cones contain photosensitive pigments whose chemical structure alters in the presence of light. The changes occurring in rods and cones in turn trigger electrical impulses in nerve cells in the retina, which are then transmitted to the optic nerves of the brain.
Central(foveal) vision permits one to see much finer detail than peripheral vision; it represents the detailed visual acuity of the eyes. Foveal vision also provides the most acute colour discrimination because of the concentration of cones. The ability to discriminate among wavelengths of light is believed to be due to a combination of photo-chemical and neurological processes. Human colour vision is trichromatic(red, green or blue), that is, it is based on the three different cone photoreceptors. The photoreceptors are characterized by having different wavelengths for peak sensitivity, but all have a broad spectral sensitivity and show considerable overlap*(Figure 2.6)*.

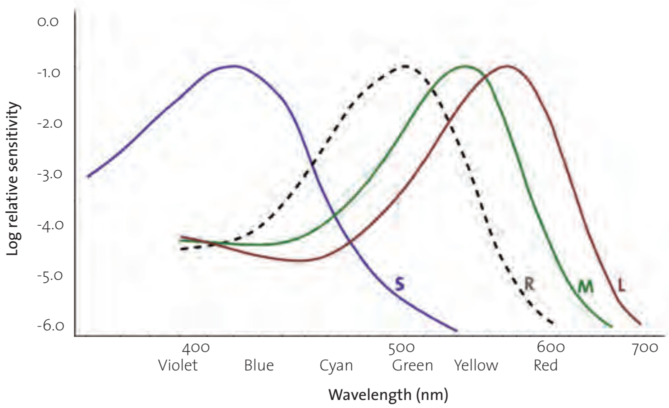


Figure 2.6 The log relative spectral sensitivities of long (L), medium (M) and short wavelength (S) cone receptors(L-M-S)

Signals from three cone types are coded in the retina and the lateral geniculate body(in the brain) into chromatic information and achromatic. The chromatic information is a result of a subtraction of incoming signals, while the achromatic information(luminance) is a result of an additive mechanism.
The outputs of the middle and long wavelength cone system(receptor levels) are in fact summed to provide luminance information; the short wavelength cones are believed to contribute negligibly to lumi-

nance information; while chromatic information is derived from defining difference in the output of the three cone systems and the combined *perception is a mixture of the chromatic and achromatic channels (Figure 2.7 and 2.8)*.

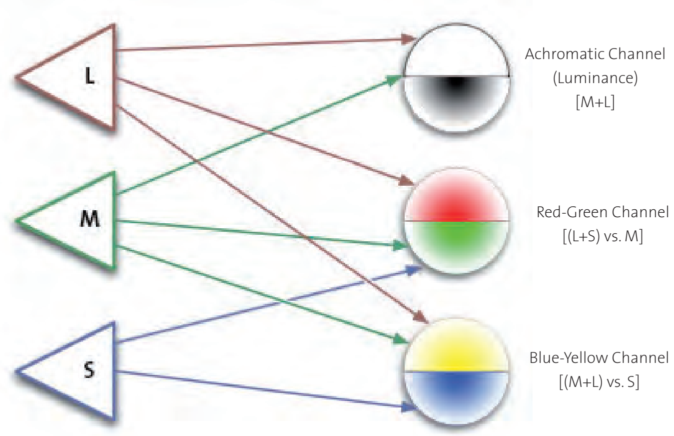


Figure 2.7 The organization of the human colour system showing how the three cone photoreceptor types(L-M-S) feed into one achromatic, non-opponent channel and two chromatic, opponent channels.

Figure 2.8 Visual deficits to perceive the colour.

The cornea and lens focus light on the multi-layered retina which transmits impulses through the optic nerve to the brain. The size of the pupil, the greater amount of light admitted into the eye. Under conditions of high luminance, the iris reduces the size of the pupil so less light is admitted. The ability of the eye to control the amount of light it admits and to change the sensitivity of the retina is called **adaptation**. When the visual system is adapted to a given luminance, much higher luminances appear as glaringly bright, while much lower luminances are seen as black shadows *(Figure 2.9)*.

The ability of the eye to focus light on the retina from one distance to another by changing the shape of the lens is instead called **accommodation**.

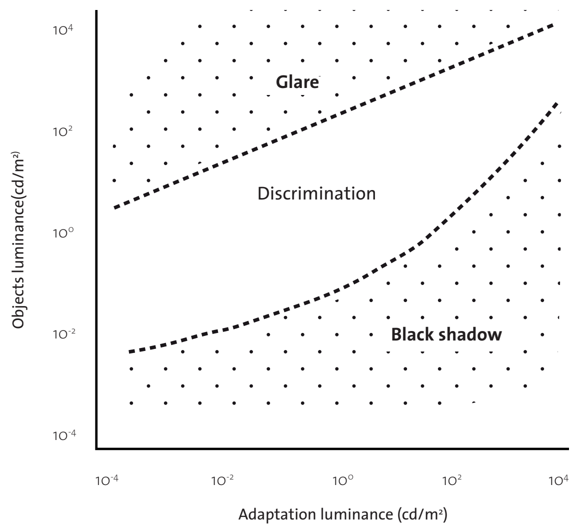


Figure 2.9 A schematic illustration of the range of object luminances within which discrimination is possible for different adaptation luminances.

The eye can detect over five million colours. All these colours are affected by numerous factors, but, most important, the perceived colour is influenced by its light source. Colour cannot be seen without light.

*To create **quality lighting** in an environment, a designer must have a thorough understanding of colour and how light sources affect perceptions of colour.*

Scientist Isaac Newton demonstrated that a beam of white or natural light could be dispersed through a prism into a spectrum of colours *(Figure 2.10).*

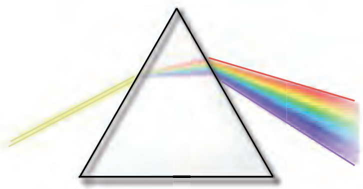


Figure 2.10 Light dispersed through a prism into a spectrum of colours.

To the physicist, light is simply part of the electromagnetic spectrum that stretches from cosmic rays with wavelengths of the order of femtometres to radio waves with wavelengths of the order of kilometres *(Figure 2.11)*.

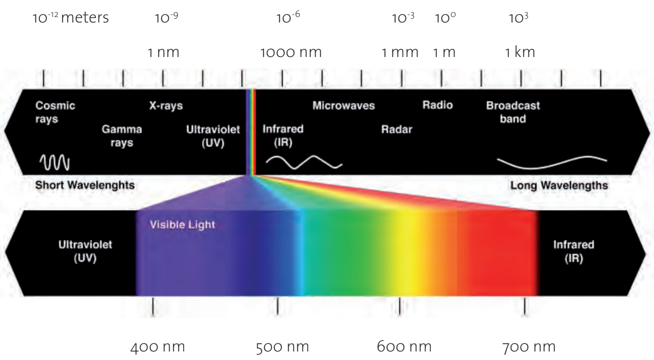
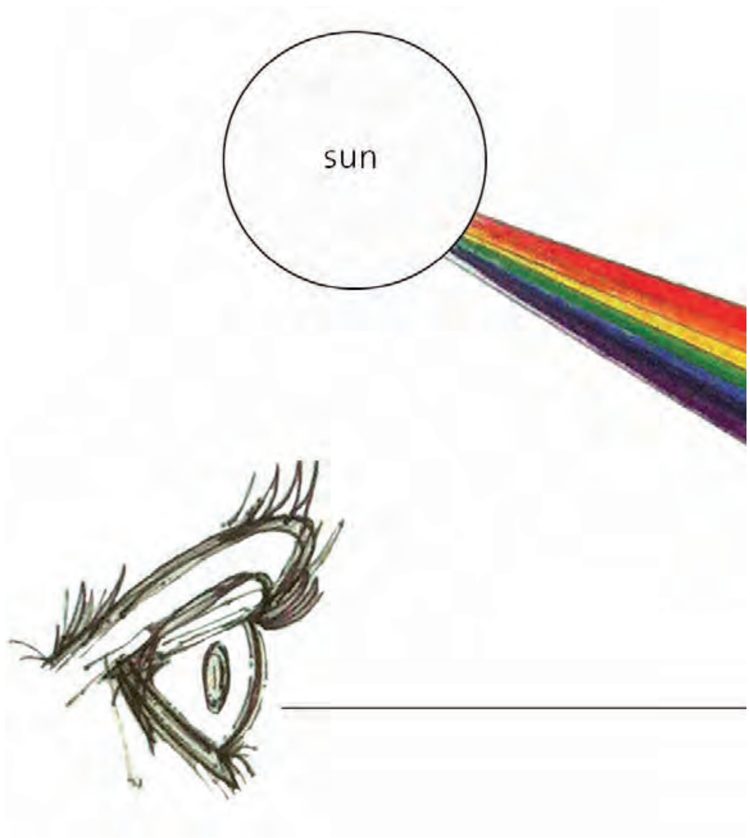


Figure 2.11 A schematic diagram of the electromagnetic spectrum showing the location of the visible spectrum. The divisions between the different type of electromagnetic radiation are indicative only.

What distinguishes the wavelengths region between **380** and **780 nm** from the rest of the electromagnetic spectrum is the *response of the human visual system*. Visual Photoreceptors in the human eye absorb energy in this wavelength range and thereby initiate the process of seeing. Colour vision is possible due to photoreceptors in the retina of the eye known as cones. These cones have light sensitive pigments that enable us to recognize color. Found in the macula, the central portion of the retina, each cone is sensitive to either red, green or blue light, which the cones recognize based upon light wavelengths. The absorption and reflectance properties of a light source and an object determine the colour we see. An object appears red because it absorbs the other colours in the spectrum, and red is reflected to the eye. *(Figure 2.11).*



The wavelengths of daylight vary according to the time of the day, sky condition, time of the year, and geographic location. Northern daylight has more blue and green wavelengths than does southern daylight; this results in a cooler appearance. This facts are important when a lighting designer selects a light source. If a light source does not have a balanced spectrum of colours, the colour of object being illuminated will be altered. For example, some 4100K fluorescent lamps have few wavelengths at the warm end of the spectrum, such as reds and oranges. When a red object is placed under this source, the red colour appears subdued. This occurs because the uneven distribution of wavelengths produced by the lamp does not allow much of the red to be reflected to the eye.

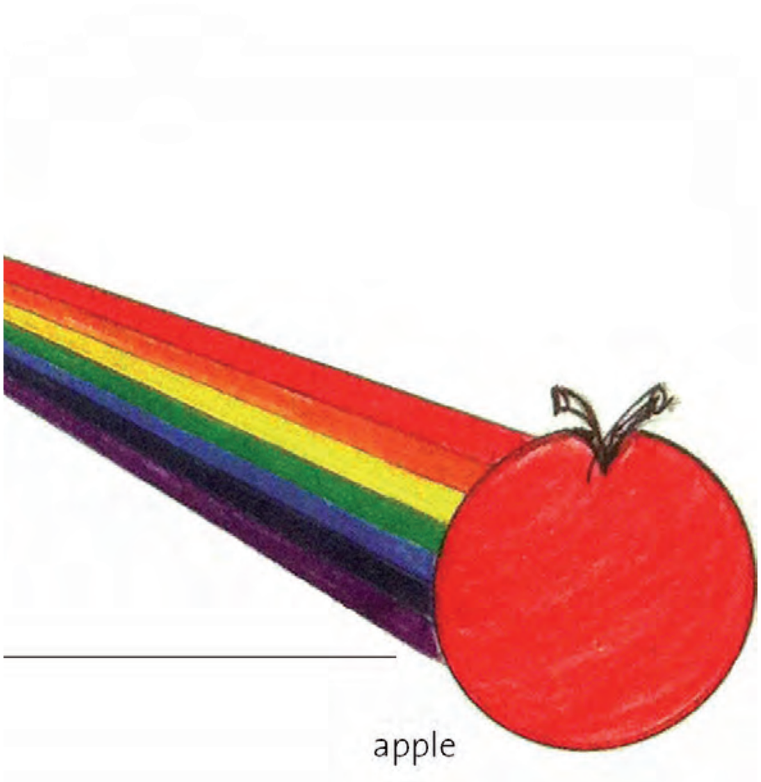


Figure 2.12 This object is red, due to the absorption of the other colours in the spectrum, and red is reflected to the eye.

Colour theory

Properties of colour are its hue, value, and intensity. **Hue** is the colour itself. Blue is a hue. Hues at the red end of spectrum are considered warm colours and are associated with warm elements in nature. Hues at the violet and blue end of the spectrum are viewed as cool colours. Cool elements of nature are associated with these colours. In order for colours to remain the desired red, or blue, the designer must select a lamp that will enhance a colour that is in either the warm or the cool spectrum.

Hue vary depending upon changes in their value and intensity. The **value** affects the lightness and darkness of a colour. Adding either white or black changes the value of colour. Navy blue has a dark value of the blue hue. Light blue has a light value of the blue hue.
The **intensity** is the strength or purity of the colour. Colours as they appear on the last circle of the colour wheel*(Figure 2.13)* are at full intensity. Adding the colour's complement decreases a colour's intensity. The complement of a colour is the colour directly across from another on the colour wheel. Thus, the complement of blue is orange. To reduce the intensity of blue, one would mix it with orange.

Figure 2.13 Colour wheel

If instead, we put close two complement colours we get effect of maximum contrast enhancing brightness of both. By studying the characters and the most characteristic colour effects, Johannes Itten settled seven distinct types of contrast, with such different laws. In addition to the contrast between complementary colours, he defined contrast of: pure colours*(hue)*, light and dark, cold and warm, simultaneity, saturation and extension.

Primary Colours

Secondary Colours

Terziary Colours

Complementary
Colours

Split-Complementary
Colours

Analogous
Colours

Triadic
Colours

Rectangular
Colours

Square
Colours

Itten's Colour Contrasts

The contrast of hue: The contrast is formed by the juxtaposition of different hues. The greater the distance between hues on a color wheel, the greater the contrast.

The contrast of light and dark: The contrast is formed by the juxtaposition of light and dark values. This could be a monochromatic composition.

The contrast of warm and cool: The contrast is formed by the juxtaposition of hues considered 'warm' or 'cool.'

The contrast of complements: The contrast is formed by the juxtaposition of color wheel or perceptual opposites.

Simultaneous contrast: The contrast is formed when the boundaries between colors perceptually vibrate. Some interesting illusions are accomplished with this contrast.

The contrast of saturation: The contrast is formed by the juxtaposition of light and dark values and their relative saturation.

The contrast of extension: Also known as the Contrast of Proportion. The contrast is formed by assigning proportional field sizes in relation to the visual weight of a color..

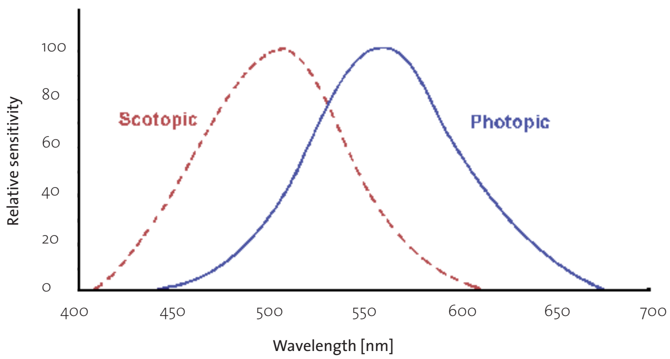


Figure 2.14 Relative luminous efficiency functions for the CIE standard scotopic observer, the CIE scotopic observer.

As mentioned earlier, the human retina has two classes of visual photoreceptors, one class operating when light is plentiful, in what are called **photopic conditions** *(cone photoreceptors)*, and the other operating when light is very limited, in what are called **scotopic conditions** *(rod photoreceptors)*. *(Figure 2.14)*.

For the photopic one, there are *specific quantities,* ***photometric*** *and* ***colorimetric***, which describe the visual effect of light.

PHOTOMETRIC QUANTITIES

The most fundamental measure of the electromagnetic radiation emitted by a source is its radiant flux. This is a measure of the rate of flow of energy emitted and is measured in watts. The most fundamental quantity used to measured light is luminous flux. **Luminous flux** is used to quantify the total light output of a light source in all directions. While this is important, for lighting practice, it is also important to be able to quantify the luminous flux emitted in a given direction. The measure that quantifies this concept is **luminous intensity.** Luminous intensity is the luminous flux emitted per unit solid angle, in a specific direction. The unit of measurement is the candela, which is equivalent to one lumer per steradian. Luminous intensity is used to quantify the distribution of light from a luminaire. Both luminous flux and luminous intensity have area measured associated with them. The lumionous flux falling on a unit area of a surface is called the **illuminance**. The unit of measurement of illuminance is the lumens/square meter or lux. The luminous intensity emitted per unit projected area of a source in a given direction is the **luminance**[lumens/square meter]. The illuminance incident on a surface is the most widely used electric lighting design criterion. The luminance of a surface is a correlate of its brightness. As might be expected, there is a relationship between the amount of light incident on a surface and the amount of light reflected from the same surface. The nature of the relationship depends on the characteristics of the reflecting surface. For a diffusely reflecting surface, **reflectance** is defined as the ratio of the reflected luminous flux to the incident luminous flux. For a non-diffusely reflecting surface, that is, a surface with some specularity, the same equation between luminance and illuminance applies but reflectance is replaced with luminance factor. **Luminance factor** is defined as the ratio of the luminance of the surface viewed from a specific position and lit in a specified way to the luminance of a perfect white diffusely reflecting surface viewed from the same direction and lit in the same way. It should be clear from this definition that a non-diffusely reflecting surface can have many different values of the luminance factor. Table 2.1 summarizes these definition.

Measure	**Definition**	**Units**
Luminous flux	The quantity of radiant flux which expresses its capacity to produce visual sensation.	Lumen[lm]
Luminous intensity	The luminous flux emitted in a very narrow cone containing the given direction divided by the solid angle of the cone, that is, luminous flux/unit solid angle.	Candela[cd]
Illuminance	The luminous flux/unit area at a point on a surface.	[lm/m^2]
Luminance	The luminous flux emitted in a given direction divided by the product of the projected area of the source element perpendicular to the direction and the solid angle containing that direction, that is, luminous intensity/unit area.	[cd/m^2]
Reflectance	The ratio of the luminous flux reflected from a surface to the luminous flux incident on it.	
Luminance Factor	The ratio of the luminance of a reflecting surface viewed from a given direction to that of a perfect white uniformly diffusing surface identically illuminanted.	

Table 2.1 Photometric quantities

The photometric quantities can be calculated or measured precisely, it is important to appreciate that they *only represent the visual effect of light in a particular state.* Specifically, they represent the bringtness response of the central of the retina, that is, the fovea, in high light level conditions. *Changing the location, field size or light level of the stimulus can change the spectral sensitivity of the visual system.*

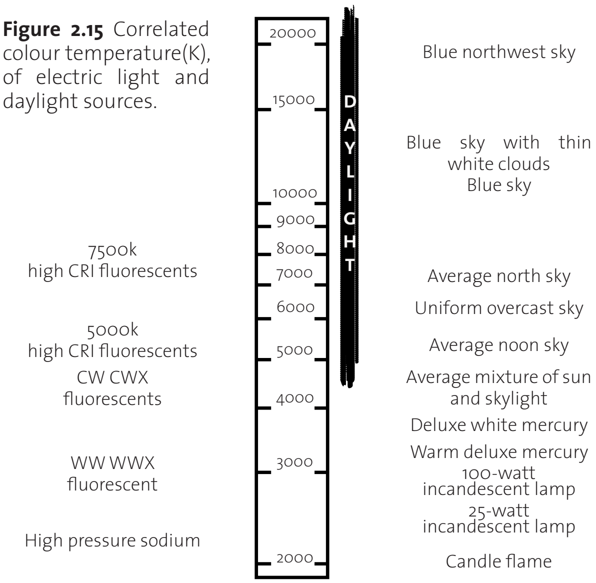
COLORIMETRIC QUANTITIES

In specifying a quality lighting system, a designer selects lamps that will enhance the colours in the environment. To assist designers with the lamp selection process, lamp manufacturers provide data about lamp colour specifications, such as chromaticity ratings and the colour-rendering index.

Chromaticity

The chromaticity, or the colour temperature, of a light source helps to create the atmosphere of a space and often reflects the quality of the interior. It indicates the degree of red or blue of a light source and it is measured by kelvins*(K)*. On a Kelvin scale, the warmer the apparent colour of a light source, the lower the number of kelvins will be. A higher number on the scale represents a cooler or blue colour. Generally, an interior that has a warm glow will have a relatively low chromaticity rating*(3000K)*. In contrast, an interior that appears to be cool and bright will have a relatively high chromaticity rating*(4100K)*. In an attempt to measure colour, an international or-

Figure 2.15 Correlated colour temperature(K), of electric light and daylight sources.



ganization for colour, CIE *(International Commission in Illumination)*, developed a diagram with colours ranging from red to violet, plotted on x and y axes *(Figure 2.16)*.

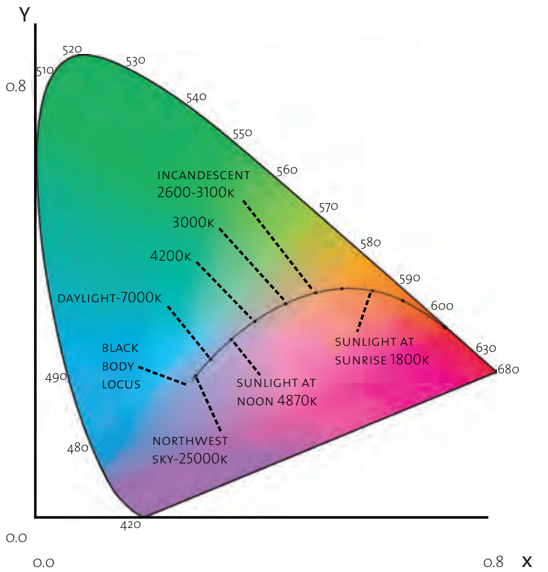


Figure 2.16 Chromaticity diagram for natural and artificial light sources.

The diagram represents correlated colour temperature *(CCT)*. The mathematics of the colours form the triangular-shaped diagram. The wavelengths of colour in nanometers are identified around the perimeter of the colour triangle. All colours in the spectrum blend in the center to become white.

Colour Rendering Index

A designer must know the colour temperature and rendering ratings of lamps in order to specify those that are appropriate. The colour rendering index *(CRI)* measures how good a light source makes objects appear. Manufacturers of lamps also provide this measurement. The CRI number represents how well a light source is able to show the true colour objects as compared to daylight itself *(CRI: 100)*. The index range is from 0-100. The higher the CRI number, the better the colour rendering ability of a lamp. The number is based upon an average of how eight colours appear in comparison to a standard test lamp. Thus, a source may be very good on most of the hues but not as good for other hues. To determine the colours of objects and surface, an interior designer should always examine the samples under the lamps and/or any daylight in the space.

To integrate a lamp's colour temperature and rendering ability, General Electric developed a chart that demonstrates the relationship between chromaticity in kelvins and the CRI. *(Figure 2.17)*.

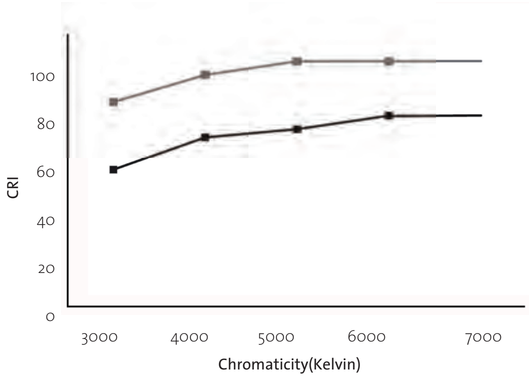


Figure 2.17 Lamp Chromaticity and CRI Comparison. Example: two different fluorescent lamps.

As shown in Figure2.1, a warm *(3000K)* fluorescent lamp has approximately the same chromaticity as a different fluorescent lamp. However, the colour rendering ability for each lamp is approximately 80 and 50, respectively. Thus, because the chromaticity is similar, both lamps will appear to be a cool light source, but the differences in CRI result in better colour rendering with the lamp with an 80 CRI. A designer selecting lamps for the high-end retail store could first select lamps with a low chromaticity rating, and then select the lamp within this grouping with the highest CRI.

How colours are perceived in an environment is determined by numerous factors, including *individuals' vision and perception*. In specifying a quality lighting environment, *a designer must understand the colour of light produced by a lamp and numerous variables that affect an object's colour.*

Visual Perception

The brain, the eyes, and the age of the individual are physiological factors that affect color perception. As addressed before*(the physics of the eye)*, the brain and eyes work together to enable us to see objects and colours. *As the corneas of the eye yellow with the age, the ability to distinguish colours decreases, especially those in blue spectrum*. As a consequence, it is also missing the ability to perceive the contrast between colours***(Chromatic contrast)*** which affects the apparent colour of an object or a written text.*(see Chapter 7.2.2. Experiment 1).* The chromatic contrasts are seven explained through the colour theory of Itten. To create even more complications in specifying colours, everyone has subjective perceptions of colour based upon psychology, cultural meanings, and life experiences. **Color constancy** is a phenomenon based upon experiences. Experience has taught us that bananas are yellow. Light sources that create unusual colours should not be used in colour-critical environments, such as health-care facilities, food display area, and most retail store. *(see Chapter 7.2.2. Experiment 3).*

Light Source Colour

The colour of light produced by a lamp determines the apparent colour of objects, the atmosphere of the space, and the quality of the interior. Manufacturers have developed a variety of lamps that have different *CRI* and *CCT measurements.* Spectral-power distribution curves provide a profile of colour characteristics of lamps correlated with radiant power*(See Chapter 6. Artificial Lighting. Sources)*. For example, the chart in the Figure .. of the chapter 6 illustrates the distribution of a fluorescent source; the lamp has high "spikes" in the green and blue spectrum. The radiant power axis emitted by the fluorescent source is the highest at the green and blue wavelengths. Generally, using this lamp in an interior with warm colors results in a distortion of colors. In contrast, the halogen spectral power distribution diagram illustrates a smooth and continuous distribution of wavelengths. This results in a good rendition for all colours. Therefore, designer will often specify halogen lamps for display and accent lighting in interiors that require good colour rendition to carry out a task. Differences in spectral-power distributions help to explain why colours can look different under various light sources. **Metamerism** occurs when two samples match each other under one light source, but do not match under a different light source. Other factors that determine how a light source affects colour are *the level of illumination* and *the age of the lamp.* Generally, when a lamp is dimmed, the warm end of the spectrum is enhanced. When the lamp life is significantly reduced, generally the intensity of all colours will be reduced. Unfortunately, there is generally a loss of efficiency with lamps that have good colour rendition. *For example*, **halogen lamps** have excellent color rendering properties*(95-100 CRI)*; however, they consume high amounts of electricity and are short-lived. *In contrast,* **a cool fluorescent lamp** may have a poorer colour rendering rating*(70-80 CRI)*, but consumes low levels of electricity and has a long lamp life. This information helps designer select the appropriate lamp for situation. In an attempt to balance a lamp's color rendering properties and efficiency, lamp manufacturers have engaged in a great deal of research and product development. The development of **LED***(Light Emitting Diodes)* sources, Energy-Efficient and High-Color-Rendering, could be the solution*(See Chapter 6. Artificial Lighting. Sources. LED).*

Object Color

The perceived color of an object or surface is determined by numerous factors, including the object, texture of the object, surrounding background, lamp, luminaire, eyes, colour constancy, brain, size of the room, light direction, intensity of the lamp, and distance of the light fixture from an object. A change in any one of these factors will change the perceived colour of an object. Figure 2.18 illustrate the perceived changes in object colours under different light sources. When an object is illuminated with a halogen lamp, all the colours, textures, and complexions are enhanced with this light source. Cool colours are enhanced with the cool fluorescent lamp. Warm colours and complexions are subdued with this lamp.

Colours have various reflectance properties that are designated in percentages *(See colour theory).* Colours that are light in value have higher reflectance properties and can reflect more light. For example, the reflectance of white is 82 percent and a dark gray is 14 percent. Accordingly each colour will have a respective luminance based on the lighting's type. In designing, we are usually not as concerned with the absolute luminances of objects as we are with their luminances relative to the other luminances in the setting. Similarly, for instance, the legibility of a text is more strongly influenced by the relationship between its luminance and the luminance of its immediate background than by its own absolute luminance. It is the concept of luminance contrast which affects the visual system. The luminance contrast of a target quantifies its visibility relative to its immediate background. The higher is the luminance contrast, the easier it is to detect the target. There are three different forms of luminance contrast commonly used for uniform luminance targets seen against a uniform luminance background. For uniform targets seen against uniform background, luminance contrast is defined as:

$$C = \frac{Lt - Lb}{Lb}$$

where:
Lb is the luminance of background and, Lt is the luminance of target.

This formula gives luminance contrasts which range from 0 to 1 for targets which have details darken than the background

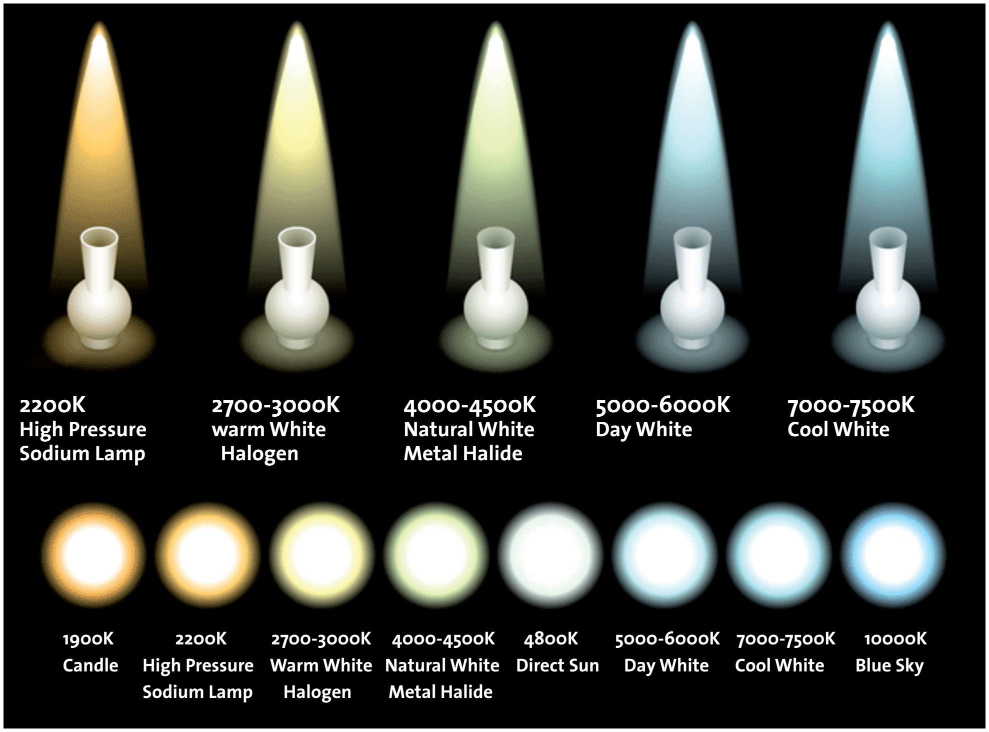


Figure 2.18 Object under different light sources.

and from 0 to infinity for targets which have details brighter than the background. It is widely used for the former, for example, dark printed text on white paper.

Another form of luminance contrast for a uniform background is defined as:

$$C= \frac{Lt}{Lb}$$

where
Lb and Lt are defined in the previous equation.
This formula gives luminance contrasts that can vary from 0, when the targets has zero luminance. It often used for self-luminous displays.

For target that have a periodic luminance pattern, for example, a grating, the luminance contrast is given by:

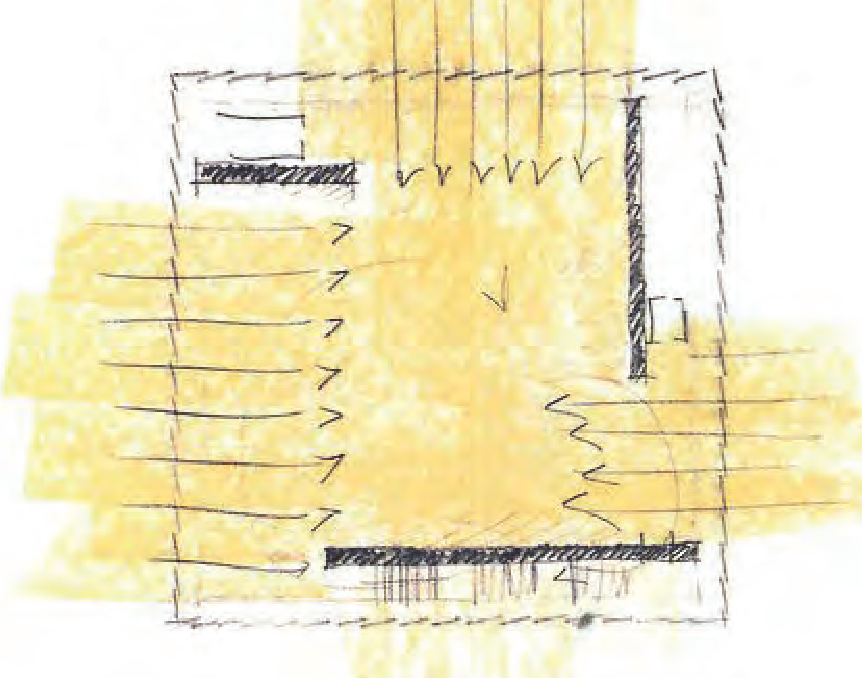
$$\mathbf{C= \frac{Lmax - Lmin}{Lmax - Lmin}}$$

where
Lmax is the maximum luminance and, Lmin is the minimum luminance.
This formula gives luminance contrasts that range from 0 to 1, regardless of the relative luminances of the target and background.

The size of a room can also alter perceived colour. For example, an intense colour applied to the walls in a small room will amplify the colour. The texture of an object can also alter perceived colour. For example, an object that has a smooth high gloss will generally appear to have a more intense colour than an object with a thick texture. This occurs because light tends to reflect off shiny objects and be absorbed by heavily texture objects. In practice, a designer might have to increase the wattage to illuminate a heavily textured object. To illuminate a shiny object, a designer might decrease the wattage or alter the angle of a light source.[2]

2 Winchip S. M., Designing a Quality Lighting Environment, Fairchild Books, 2004

Chapter 5: **Daylighting Design**



PETER ZUMTHOR's sketch for the Bregenz Museum, a floor plan with light flooding in, and a simple section".

Natural light has always played a dominant role in architecture, both to reveal the architecture of the building and to create a particular atmosphere, as well as to provide the occupants with visual comfort and functional illumination. *It is not enough simply to provide the appropriate illumination levels*, but direct and reflected glare must be controlled and patterns of contrast must be appropriate, because dissatisfaction arises 'as much from the permanent exclusion of sunlight as from its excess'[3].

We also have to bear in mind, when considering indoor functional aspects of daylighting design, that *buildings are seen both from the outside and from the inside*[1]. First, we have to consider the interaction between the building and the lighted open space with its lighting sky, and secondly the interaction between the building and the internal lighted room which receives its natural light from the external environment.

From these considerations, it is implied that daylighting design exerts a big impact on the external

---

3 M. Millet, Light Revealing Architecture, Van Nostrand Reinhold, 2004

appearance of buildings. The opening is often not a simple hole containing glass in a thin wall: there are various blinds, overhangs, side fins etc. used in practice to control daylighting and overheating. Some of these devices are fixed, others are moveable and controlled, often used in combination and linked in with glazing materials.
Before effective artificial lighting became available, it was particularly important to get the daylighting design right: especially in southern countries, it was, and still it is, difficult to use sunlight directly in every working life because of its high intensities and constant variation due to sunpaths and meteorological changes. Taking advantage of different surface configurations and of a number of physical phenomena, such as reflection, refraction, diffusion, absorption, etc, daylight should be used in a diffused form, ideally as an indirect light. It is important therefore that designers envisage the visible environment as a highly structured three-dimensional light field. *In northern Europe* on the other hand, shortage of daylight, especially in winter. When the use of glass became reasonably affordable, made it necessary to provide relatively large windows and to secure good sunlight and skylight penetration by use of high ceilings and open plan forms.
Today there is a current need to find better ways of integrating perceptual, physical, scientific and engineering approaches, taking proper account that *daylight is the complete process of designing buildings which utilize natural light to its fullest*. The key parameters to consider in choosing a system are[4] :

• *Siting the building*- that is, orienting it for optimum solar exposure
• *Choosing fenestration* to permit the proper amount of light into the building, taking into account seasons, weather and daily solar cycles
• *Shading the facade and fenestration* from unwanted solar radiation
• *Adding appropriate operable shading devices*, such as blinds and curtains, to permit occupant control over daylight admission
• *Designing electric lighting controls* that permit full realization of the energy savings benefit of daylight.
It is also important to focus on the major objectives for applying daylighting systems:

• redirecting daylight to under-lit zones
• improving daylighting for task illumination
• improving visual comfort, glare control
• achieving solar shading, thermal control.

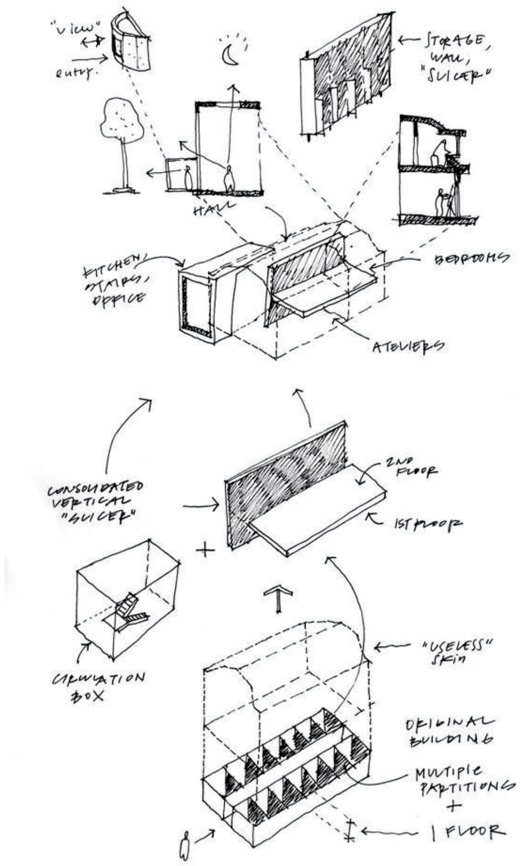


Figure 2.20: Daylighting Design concept

4 *Dahl Torben, The architectural potential of climate in: Climate and Architecture, Routledge, November 2009.*
B.H. Evans, Daylight in architecture, McGraw-Hill Inc.,US, First Edition, August 1981

Natural light source and its features. Points to remember about daylight

Daylighting is an excellent light source for almost all interior spaces: windows, skylights and other forms of fenestration are used to bring daylight into the interiors of building. The key to a quality lighting environment is distinguishing between sunlight and daylight[5] : sunlight is considered light that enters in a space directly from the sun; this type of light is generally not good lighting for an interior. Direct sunlight can produce glare and excessive heat, and it can fade materials *(the normal sun-and-sky color temperature at noon on a sunny day is 5500/6000 K).* Daylight or skylight is the term which describes the desirable natural light in space; daylight results in a perceived even distribution of light that avoids the glare and all effects of direct sunlight. A designer should always focus on ways to integrate daylight into interior while avoiding the glare sunlight (*the cold blue light from the winter north sky is over 10000 K. The Color Quality (CRI) is excellent).*

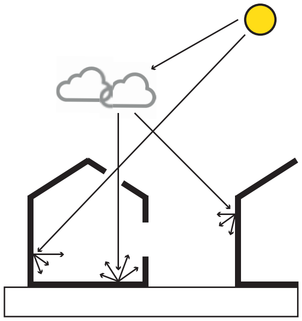


Figure2.21: LIGHT TYPES. The three types of daylight: sunlight, skylight and reflected light.

Light is also an important part of the internal climate and a prerequisite for many functions in the building. When the building body screens against the external climate, it also screens against daylight. Consequently, it is a balance between the external climatic conditions, the building's screening and light filtering function and the light requirement that creates the specific visual environment in a building.

Planning quality daylight for an interior requires *examining both the advantages and disadvantages* of the source. Advantages to integrating daylight into interiors include energy savings resulting from a reduction in electrical lights and passive solar energy penetration in the winter. Daylight also has positive psychological and physiological effects on people by reducing stress and encouraging positive attitudes; in people with sight loss homes, a benefit of good lighting is in aiding detailed visual tasks. On the other hand, disadvantages of natural light often are a result of the direct sun penetrating in a space: disadvantaged associated with windows include glare, noise penetration, cleaning maintenance, lack of privacy etc.; in addition, the beautiful views enjoyed during the day could become "*black holes*" at night.

Eye pathologies, such as age-related macular degeneration, cataracts, glaucoma and diabetic retinopathy, are common among the older population. It would therefore seem reasonable to expect extra-care housing and private indoor environment to be well designed for the needs of people with visual impairments, including with regard to daylighting *(See Chapter 1.1: Case Studies)*. However, daylighting in older people's housing is sometimes poor, even where dwellings have been specifically designed for older people. This might reflect a lack of awareness of the lighting needs of older adults. Although there is little guidance on aspect in relation to people with sight loss, previous research indicates that people with sight loss appreciate similar qualities in a view as people with normal vision.

In order to take full advantage of all the benefits offered by daylight it is necessary to acquire a deeper understanding of its proper behaviour. Often studies on lighting have considered artificial and natural light as equivalent, addressing merely the illuminance levels. This attitude leads to reductive interpretation of measurable, dependent variables, and at the same time under-evaluates the advantages of daylighting. Technical solutions alone will not lead to improve lighting

5 Dahl Torben, The architectural potential of climate in: Climate and Architecture, Routledge, November 2009.

standards, as building designers' actions are conditioned by an assemblage of social, economic and institutional factors. For example, window sizes are not determined by daylighting considerations alone, but by factors including construction costs, and designers' awareness of technical issues. Often designers are unable to determine whether a space is sufficiently illuminated or whether it appears dark. It is often assumed that visual capacity is limited only by the strength of the task illumination, a statement which suggest that better vision is simply a matter of increasing the incident illumination. However, Technical solutions are more likely to be successful when they are developed with an awareness of the ways in which contingencies enable and constrain the uptake of such solutions, and of where additional support or regulation might be required. It is very important in designing a good visual environment to consider that the way surfaces are illuminated is often more important than how much light falls on them. Despite the common misconception that surface illuminance is the only relevant parameter for visual comfort, a more comprehensive attitude to visual perception is needed. This should include notions of[6] :

- spatial distribution of daylight illuminance
- luminance ratios
- shape from shadows
- colour rendering
- glare
- visual noise.

With this purpose in mind, it is important to analyze all the possibilities available to architects: the first step is to achieve a good approximation of the effects that the use of daylighting components has on architectural design.
It may be difficult to distinguish which characteristics of an element or component are most significant: in many cases, a specific component may produce different effects in terms of the lighting or thermal conditions of a building, therefore it is necessary to select which of these effects is most important.

6 B.H. Evans, Daylight in architecture, McGraw-Hill Inc.,US, First Edition, August 1981

The Basic Components:
This Paragraph consist of a detailed list of daylighting systems. All of these systems have different characteristics and different importance in real-life design cases[7]; it is impossible to develop a unified rating scale or to define a clear-cut selection method for choosing the best daylighting system in a given situation.
Nonetheless, there are some general strategies for making decisions about using a daylighting system in a design. First, a designer should focus on these **questions**[8]:

- Is it useful to apply a daylighting system in my case?
- What kind of problems can I resolve with a daylighting system?
- What benefits could I achieve with a daylighting system?

Top Lighting
One of the most common ways to introduce daylight is through skylight and other means of top lighting. Top lighting behaves as direct electric lighting doesby radiating light downward. Principles commonly used for designing electric lighting systems can also be used for *top lighting*, which *is the easiest form of daylighting and is relatively unaffected by side orientation and adjacent buildings*. In the following page are shown different classic prototypes for top lighting.

7 B.H. Evans, Daylight in architecture, McGraw-Hill Inc.,US, First Edition, August 1981
M. Karlen. J.Benya, Lighting Design Basics, John Wiley & Sons Inc, 2004
8 Rosemary Bakker, Household Tips for People with Low Vision, Cornell University, 2011

The Skylight: or horizontal glazing, permits direct solar and sky radiation through a fenestrated aperture. They also provide excellent ways of illuminating spaces away from windows, such as hallways and are an especially good light source for geographic areas that experience a high number of overcast days *(Figure 2.22);*

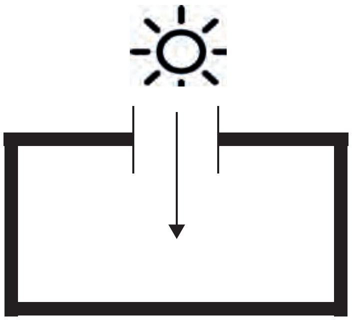


Figure 2.22: Skylight scheme.

The single clerestory: produces both direct and indirect lighting by introducing light through a vertical clerestory window. Depending on the adjacent roof, some of the light may be reflected downward by the ceiling into the space. However, depending on site orientation, the relatively high percentage of direct light can be glaring and as a window, it could deteriorate fabrics and wood in the environment below *(Figure 2.23)*;

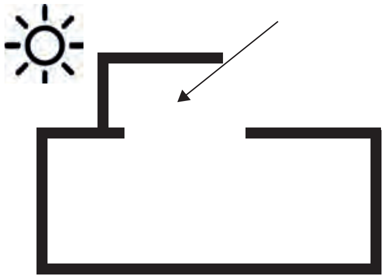


Figure 2.23: The Single Clerestory scheme.

The sawtooth single clerestory: produces both direct and indirect lighting but, by bouncing a high percentage off the adjacent slanted ceiling, increases the amount of downward light and cab minimize the amount of direct light. If the sawtooth glazing faces north, it can be an excellent source of natural light for a large interior area. It increases the light level in the interior, usually with diffused light *(Figure 2.24)*;

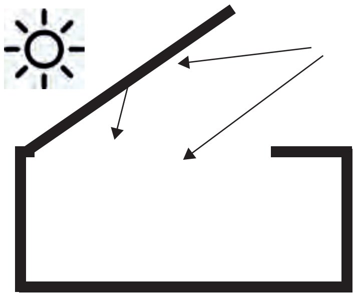


Figure 2.24: The sawtooth single clerestory scheme.

The monitor or double clerestory: is a raider section of a roof, including the ridge, with vertical openings; it also permits abundant daylight, especially in building where solar orientation or weather do not permit the sawtooth or other more unusual designs. With proper choice of glazing and overhang, a monitor can produce exceptionally balanced and comfortable daylight *(Figure 2.25)*;

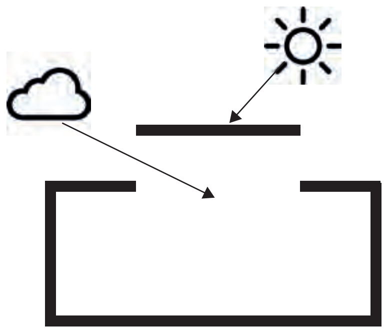


Figure 2.25: The monitor or double clerestory scheme.

Atrium: a space enclosed laterally by the walls of a building and covered with transparent or translucent material *(Figure 2.26)*;

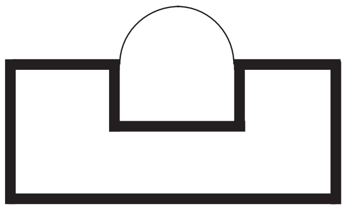


Figure 2.26: The atrium scheme.

Light-Duct: which can conduct natural light to interior zones of a building which are not otherwise linked to the outside but are not far from the exterior; Its surfaces are finished with light-reflective materials in order to direct and diffuse natural light downwards and the section of the duct small *(Figure 2.27);*

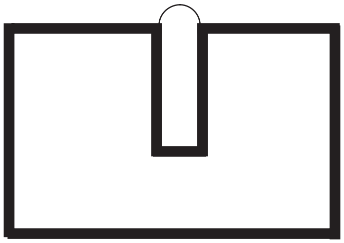


Figure 2.27: The Light-Duct scheme.

Translucent Ceiling: an horizontal aperture partially constructed with translucent materials *(Figure 2.28)*.

Figure 2.28: The Traslucent ceiling scheme.

Side Lighting

Side lighting employs vertical fenestration *(usually windows)* to introduce natural light. A window is an opening in the vertical enclosure of a building which allows an interrelationship between the exterior and the interior. A window permits luminous, thermal, and acoustic interchange as well as natural ventilation and view and it is characterized by its type, size, shape, position and orientation. In addition, controls may be added to regulate specific interchanges.
Unlike top lighting, side lighting tends to introduce light that can be too bright relative to the room surfaces, sometimes causing glare. An additional problem caused by side lighting is the limits of penetration into the space. Generally, the effect of the daylight is lost at a distance from the windows about 2.5 times the window's height. Many modern buildings employ a light shelf to shade the lower part of the window, or view glazing, permitting clearer glass.
The design of a window opening affects the quantity of light entering a room[9]. Flush openings, the most common design for windows, are not designed to reflect light into a space. By contrast, a light shelf reflect more light into an interior. In general, larger openings will allow more daylight into a space. However, windows in a horizontal design are generally preferred in order to maximize a view and to accommodate the eye's natural direction of movement; on the other hand, to maximize the amount of daylight in a space, the windows should be placed high on a wall. Light entering a window close to a ceiling will reflect off of the ceiling and possibly the adjacent walls and then into the room.
In the last years, different lighting guidelines had point out that the recommended minimum sill height of 800mm is too high to permit a seated person a good view. *Achieving a lower sill is made complicated by the Building Regulation* requirement that glass in windows, between the finished floor level and a height of 800 mm, be robust or designed to break safely. Generally this requires the use of more expensive types of glass, which has an impact on construction costs. It was suggested that construction costs could be minimized by putting a transom at 800 mm, with toughened glass below and ordinary glass above but there are other factors that make it difficult to create low sills include the need in some housing schemes to allow space for radiators under windows. Following, different typologies of Side Lighting[10].

9 S.M. Winchip, Designing a Quality Lighting Environment, Fairchild Books, 2004
10 B.H. Evans, Daylight in architecture, McGraw-Hill Inc.,US, First Edition, August 1981
M. Karlen. J.Benya, Lighting Design Basics, John Wiley & Sons Inc, 2004

The Window: it permits the lateral penetration of light and the interchange of view and natural ventilation. A window increases the luminous level in the interior zone close to the window, but the light level drops off rapidly with distance from the window *(Figure 2.29)*;

Figur 2.29: The Window scheme.

The Porch: a covered light space attached to a building at ground level, open to the exterior environment *(Figure 2.31)*;

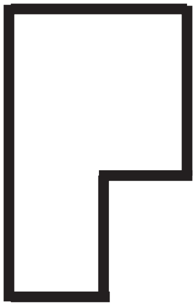


Figure 2.31: The Porch scheme.

The Greenhouse: that is attached to a building by one or more of its faces, the others being separated from the exterior by a frame supporting transparent or translucent surfaces *(Figure 2.33)*.

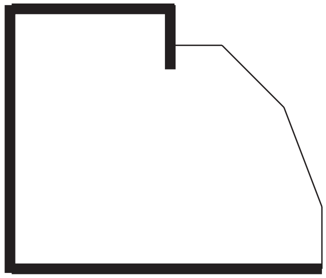


Figure2.33: The Green-HOuse scheme.

The Gallery: that is, a covered light space attached to a building *(Figure 2.30);*

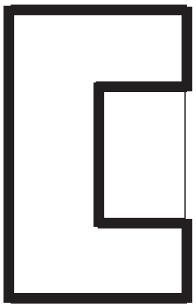


Figure 2.30: The Gallery scheme.

Translucent Wall: the surface separates two luminous environments, permitting the lateral penetration of natural light and diffusing it through the translucent material. A translucent wall modifies the natural light which penetrates into a space, providing a homogeneous diffuse light level in the interior zones close to the wall *(Figure 2.32)*;

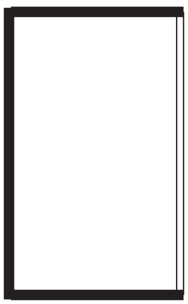


Figure 2.32: The Translucent Wall scheme.

A Curtain Wall: typically implies a continuous translucent or transparent vertical surface, with no structural function, that separates the interior from the exterior of a building. It permits lateral penetration of natural light, direct solar gains and interchange of view but often does not allow ventilation *(Figure 2.34)*;

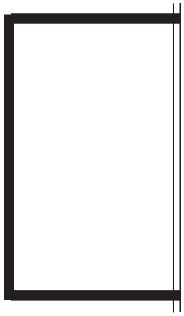


Figure 2.35: The Curtain Wall scheme.

The Light-shelf: The top of the shelf is reflective, intended to bounce light inward and onto the ceiling, which provides for deeper light penetration and improved interior light quality. The ceiling is an important secondary part of the light shelf system because light is reflected by the light shelf towards the ceiling and then reflected from the ceiling into the room. The characteristics of the ceiling that affect this process are surface finish, smoothness, and slope. Although a ceiling with a specular surface will reflect more light into the room, care should be taken to avoid glare from the ceiling reflections near the light shelf. To avoid glare, the ceiling finish is usually white diffusing or low-gloss paint. On the other hand, the daylight glazing is generally darker or more reflective than the view glazing to prevent direct solar radiation and glare from a bright sky. Each light shelves should be designed specifically for each window orientation, room configuration, and latitude *(See also Chapter 7.2.3)*. They can be applied in climates with significant direct sunlight and are applicable in deep spaces on a south orientation in the northern hemisphere *(north orientation in the southern hemisphere). (Figure 2.36)*

Figure 2.36: The Light- shelf scheme.

The building facade possibilities of screening against and at the same time controlling sunlight and daylight are manifold. However, the optimum solution depending on latitude and thus the character of light, and hence the most appropriate design will differ from one location to another. Thorough knowledge of a place's climate and light types, coupled with careful design will ensure optimum use of light within the building for different function and location *(See Chapter 1.1: New Design in different Climates).*

Solar shading uses building elements to prevent direct solar radiation from entering the space during the cooling season: it interferes with daylighting indoors and it could be fixed or adjustable; adjustable shading devices are sometimes operated for visual control reasons and sometimes for thermal control reason, and sometimes for both.

For examples, *overhung soffits*, *canopies* and *awning* are the most common forms of external solar shading, while *blinds*, *curtains* and *shades* are the most common forms of interior shading. Solar shading is difficult to design for east-and-west-facing facades because preventing direct solar penetration very early or very late on a summer day is impossible without blocking the view. Dark shades prevent glare but

absorb solar energy and become warm, heating the space.
Here are different prototypes for **Shading Devices**.

Optical Division: is a control element, placed in a pass-through component, which shares two environments and modifies the characteristics of the radiation passing through it; it diffuses, redirects, or control the light intensity, depending on the specific treatment of the division. *(Figure 2.37)*;

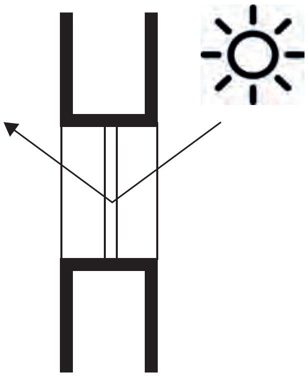


Figure 2.37: The Optical Division scheme.

Prismatic Division: redirects light because of its optical and geometrical characteristics; natural light is redirected by the prismatic panel, changing the beam direction depending on the angle of incidence. Horizontal slats can screen against the Sun by means of a given angle determined by the distance and depth of the slats. They are most efficient against the high solar angles around noon, whereas the low Sun is hard to screen without shutting off the window completely. In addition the horizontal slats are flexible, they can be a very efficient means of controlling both light, view and climate in the room.
Vertical slats, on the other hand, primarily screens against the low Sun, whose light comes in at an angle from the side. Vertical slats make it possible to look out of the entire height of the window, but at the same time they control the direction of both the view and the incident light depending on which way they are turned.

A combination of horizontal and verticals slats is typical on countries where there is a need to screen against both light and heat. The traditional shutter as we know it from many countries consists of horizontal slats in a frame, where the frame cab be opened when needed. It is a flexible simple and efficient way to adjust light and is the most suitable in countries where excess light, and hence solar gain, is a problem. However, its poor visual transparency restricts its use *(Figure 2.38)*;

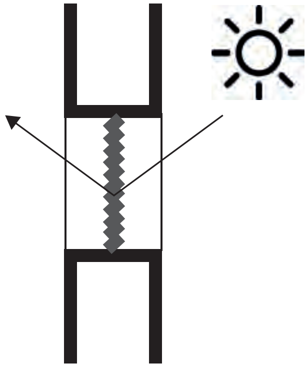


Figure 2.38: The Prismatic Division scheme.

Awning: made of opaque or diffusing flexible material placed on the exterior of a pass-through component to obstruct or diffuse direct solar radiation *(Figure 2.39)*;

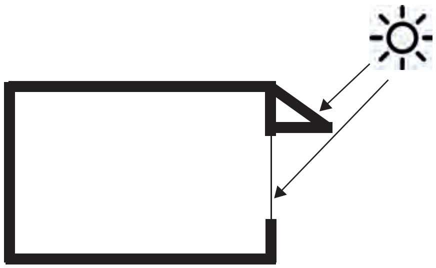


Figure 2.39: The Awning scheme.

Curtain: made of opaque or diffusing flexible material placed inside a pass-through component to protect against view and to protect the interior zones close to the opening. It may rolled up or drawn laterally away, leaving the windows open to radiation and view if desired. *In relation to sunlight, most of the specialist guidance on design for people with sight loss focuses on the need to enable occupants to control the amount of sunlight that enters their home through the use of curtains, in order to reduce glare. (Figure 2.40)*;

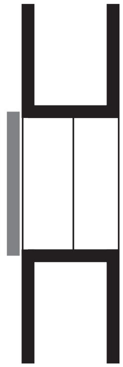


Figure 2.40: The Curtain scheme.

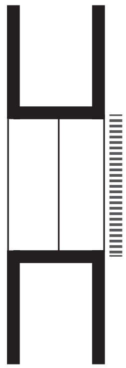


Figure 2.42: The Brise-soleil scheme.

Overhang: is part of the building itself, protruding horizontally from the facade above a vertical pass-through component. It protects the zones close to the openings of the building, obstructing high angle direct solar radiation *(Figure 2.41)*;
Light-shelf *(See also in Side Lighting)*: as a shading device, it is usually placed horizontally above the eye in a vertical pass-through component, dividing it into a upper and a lower section. It protects the interior zones close to the openings against direct solar radiation, and redirects light falling on the upper surface to the interior ceiling *(Figure 2.36)*;
Brise-soleil: is an exterior, fixed structure covering the whole pass-through component or a larger area. If differs from Louvres, which can be fixed or adjustable, depending on the orientation of the slats *(Figure 2.42)*;
Shutter: totally obstructs radiation. It may be exterior or interior, and is openable. Is a continuous opaque surface which totally blocks daylight and views *(Figure 2.43)*.

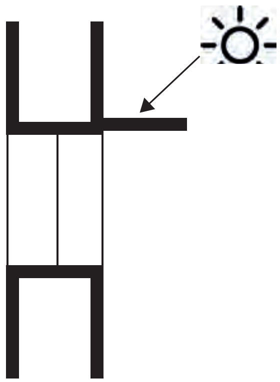


Figure 2.41: The Overhang scheme.

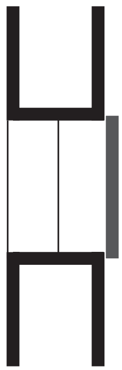


Figure 2.43: The Shutter scheme.

Integrating of Daylighting and Electric Lighting

To harvest the energy-saving benefits of daylighting, electric lights must be switched off or dimmed. This can be designed in several ways and each of them has merit. The use of both electric light and daylight often raise the question of whether the electric light source should match the natural light. In most cases, choosing an electric light source that is appropriate, independent of daylight, is probably the best.
When integrating electric and natural light, lighting design requires a plan that provides the flexibility of having electrical sources in areas away from windows and lights that dim or turn off in areas close to the windows.
The brightness of a window could make appear that the surrounding wall area is dark. Thus, to assist the eye in the adaptation process, people will often turn on lights even on a sunny day; to reduce the perceived need for additional light, the wall area around a window should be a light color, and, if possible, a skylight or other source originating from the ceiling should illuminate the wall.
Other aspect to bear in mind is the *site orientation* of a structure which affects the type of daylight that enters the window. Light entering on the south side of a building has significant variation intensity and color; as opposite, northern light generally has a constant intensity and even spectrographic characteristics.

Currently, in response to energy conservation and sustainable buildings, many manufacturers are developing more effective daylight-integration products; lighting control systems are key to effective and efficient daylight integration and are represented by daylighting controls and motion sensors (*See also Photosensors in Chapter 6)*:

Daylighting controls are photoelectric eyes that turn lights off or dim them when daylight is sufficient. For interior spaces, photoelectric dimmers reduce the energy used by electric lights in spaces where windows or skylights provide most of the light actually needed in the space and increase light levels at night and on dark days.

Motion Sensors detect the presence of people and respond by automatically turning lights on. It is possible to replace an ordinary switch with a motion sensor switch, making lighting control hands-free and assuring that lights will go off when people are no longer present.

Chapter 6:

Artificial Lighting

Light occurs in nature and sunlight, moonlight and starlight are the most important sources of light to life. However, because of their need for additional light, humans have learned to create light as well. If natural light sources occur within nature and are beyond the control of people, man-made light sources can be controlled by people too, more or less when and in the amount wanted, this include: wood flame, gas flame, electric lamps, photochemical reactions, etc. *Electric light sources became a reality with the invention of the incandescent carbon-filament lamp in 1879* and due to their obvious advantages in terms of availability, safety, cleanliness, and remote energy generation, electric lamps have displaced almost all other man-made sources for lighting of the built environment[11].

“ *As business and pleasure become year by year more closely crowded into our lives, and as life itself becomes more full of excitement and events, the importance of*

11 S.M. Winchip, Designing a Quality Lighting Environment, Fairchild Books, 2004 *rest and home comfort increases, and what were the superfluous luxuries of our ancestors become necessities to the overstrained nerves of men and women today. In our English climate and with our English habits so large a proportion of our lives is passed by electrical light, that the nature of that light becomes an all-important factor in matters of comfort and discomfort, rest and fatigue." [Gordon, 1891]*[12]

Throughout the world, one's residence is the place for self-expression, contentment, personal relationship, and self-renewal. *A quality residential lighting environment enhances the way people live in their homes by fulfilling functional and aesthetic needs*. The problem faced by those attempting to **improve the lighting of homes for people with sight loss is that lighting is simultaneously too easy and too difficult**[13].

It is too easy to provide some form of lighting and too difficult to provide good lighting. To provide good lighting it is first necessary to identify that the existing lighting is inadequate in some way and then to determine what should be done to improve it.

In practical terms, light sources can be discussed in terms of qualities of the light they produce. These qualities are critical to the result and must be understood when choosing the source for a lighting plan. How a lamp operates determines virtually everything about the light created by it. Furthermore, *the choice of artificial lighting systems and the relationship to daylighting strategies is central to the achievement of energy efficiency*. In the design of electric lighting systems there are three levels of initial decisions to be made relating to[14]:

-the lighting strategies
-the type of lamp
-the type of luminaire.

The choice of lamp will be determined by its characteristics, such as colour rendering properties, efficacy, run-up time when switched on, control, cost, life and maintenance. In determining the choice of luminaire, the following are issues that should be considered: light distribution, utilization factor, safety etc.

A historical review[15] of the development of residential lighting helps to provide an understanding of some detrimental practices that have basically never changed. Many current luminaires are based upon design that were suitable for gas illumination *(frequently placed in the center of a ceiling)*, but are not appropriate for electrical energy and have negative consequences *(See Chapter 7.3.4.3)*. Still today is common to visit an apartment *built to meet the minimum code requirements*, which results in little natural illumination and one luminaire in the entryway, dining room, kitchen, etc. In most of these cases a builder does a generic lighting plan then, after the residence in constructed, an interior designer is retained to enhance the lighting; this approach greatly reduces the options available.

On the other hand, interior designers must recognize applications that have become practice throughout the years and evaluate the appropriateness for today's interiors and technologies. An integrated approach involves analyzing various lighting options within the context of the users of the space, their activities, daylight, furniture design, etc. and which is a major element in the total composition. *Electrical lighting does not have to be uniform and stagnant.* A goal for electrical lighting should be to imitate the same wonderful variability of daylight; controls can help to create variability in the effects of lighting and can also play an important role in establishing a desired mood.

Pocklington[16] research into lighting the homes of people with sight loss found:

- *Low levels of lighting*
- *Uneven lighting, shadows and dark areas*
- *Light fittings allowing a direct view of the lamp, causing glare*
- *Differences between light levels in different spaces causing adaptation problems when moving from room to room*
- *Poor control with inadequate switching or dimming*
- *Lack of information on potential improvements.*

12 S.M. Winchip, Designing a Quality Lighting Environment, Fairchild Books, 2004
13 P.Boyce in: Thomas Pocklington Trus, GOOD HOUSING DESIGN_LIGHTING, Good Practice Guide 5, 2010.
14 B.H. Evans, Daylight in architecture, McGraw-Hill Inc.,US, First Edition, August 1981
15 S.M. Winchip, Designing a Quality Lighting Environment, Fairchild Books, 2004
16 Thomas Pocklington Trus, GOOD HOUSING DESIGN_LIGHTING, Good Practice Guide 5, 2010.

What It must be understood is that there is no one perfect lamp but getting to know the various properties of the lamps that are available will help in choosing the best luminaires and light bulbs related to people living in that specific indoor environment.

All lamps fit into four categories: *incandescent and halogen, fluorescent, high-intensity discharge (HID) and light-emitting diode (LED).*

Sources[17]

What is the best bulb lamp for people with low vision[18]?

New technologies have created a variety of high quality light bulbs, including incandescent, full spectrum, compact fluorescent and halogen. No one light bulb is best for everyone or for every activity. Some individuals choose full spectrum bulbs for close-up tasks and incandescent or compact fluorescent bulbs for general room lighting. Others prefer regular incandescent bulbs for reading. Finding the right bulb can also be a confusing task given the numerous types on the market today. It helps to be equipped with a bit of technical information which help to choose wisely.

Incandescent and halogen Lamps

Incandescent lamps in general are what we are most familiar with. They come in many sizes and shapes, as well as wattage and voltage beyond the standard household bulb. Incandescent lamps generate light when electric current heats the lamp's filament: the hotter the filament, the whiter the light is. The problem is that as the lamp filament gets hotter, the more rapid the evaporation of the metal from the filament is. *Most people think that daylight and incandescent light are the same color. This couldn't be further from the truth*. They are almost at opposite ends of the color spectrum. Going back to what was said in Chapter 4 with regard to the CCT, Figure 2.15-2.16 show at the top of the charts incandescent and fluorescent lamps, which give off a warm (yellower) color while at the bottom of the chart are the more blue-white sources of light, such as daylight and full-spectrum fluorescent, which are very cool colors.

Here are three main Incandescent light sources:

-*Standard Incandescent Lamps* today use tungsten filament that generate a warm-colored white light and last about 750 to 1000 hours. The temperature of the incandescent lamp bulb is generally too hot to touch but luminaires are designed to prevent inadvertent contact. The color temperature of incandescent lamps is about 2700 K, generating a warm-toned light.

-*Incandescent Halogen Lamps* give off whiter light and last longer than standard incandescent lamps. Lamp life for halogen lamps ranges from 2000 hours to 10000 hours. Some types of halogen lamps use a quarts glass bulb and get extremely hot, requiring special protection for safety. The color temperature is about 3000 K, making their light appear slightly whiter and cooler than incandescent.

-*Low-voltage incandescent and halogen lamps* are smaller than regular lamps and are particular popular for specialty lights and for display lighting in retail, museums, homes, etc.

All kind of Incandescent lamps mentioned above, operate in virtually any position. They start and warm up almost instantly and can be extinguished and restarted at will; they can be dimmed easily and inexpensively extending their life significantly. *Standard Incandescent lamps generated between 5 and 20 lumens per watt; halogen lamps generate between 15 and 25 lumens per watt*. The most efficient incandescent light sources are the latest infrared-reflecting halogen lamps. Designers tend to prefer incandescent and halogen lamps for their color and versatility.

Today halogen lamps have replaced incandescent ones and are commonly used in residential downlighting and outdoor lighting, hotels and especially in retail displays.

17 B.H. Evans, Daylight in architecture, McGraw-Hill Inc., US, First Edition, August 1981
M. Karlen. J.Benya, Lighting Design Basics, John Wiley & Sons Inc, 2004
P. Boyce, Human Factors in Lighting, CRC Press, 2014.
18 Rosemary Bakker, Household Tips for People with Low Vision, Cornell University, 2011

In Detail:

Incandescent Lamps

The lamp filament, when heated to a temperature of approximately 2800 K, becomes white hot and emits radiation throughout the visible spectrum with a bias towards the higher wavelengths. The outer glass envelope is filled typically with a mixture of nitrogen and argon whose function is to limit the evaporation of tungsten from the filament and, additionally, to assist in the prevention of arcing across the lamp filament. The GLS *(General Lighting Service)* lamp is dimmable, and it will operate in any position*(Figure 2.44)*.

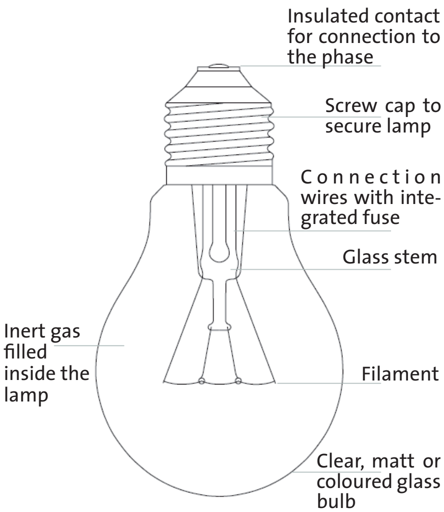


Figure 2.44: Incandescent light bulb.

Incandescent Halogen Lamps

Halogen lamps might be considered an advanced or improved general incandescent lamp. According to General Electric Lighting: "*They are just like standards incandescent but contain an halogen gas which recycles tungsten back onto the filament surface. The halogen gas allows the lamps to burn more intensely without sacrificing life*".

It is often labeled a "*white*" source of light. That's a relative term. As was mentioned in the previous paragraph, it is whiter than standard incandescent lamps by 200 K, but it's 2000 K yellower than daylilght. That's quite a large difference. It is only whiter than standard incandescent when it is operating at full capacity. An additional advantage is that the lamp body is smaller and stronger than that of the incandescent lamp of similar rating, hence the luminaire can be made smaller and tighter control of the light distribution is possible.

Halogen have a number of advantages:
-tend to be smaller in size than standard incandescent sources
-they produce more light than standard incandescent sources of comparable wattage
-they have better optical control than most standard incandescent, fluorescent, HID sources
-they come in a variety of shapes and sizes.

Halogen also have disadvantages:
-the light yellow when dimmed, as with all incandescent sources
-dimming may shorten lamp life
-the glass envelope should not be touched without wearing gloves. They are now called "*double-envelope halogen lamps*" because they have a second layer of glass around them.*(Figure 2.45).*

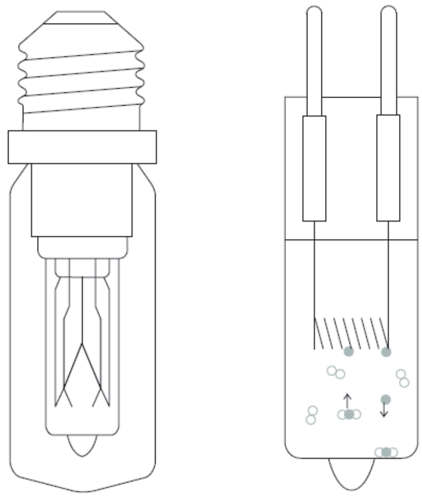


Figure 2.45: Halogen lamp for mains voltage with screw cap and outer envelope (left). The outer envelope means that the lamp can be operated without a protective glass covering.
Low voltage halogen lamp without pin base and axial filament in a quartz glass bulb (right).

Dichroic reflector Lamps 

Low voltage dichroic reflector lamps have a special type of reflector which transmits outwards mostly visible radiation, whilst simultaneously allowing the infrared radiation to pass through the reflector and out through the back of the lamp *(Figure 2.46).*

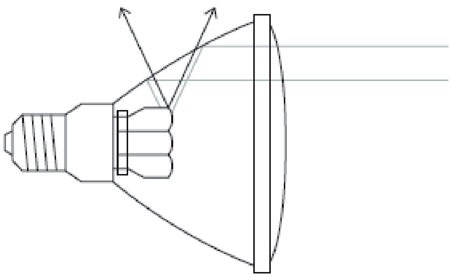


Figure 2.46: Lamp with dichroic cool-beam reflector. Visible light is reflected, infrared radiation trasmitted, thereby reducing the thermal load on the illuminated objects.

Fluorescent Lamps 

Fluorescent lamps use the principle of fluorescence, in which minerals exposed to ultraviolet light are caused to glow. Inside the envelope are droplets of mercury and inert gases such as argon or krypton. At each end of the fluorescent tube are electrodes. When electricity flows between the electrodes, it creates an ultraviolet light. The ultraviolet light causes the phosphor coating to glow of "*fluoresce*" releasing the characteristics fluorescent light from the whole tube. The color temperature of the light will vary depending on the phosphors used. *A fluorescent lamp requires a ballast in order to work properly* which is an electrical component that starts the lamp and regulates the electric power flow to the lamp. There are two types, magnetic and electronic, of which the latter is generally more energy-efficient and quieter, and it reduces lamp flicker considerably.

Fluorescent lamps are sensitive to temperature. Bulb temperature is critical for proper light output, and lamps operated in very cold or very warm situations generally do not give off as much light as when operated at room temperature.

Most common fluorescent lamps are straight tubes. They are preferred for general illumination because of their cost effectiveness and energy efficiency *(Figure 2.47).*

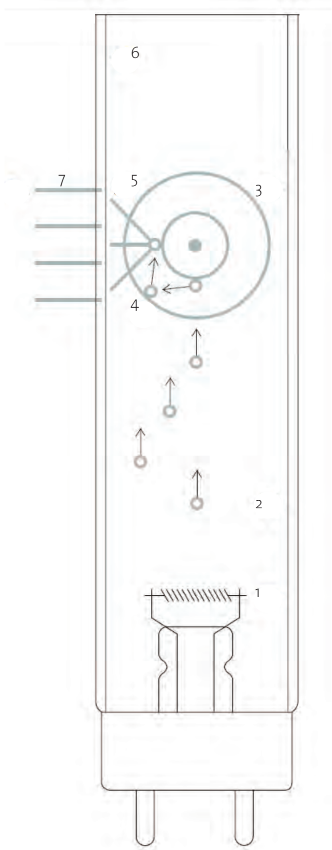


Figure 2.47: When leaving the electrode (1) the electrons (2) collide with mercury atoms (3). The mercury atoms (4) are thus excitedand in turn produce UV radiation (5). The UV radiation is transformed into visible light (7) in the fluorescent coating (6).

Compact Fluorescent Lamps

Known in the industry as CFLs, have opened up a whole range of use that were not possible with larger-sized fluorescents. This type of lamp is being improved more quickly than any other source on the market *(with HID and LED sources as second)* and today are rapid-start, quiet, dimmable and in a variety of color temperature; great strides have been made on all fronts compared to the past with the first compact units.

There are two major types of compact fluorescent lamps: those with *screw bases*, designed to directly replace incandescent lamps in incandescent lamp sockets, and those with *plug-in bases* designed to fit into sockets in luminaires designed specifically for compact fluorescent lamps. The first ones can be dimmed with an incandescent dimmer.

It is true that early fluorescent lamps were awful, but time have changed. There were just two colors available in fluorescent for the longest time: cool white or warm white. Cool white gave a greenish cast, while warm white gave an orange facsimile of incandescent. Now there are many colors available in fluorescent lamps; these colors are obtained from a mix of phosphors. Tri-phosphor fluorescent lamp have some of most usable color temperatures for residential use distinct in three ranges:

- *warm white:* ideal for bedrooms, dining rooms and lounge
- *cool white:* useful for kitchens, storerooms and offices
- *daylight white:* this has a bluish "daylight" or "northlight" appearance.

Fluorescent have a number of advantages:

-Longer lamp life, almost 22000 hours. Compact fluorescent are rated at 10000 hours, a huge difference
than the previous ones.

-Lower maintenance time and cost

-More lumen output. Fluorescent lamps can produce three to five more lumens for the same wattage as an incandescent lamp; here, it can be seen how using fluorescent lamps can produce significant energy savings.

-Cooler source, they don't give off much heat as incandescent sources

-Color variety, there are a huge number of color temperatures available, while incandescent lamps are available in relatively few.

-Dimming, they do not change significantly in color temperature when dimmed, as incandescent sources
do.

Fluorescent also have disadvantages:

-Lamp life and Lumen output, halfway through its life, a fluorescent may produce 20 percent less light than when new.

-Hum, it is caused by a magnetic ballasts.

-Relative inability to accent, fluorescent lamps are relatively large light sources; through the use of integralreflectors, manufacturers are able to achieve some success with fluorescent luminaires, such as wallwashers for art.

-Temperature restrictions *(Figure 2.48).*

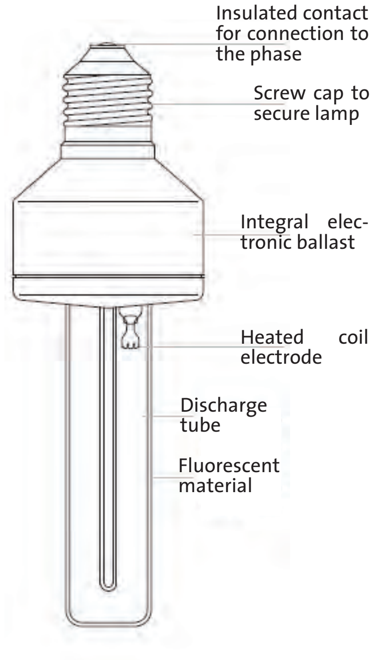


Figure 2.48: Compact Fluorescent Lamp.

Light-Emitting Diodes (LEDs)

The LED is a semiconductor that emits light when a current is passed through it. The spectral emission of the LED depends on the materials used to form the semiconductor. For light, the most common LED material combination is now *aluminium-indium-gallium-phosphide*. The light output of LED is determined by the current through the semiconductor and its temperature. Basically, *the higher is the current and the lower is the temperature, the higher is the light output*. The current is controlled through control gear called driver. LED can have a long life of up to 60000 hours; as for luminous efficacy, the latest high-flux can have a long life efficacies up to 100 lumens per Watt. Their small size offers great possibilities in accent and decorative lighting.

It might be thought that the fact that LED is a narrowband source of light would preclude its use for general lighting but this is not the case. There are two methods for producing white light using LED: one method is to combine the outputs of three, four or more different LEDs in one luminaire. *The number of different LEDs used represents a trade-off between luminous efficacy and color properties*; the problem with this approach is that the light output of LED with different peak wavelengths decreases at different rates, meaning the color properties change over time and need to be stabilized.

The other method by which LED can create white light is to use LED-emitting UV to illuminate one or more phosphors that emit light in the rest of the visible range. This approach has the advantage that when multiple LED are used to generate enough light output for practical application, illuminating a separate phosphor surface averages out any colors differences between the individual LED *(Figure 2.49).*

As regard white or blue LED light sources for lighting, for example, they are efficient for younger people but not so much for older people. Effective intensity of such blue-rich light sources should be evaluated and used appropriately in elderly lighting design[19].

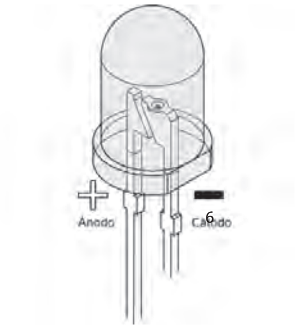


Figure 2.49: LED Lamp.

19 K. Sagawa, *Vision of the elderly and visually impaired -for Accessible Design in Light and Lighting, 26th Session of the CIE Beijing, 2007;*

Real Light Sources, Colour Spectra

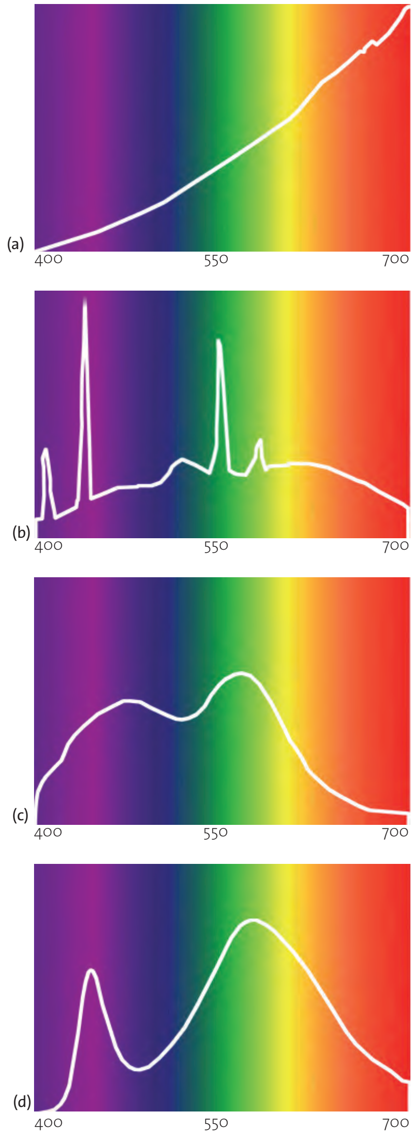


Figure 2.50: Real Light Sources, Colour Spectra.
(a) Incandescent Lamp 2800 K
(b) Fluorescent Lamp 5000 K
(c) Daylight
(d) LED Light 5000k

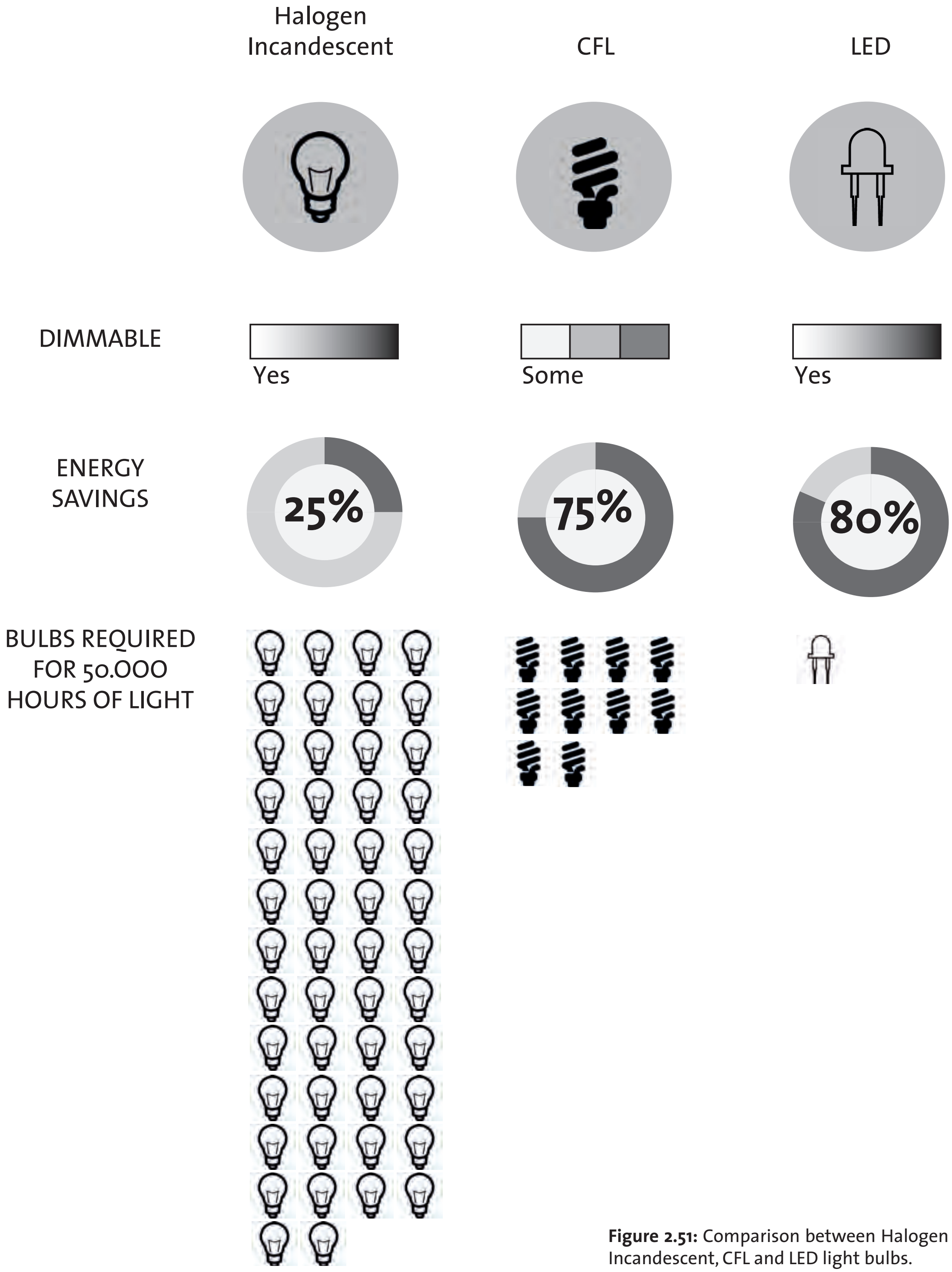


Figure 2.51: Comparison between Halogen Incandescent, CFL and LED light bulbs.

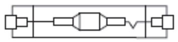
HID Lamps

High-intensity discharge (HID) lamps are designed to emit a great deal of light from a compact, long-life light source. Most HID lamps approximate a point source of light, making them excellent sources for spot lighting equipment such as track light, display lights and even stadium lights. HID lamps are generally energy efficient, producing 50 to 100 lumens per watt. As in fluorescent lamps, a ballast regulates the amount of power flowing into HID lamps. Magnetic ballasts are generally used for most HID lamps, although electronic ballasts are becoming increasingly popular. HID lamps require time to warm up, they get progressively brighter over several minutes until reaching full light output *(2/5 minutes)*.

The truth is that it's going to be a while before we see HID sources being used much for residential interiors. They are better suited for exterior lighting for their large size, they require a ballast and are not fully dimmable.

Inside the glass envelope of an HID lamp is a small cylinder called "*arc tube*". It is filled with a blend of pressurized gases. A ballast directs electricity through the tube and charges the gases to produce light.

Metal Halide Lamps



Metal halide lamps produce white light of a good color quality and are available in many sizes, from compact lamps to huge lamps for lighting stadiums. Standard metal halide lamps tend to have a color temperature of 3700 to 4100 K and appear cool and slightly greenish. Their CRI is 65 to 70. Standards metal halide lamps are used where color is not critical, such as sport arenas, parking lots etc. The latest metal halide lamps are called ceramic metal halide lamps and exhibit superior color rendering (*80 to 85)* and a choice of warm *(3000 K) or cool (4100 K)* lamps.

Metal Halides inside the arc tube are scandium and sodium; when the arc tube reaches an operating temperature, the MHs are vapourized. At the core of the discharge, the MHs separate into metals and halogen, the metals emitting radiation in visible region. They need several minutes to attain full light output and, when hot, several minutes to restart after being switched off. *(Figure 2.52)*

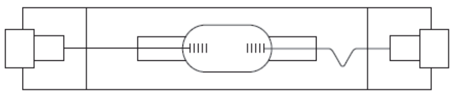
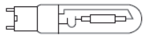


Figure 2.52: Double-ended metal halide lamp with compact discharge tube and quartz glass outer envelope.

Sodium Lamps



The two types of sodium lamps are *high-pressure sodium (HPS) lamps and low-pressure sodium (LPS) lamps*. HPS lamps exhibit a golden-pinkish light that tends to create spaces with a distinctly brown or dirty quality. Low-pressure sodium emits monochromatic yellow light, creating stark scenes devoid of color altogether. Although HPS lamps offer very high lumens per watt, their color deficiencies limit use to lighting roads, parking lots, heavy industrial workspaces, warehousing, security lighting, and other applications where light color is not important. LPS lamps are even higher in lumens per watt, but their color is poor that their use is limited to security lighting *(Figure 2.53).*

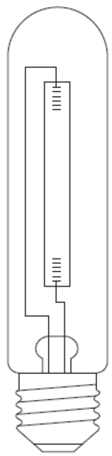
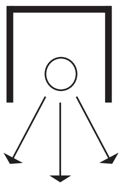


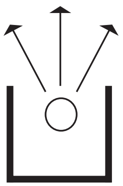
Figure 2.53: Single-ended high-pressure sodium lamp with ceramic discharge tube and additional outer glass envelope.

Direction of Light and correct Luminaires in a Domestic Environment

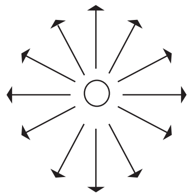
A luminaire is defined as the apparatus containing the light source, which connects it to the electricity supply and may include a shade, cover, reflector, ballast or transformer. Its main function is to support the light source (lamp), protect it from damage and direct light. Lighting fixtures are luminaires that are permanently attached to a building. In other words, a table lamp is a luminaire but not a fixture. The choice of luminaire type is fundamental on the overall appearance and psychology of a room and its ambience.
Luminaire are characterized by the manner in which light is distributed:



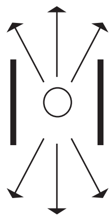
-Direct luminaires emit light downward. These include most types of recessed lighting, including downlights and troffers. Direct luminaires tend to be more efficient by distributing light directly onto the task area. They generally create dark ceilings and upper walls that can be dramatic but also uncomfortable due to high contrast. Direct lighting is typically used in buildings lobbies, offices, restaurants, etc.



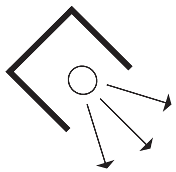
-Indirect luminaires emit light upward, bouncing light from the ceiling into a space. These include many styles of suspended luminaires and some portable lamps. Indirect luminaires tend to create comfortable, low-contrast soft light that psychologically enlarges space. Indirect lighting is generally preferred for spaces in which people spend a lot of time working, although some task light or other directional light is generally recommended to eliminate the bland character.



-Diffuse luminaires emit light in all directions uniformly. These include most types of bare lamps, chandeliers and some table and floor lamps. Diffuse luminaires tend to create broad general light that often is considered glaring due to lack of side shielding. Most chandeliers are diffuse luminaires and they are often chosen for ornamental reasons or for utilitarian applications; in any case other lighting must be present. Without other light, diffuse luminaires tend to create a flat, uninteresting light that is often uncomfortable.



-Direct/Indirect luminaires emit light upward and downward but not to the side. These include many of suspended luminaires. Direct/indirect luminaires are often a good compromise between the efficiency of direct lighting and the comfort of indirect lighting.



-Asymmetric luminaires are usually designed for special applications. Wallwashers are a form of direct luminaire with a stronger distribution to one side so as to illuminate a wall. Asymmetric luminaires are chosen when accent lighting of objects is desired. For example, choose a wallwasher to illuminate a wall, an accent light to illuminate a painting or sculpture.

Styles of Luminaires[20]

Downlights

Downlights are often called cans or top hats. A type of *direct luminaire*, they are usually round and recessed in the ceiling. Their principal use is general illumination in a wide range of residential and commercial application, especially in halls, corridors, stores, etc. Downlighting can be equipped with incandescent, halogen, low-voltage incandescent, compact fluorescent, or HID lamps. They typically consists of two parts: the can above the ceiling and the trim installed from below the ceiling *(Figure 2.54)*.

(a)
(b)
(c)
(d)

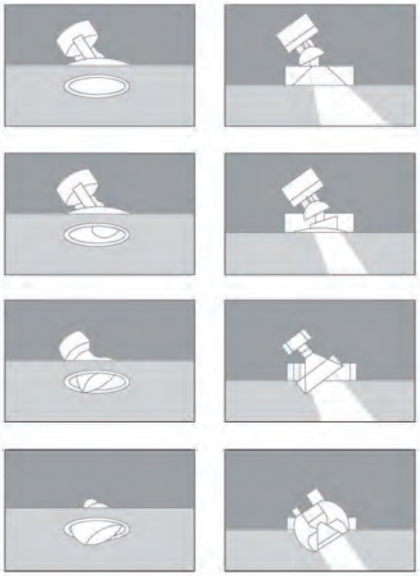


Figure 2.54:
(a) Dowlight with dark reflector
(b) Dowlight with anti-dazzle mask
(c) Dowlight with cardanic suspension
(d) Dowlight spherical version

20 R. Whitehead, Residential Lighting. A practical Guide, John Wiley & Sons Inc, 2004

Wallwashers

Wallwashers are available in several types:

-Eyelid wallwashers are, essentially, downlights with an eyelid- shaped shield on the room side;

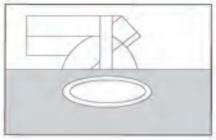
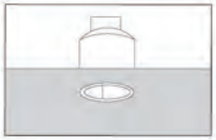


Figure 2.55
Wallwasher for CFL.



Wallwasher with ellipsoidal reflector for halogen lamps.

Wallwasher with sculpture lens and reflector attachment for reflector lamps.

-Recessed lens wallwashers resemble downlights but use an angled lens to throw light to one side; they have the advantage of not interrupting the sight line of the ceiling;

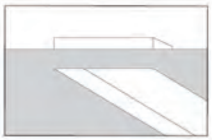


Figure 2.56
The direct light component is cut off, the reflector contour produces especially uniform lighting.

-Surface and semirecessed lens and open wallwashers throw light onto an adjacent wall and generally work best;

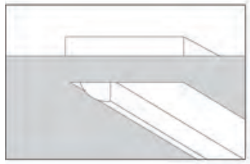


Figure 2.57
A supplementary prismatic diffuser below provides light directly from the top of the wall

-Downlight wallwashers are downlights designed to illuminate rather than scallop an adjacent wall, but not well enough to display purposes.

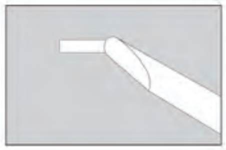


Figure 2.58
Cantilever- mounted wallwasher

Accent Fixtures

Accent fixtures allow light to focus on art and building surfaces:

-Recessed accent lights appear as downlights but internally permit rotation and elevation of the light

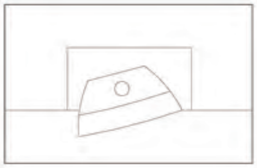


Figure 2.59 Asymmetric louvred luminaires

-Eyeballs and pulldown accents resemble downilights, but their appearance belies the ability to be adjusted.

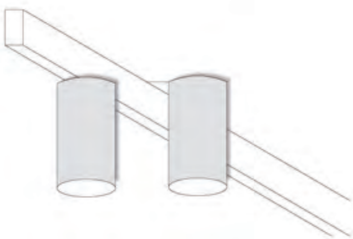


Figure 2.60 Pulldown accent lights

-Track lighting systems are designed to accent art and retail displays; for ease and flexibility of use, lampholders can be relocated to any point on the track. Track lighting is the solution for accent lighting in some situations, such as where there is not enough ceiling depth to install recessed units or in spaces such as artist's studios where the lighting must be highly flexible. They cannot be a good source of ambient illumination, because it is normally mounted on the ceiling and too close to it to produce any adequate indirect lighting. Track lighting, due to the usual configuration of the fixtures, is typically very directional. However, if it is used to light for example the inside cabinets or countertops, people heads can get in the way, creating casting shadows onto the work surface.

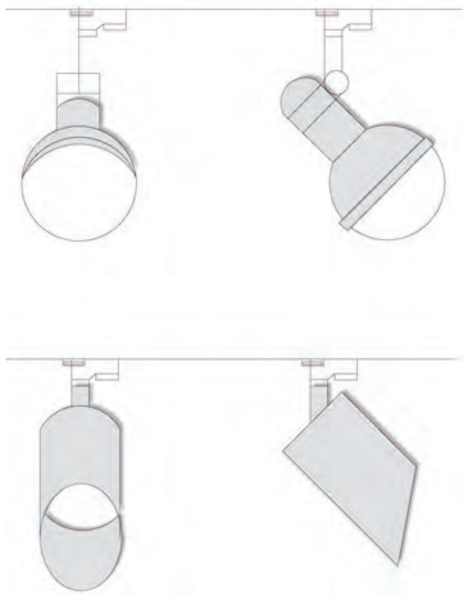


Figure 2.61: Spotlights of different designs and technical performance. Spotlights and washlights whose design is based on fundamental geometrical forms.

Decorative/General Luminaires

Here is a list of the main Decorative Luminaires:

-Chandelier which are ornate luminaires generally consisting of many small incandescent lamps that simulate the effect of candle flames. They are used for general illumination in dining rooms, foyers and other formal spaces *(Figure 2.62).*

Figure 2.62: Chandelier

-Ceiling drums are round or square luminaires that mount to the ceiling surface. They typically are used as corridor lights, rest room lights and in many locations where a modest amount of light is nedeed. Drums can be utilitarian or ornamental *(Figure 2.63)*

Figure 2.63: Ceiling drums

-Pendants are also ceiling-hung decorative fixtures. In general, the term pendant is used for hanging luminaires less formal than chandeliers that are used in officies, restaurants, and many other places. Most pendant luminaires are incandescent lamps *(Figure 2.64).*

Figure 2.64: Pendant lamp

-Close-to-ceiling luminaires are similar to pendants but mount closely to the ceiling to allow use in most rooms with conventional ceiling heights. Many of them spread some lateral light across the ceiling, which is a distinctive advantage *(Figure 2.65).*

Figure 2.65: Close to ceiling luminaire

-Torchères are floor lamps designed specifically for uplighting. Tochères provide excellent ambient light for a room. Their main job is to fill the volume space with an overall illumination that softens the shadows on people's faces and shows the architectural detailing. Most use incandescent or halogen sources, although compact fluorescent options should be considered for commercial and hospitality applications *(Figure 2.66).*

Figure 2.66: Tochères

-Sconces are ornate or decorative wall-mounted luminaires. Often match an adjacent chandelier and exhibit a wide range of style, from crystal fixtures with flame-tip lamps to modern design; wall sconces provide the ambient light for the room and allow the chandelier to be dimmed, so that gives the illusion of providing the illumination without attracting too much attention to itself. Place a series of wall sconces mounted on the soffit above the overhead cabinets will also provide a modern source of ambient illuminaton in the kitchen. They can be equipped with incandescent or compact fluorescent lighting to provide an attractive and effective light *(Figure 2.67).*

Figure 2.67: Sconces

Task Lighting

-Linear luminaires are the first step toward successful light in the kitchen with a type of light mounted below the wall cabinets; this type of lighting provides an even level of illumination along the countertops and is much more shadow-free. These linear task lights could be found in incandescent or fluorescent versions. As opposite, if the linear luminaires are mounted above the cabinets, another ambient lighting is provided in the space between them and the ceiling *(Figure 2.68).*

Figure 2.68: Linear luminaires

-Portable tabletop luminaires with solid shades often do the best job for casual reading, because they better direct the light and do not visually overpower the room when turned up to the correct intensity for the job at hand *(Figure 2.69).*

Figure 2.69: Portable tabletop

Switching and dimming

Since light was invented, switching has been essential: even candles and gaslights were turned on and off and sometimes even dimmed. With electric lighting, switching and dimming is easy: when we wish to darken a room for sleep, we turn off lights and this is generally called *switching; dimming*, when a light operates even if its power is varies, is generally used to create an intimate room. In addition, it is now frequently used to save energy. In many spaces, windows introduce enough light to permit interior lights to be dimmed; the combination of daylight and reduced electric light still provides adequate illumination.

As controls become even more sophisticated, interior designers have many ways to improve the efficiency of lighting systems and provide flexibility for users, and all through: *preset dimming, time control, lumen maintenance etc*.

The preset dimmers permit the light level from each dimmer to be set and memorized. The most common preset dimming device is a four-dimmer, four-scene controller typically used to control light in large residential living rooms, hotels, restaurants, where combinations of lighting are used for different times of day or for different functions.

On the other hand, *many lighting systems are best controlled automatically by time*. For instance, the lights in a store with fixed hours of operation can go on and off automatically through the use of a time switch. In larger buildings, computerized energy management systems may be programmed to run many time schedules for various lighting systems.

Another kind of lighting system is that of *Lumen maintenance controls* which is designed to take advantage of the overdesign of lighting systems so that as lamps age and luminaires become dirty, designed lighting levels are maintained. Systems to perform this function use a special type of interior photoelectric cell and dimming of fluorescent or HID ballasts.

Code Requirements:

Building codes require lighting controls in two ways:

- The *National Electric Code* requires switches by every door in residential occupancies, including private homes, apartment and condominiums.
- Energy codes, like *ASHRAE/IESNA 90.1* and various state codes, require switching in every nonresidential space. This is primarily to encourage people to turn lights off when they are not needed. In many cases, the switching must be automatic, as with a motion sensor.

Control Devices[2]

Lighting controls include a broad category of techniques and equipment that are designed to enhance an environment and conserve energy; they can operate either manually or automatically and include switches, dimmers, timers, occupancy sensors and photosensors:

Switches

Switches turn lights on and off, is the easiest and oldest means of controlling lights. Most switches are levers and mechanical devices that open and close electrical contacts in the power circuit directly feeding the lights. Some switches features a finder light or a pilot light and they should be located next to the door as you enter a room, preferably on the latch side.

Dimmers

Dimmers are control devices that vary the light level and power to lights. For incandescent lights, dimmers or dimmer switches are usually used in place of regular switches. For fluorescent lights, the fluorescent ballast must be a dimming type connected to a compatible dimmer switch. In a preset dimmer, the switch and the dimmer require separate actions; preset dimmers are generally better because they permit setting a preferred light level and leaving it there even when lights are switched.
Lighting designers, in addition to considering dimmer style differences, must also select dimmers according to their load, called the dimmer rating (in Watts) which vary according to each type of artificial light source: for incandescent and halogen lamps, dimming results in energy savings, longer lamp life and a warmer color; fluorescent and HID lamps are difficult to dim and require special dimming ballasts.

Timers

Timers control lighting systems by turning lights on and off at designated times. Timers can be very simple devices that a home owner manually sets and plugs into a wall socket, or they can be a component in very sophisticated computer programs which include astronomical data that automatically adjust when lights turn on or off according to the amount of daylight at a particular time for a specific geographical location.

Occupancy sensors

They are designed to turn lights on or off based upon whether there are people in a room. Generally, occupancy sensors are practical in spaces for security purposes or with few people. Sensors detect people in a space by discerning sounds, movements, or body heat. They can be mounted on the ceiling, on walls,

2 M. Karlen. J.Benya, Lighting Design Basics, John Wiley & Sons Inc, 2004 or in the corners of a room. They are also available for wall switches; each sensor has a designed angle of coverage and an effective range. In determining the location sensor, the most important consideration is to maintain an unobstructed view. The wrong type of sensor or inappropriate location will cause a false on or off.

Photosensors

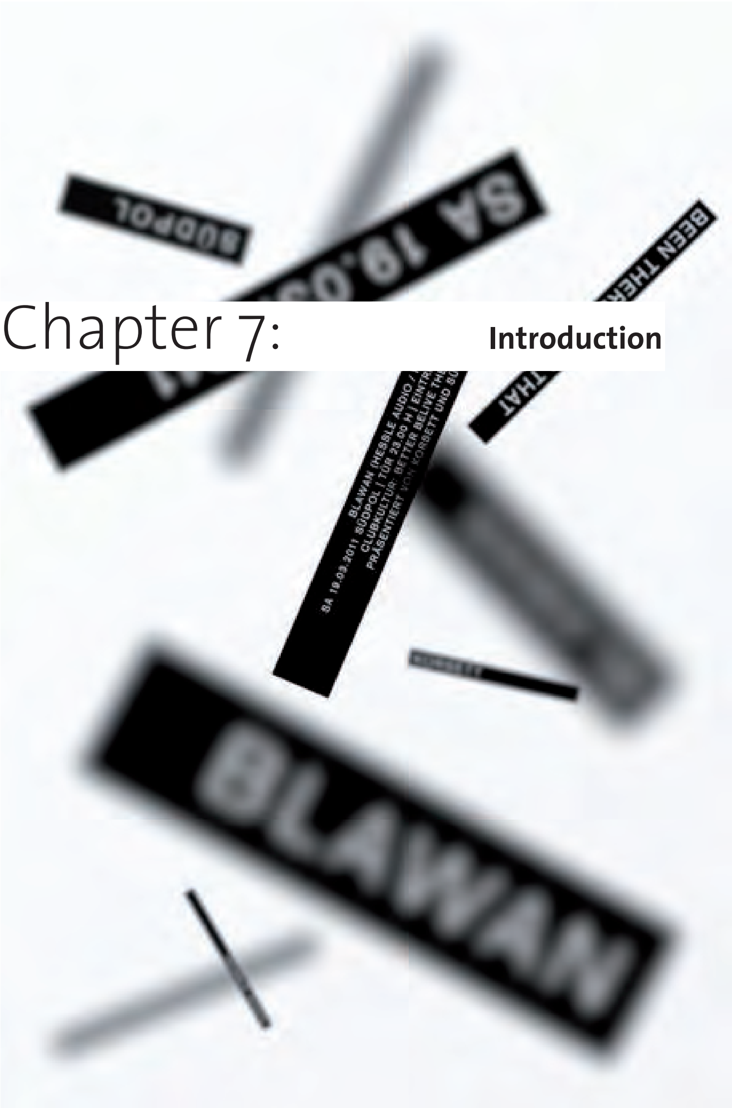
Are devices that detect the amount of illumination in a space and then send signals that control electrical light sources by switching on and off or by adjusting illumination levels to reach the optimum point. Photosensors are used often for daylight integration applications (see previous Chapter 6). By using photosensor, electrical light sources can be adjusted to accommodate fluctuations in the quality and quantity of daylight in a space or on a task. As with occupancy sensors, an important element of success with photosensors is a proper mounting location. Photosensors can be mounted on a ceiling close to a task, directly on the surface of a work area, or next to a window or skylight.

Section III

Full-Scale Study in a Room Laboratory

“If I can’t see it’s not just my eye fault”
[Lucia Baracco et al, Questione di Leggibilità, Progetto lettura Agevolata, Venezia, 2005]

Chapter 7



Chapter 7: **Introduction**

The second half of the twentieth century witnessed the unprecedented rise of the socio-demographic group known as “Third Age” or “Young Old”; it is estimated indeed, that about 5% of them, aged 65, and about twice this rate in “Older Adults”, another term to define this new social class, aged 80 and over, suffer from severe age-related visual impairment; as a consequence, the design of every environment, private and public, began to be influenced for the first time by the aging population.
Starting from this foreword, the main purpose is primarily to show how, with both artificial and natural lighting design and control, the elderly and visual impaired people could perform instrumental activities of daily living without, if it’s possible, other modes of compensation (hearing, touch, other people’s help) and, as a consequence, to reduce the gap existing between Everyday Competence (EC) and this specific social group.
The term “*Everyday Competence*” refers to the ability to solve problems associated with everyday life; expectations regarding everyday competence vary for

the elderly with normal vision versus the elderly visually impaired, as well as solutions options. The tasks associated with everyday competence *(also known as iADL = Activities of Daily Living)* change culturally and contextually. Many in-depth analysis[1] have been conducted with regard to the subjects' activities, furniture preferences, key role of glass and daylighting systems in northern countries climates before starting the real experiments' project.

In particular, it is crucial to acknowledge that visual impairment is directly linked to functional declines that affects older adults' relations with their physical environment; when it fails to meet not only the elderly, but also the visually impaired or with some problems' sight people' needs, these subjects can certainly find, and have always found, alternative modes of compensation to overcome the difficult situations they encounter in their activities. An example for an environment-related mode of compensation would be the alteration of light conditions inside the apartment; but to really solve the problem, actions must be taken upstream through careful design not only in indoor environments but also through a wiser awareness by the architect himself.

The study was carried out thanks to the availability of Barbara Szybinska Matusiak[2], who

1K. Sagawa, Vision of the elderly and visually impaired -for Accessible Design in Light and Lighting, 26th Session of the CIE Beijing, 2007;

G.K. Cook, Innovation in light reflectance value - measurement and application, 26th Session of the CIE Beijing, 2007;

A. Tenner, Activity light for the elderly, 26th Session of the CIE Beijing, 2007;

Y. Zhang, Experiments and researches of reading lighting for the elderly, 26th Session of the CIE Beijing, 2007;

I. Youko, Emergency lighting with considering adaptation of eyes, 26th Session of the CIE Beijing, 2007;

C. Chain, Public Lighting specification for visually impaired people: results from an experiment, 26th Session of the CIE Beijing, 2007;

A. Vidovszky-Németh et al, Brightness, Visual comfort and Task Performance, 27th Session of the CIE Sun-City, 2008

L. Geerdinck et al., Comfortable lighting for seniors: the effect of illuminance and colour temperature on the visual acuity in later life, Session of Lux Europe, Istanbul, 2009;

M. Wei and K.W. Houser, Colour discrimination of seniors with and without cataract surgery under illumination from two fluorescent lamp types, Session of the CIE, 2012;

J. Wienold, Quantification of age effects on contrast and glare perceprtion under daylight conditions,Session of CIE, 2012;

A. Logadòttir, Comparison of user satisfaction with four different lighting concepts, Session of CIE, 2013;

A. Lewis- J. Torrington, Extra-care housing for people with sight loss: Lighting and design, Lighting Res. Technol. 2013, 45: 345-361;

CM Lasagno et al, Transitional spaces from exterior to interior as functional vision barriers in ageing, Lighting Res. Technol. 2014, 46: 706-715;

A. Lewis, Daylighting in older people's housing: Barriers to compliance with current UK guidance, Lighting Res. Technol. 2015, 47: 976-992;

Hans-Werner Wahl,1 Frank Oswald,2 and Daniel Zimprich, Everyday Competence in Visually Impaired Older Adults: A Case for Person-Environment Perspectives, The Cerontologist, Vol. 39, No. 2, 140-149, 1999;

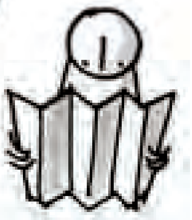
Lucia Baracco et al, Questione di Leggibilità, Progetto lettura Agevolata, Venezia, 2005.

2 Professor at the Department of Architectural Design, Form and Colour StudiesContinuing and Professional DevelopmentFaculty of Architecture and Fine Art. She joined the Faculty of Architecture at NTNU in 1994 as a research fellow. Her doctoral project was devoted to daylighting in linear atrium buildings at high latitudes (finished 1998). Since then she has been involved in many Norwegian and international scientific projects dealing with daylighting and artificial lighting in architecture, e.g. project manager of the "Visual environment in apartment buildings", project leader for the bilateral Polish-Norwegian scientific project STEP, partner of the Translucent façade project and member of the SYN-TES, the Nordic network. Nowadays she is the leader of two NFR projects: "DayLighting" and "HOME". She is also strongly involved in the activities of the international organizations: CIE, AIC and IEA and is the member of the CEN international group working on the proposal of a new European standard for daylighting in buildings.

gave us not only valuable comments and suggestions in the whole phase of the study, but also the access to the Room Laboratory at NTNU *(Norwegian University of Science and Technology in Trondheim - Faculty of Architecture and Fine Art)* where previous studies about similar topics[3] were performed few years ago. Finally, thanks are due to the optometrist Klaus Sjøhaug[4], put in contact with us through the Professor B. Matusiak, who provide us some of his patients' names who might have been interested in our study. Participants were chosen from these two diagnosis groups: macular degeneration and cataract. In the experiments some subjects with normal vision took part also, it enabled better understanding of the needs and preferences of the first two groups.
In a light condition such as Norway where, long periods of total absence of natural light; interchange periods with total absence of dark, a careful lighting design is crucial for the strong relationship existing between humans, artificial and natural lighting control and, the built environment. For this important reason both artificial and natural lighting scenarios were tested and designed in the study. The focus was not only at the "light" itself but also at the interiors design, how it could affect human well-being and, finally, to the key role of colour and luminance contrast in indoor environment; the human visual perception indeed, is based on the existence of contrasts of light, shade and contrast of colours; for this reason the term "contrast" is used in both a physical and a perceptual sense.

The Study consists of four experiments carefully designed regarding previous studies about Accessible Design *(See Section I, Chapter 1.1)*, the interaction between Light and Human on its fullest *(See Section II, Chapter 3-4)* and relative Lighting Guidelines *(See Section I, Chapter 2.1)*. The performance and preferences were evaluated for both people with normal sight and with visual impairments.

Experiment 1: Pick out a book from the library. It was really a colour discrimination test under two different artificial light scenarios. The most important question was which of them was preferred by the subject to complete the task. Contrast, or the luminance difference between characters and the background, are one of the most important factors that affect the legibility of a written text; today more and more texts or covers books with lower contrast make the reading or the recognition very difficult for visually impaired people.



Experiment 2: Reading. The main aim of this test was to compare different sun shading devices under conditions of natural light only under; both, clear and overcast sky conditions, and to find out which of them was better for the task's performance according to the subjects' needs and visual comfort and, in addition, to find out what kind of printed

3 Barbara Matusiak, Per Fosse, Daylighting Preferences for Subjects with Visual Impairment and for Subjects with Normal vision, a Full-Scale Study in a Room Laboratory, Session of Lux Europe, Istanbul, 2009;
4 Doctor Klaus A. Sjøhaug has graduated at the Indiana University(USA) in the 1988. He has worked as an optician at the eye's department of St. Olavs Hospital and he has taught at the University College Buskerud(NO). Today he has an eye-clinic in Trondheim(NO) and he works as a consultant for the Assistive Technology in the field of low vision.

text is easier to read for each visual impairment.

Experiment 3: Object wRecognition. The test aimed at comparing user's satisfaction with two different artificial lighting concepts and to find out which medicines' label was easier to read. It consisted of two parts: in the first one, subjects were asked to recognize stuffs from a distance of about 4 meters sitting by the table; the second part was focused on the recognition of specific objects from a short distance of about 1 meter, in this particular case: medicinal products. Especially the second part represented a reoccurring issue for visually impaired people: the expire date given on food or pharmaceutical packaging, which is undoubtedly one of the most important information for consumers. The expire dates are impressed or printed on the box with different techniques and for some of these it is easy to obtain a quality print that meets the legibility requirements.

Experiment 4: Watching TV. The main aim of this test was to compare two different artificial lighting scenarios for TV watching. The subjects were answering questions about the kind of artificial light sources, their position, their visual comfort qualities in different positions, about glare from light sources and reflections on the screen.
A questionnaire was carried out at the end of each experiment. The participants answered questions about the importance of visual comfort and their preferences about artificial lighting, illuminance and light distribution.

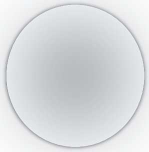
The full-scale experiments were carried out between June and August 2015 and results try to answer the research question: *Is it possible, through a careful natural and artificial lighting design, safeguard the same accessibility both for normal and visually impaired people in daily tasks performance?*

Keywords: *natural and artificial lighting projects, everyday competence, age-related visual impairments, colour and luminance contrast.*.

7.1 Participants

In order to find out how interior daylighting/lighting preferences are correlated with specific abilities of the elderly's visual system, subjects with visual impairments and subjects with normal vision(after cataract surgery) were invited to take part in the research study. The visually impaired participants were chosen from the two following diagnosis groups:

• Macular Degeneration , often Age-Related Macular Degeneration *(M)*, is a medical condition that usually affects older adults and results in a loss of vision in the centre of the visual field *(the macula)* because of damage to the retina. It is a major cause of blindness and visual impairment in older adults, afflicting 30-50 million people globally. Macular degeneration can make it difficult or impossible to read or recognize faces, although enough peripheral vision remains to allow other activities of daily life.



• A Cataract (C) is a clouding of the lens in the eye leading to a decrease in vision; it is the consequence of a biochemical phenomenon that occurs with increasing age. Cataracts are the cause of half of blindness and 33% of visual impairment worldwide. Symptoms may include faded colours, blurry vision, halos around light, trouble with bright lights, and trouble seeing at night. This may result in trouble driving, reading, or recognizing faces. Poor vision may also determinate an increased risk of falling and depression.

7.2 Method and procedures

7.2.1 Subjects' selection

The study sample consisted of 5 older adults with several age-related loss in vision. Of these 5 older adults, 2 participants were affected by macular degeneration, other 2 older adults by cataract and the remaining subject, was also included in the study as a control "group" of older adults. All of them were aged between 75 and 80 years. These individuals were referred as visually impaired older adults. Irreversible visual loss was one criterion of selection. All participants had a full ophthalmological evaluation where their diagnosis were confirmed by the optometrist Klaus A. Sjøhaug prior to the study in the Room Laboratory at NTNU. These 5 subjects gave their formal consent and went through the study, whereas other 4 who were also invited, refused. Based on background information available from ophthalmologists, no selection bias with respect to age, sex, or eye disease could be determined. The visually unimpaired control subject was recruited through Doctor Klaus himself. Since the number of participants was limited, they have been called several times to the laboratory in order to better understand their needs and to make the obtained results more reliable. Three categories were represented: macular degeneration, cataract and visually unimpaired. The study's results do not provide data which represent a generalization of each visual impairment category but refer precisely to that group of subjects analyzed.

During the examination in the Room-Laboratory the participants used the best glasses possible, in accordance with their refraction status. All of them gave their informed and written consent after the aims and procedures were fully explained.

7.2.2 Description of the experimental rooms in the Room Laboratory

The main study's aim is to improve the performance of everyday activities, through natural and artificial light's quality design; for this reason an **abstract "apartment"** was built in full scale in the Room Laboratory developed By Barbara Szybinska Matusiak in 2006 *(http://www.ntnu.edu/kit)*. It is situated at the third floor in the Central Building of the NTNU- campus called Gløshaugen. Its orientation is West-East, the two glazed walls' views are toward other University buildings and/or trees; only the west oriented façade and view was used for the project.
A high-raise building situated south for the Room Laboratory shadows all windows for sunlight during noon hours: 11:00-14:00. To test natural light devices the direct sunlight was needed, therefore the experiments were carried out from 16:30 pm to 17.30 pm, when the sun was in the front of west façade. In the artificial light part of the experiment, instead, all rooms were completely darkened by sun-proof roller curtains.
The Room Laboratory has two horizontal ceilings in metal mesh, adjustable in height; one of them was used as the supporting framework for the project, in fact the ceiling was able to bear ceiling panels, to give a support for wall panels and the luminaires were fixed to it *(Figure ..)*.

N

Project area under the supporting framework.

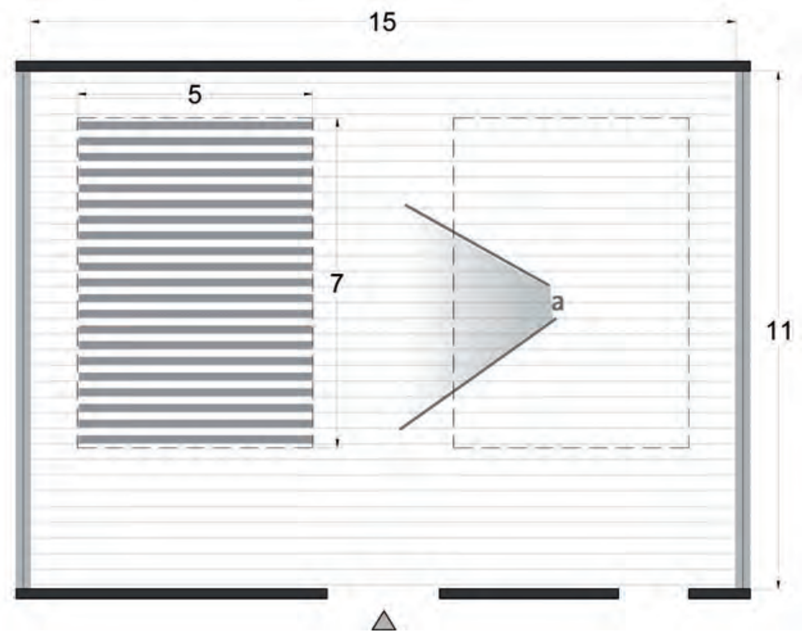


Figure 3.1_a: Plan of the empty Rom-Lab

Figure 3.1$_b$: The dimension of the RomLab *(15 m x 11m x 2.5m)* allowed the realization of experimental rooms in scale 1:1. The picture 3.1$_a$ *(View a)* shows the supporting framework *(5m x 7m)* in metal mesh used to fix the different construction's components.

In front of the west glazing facade, an internal wall was constructed of white boxes*(50x50x25cm. Figure 3.3 Component 1)*; the other sidewalls, instead, were made of white, vertical elements*(5x60x250cm. Figure 3.3Component 2.)*, their top was fixed to the metal structure. The last building component, fastened to the framework through plastic ties, was the ceiling which was assembled by white, horizontal elements*(cut to size, Figure 3.3, Component 3)*, the white colour was chosen to increase the sunlight's reflection especially to evaluated the light-shelf's performance. The total dimensions of the apartment were 6.1x4.8 m and was composed of three experimental rooms: the hall *(3x1.5m)*,the living room *(3x3m)* and the kitchen *(3x4.5m)* *(Figure 3.3)*.

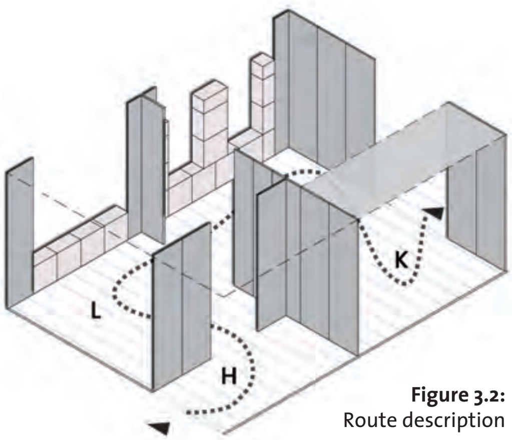
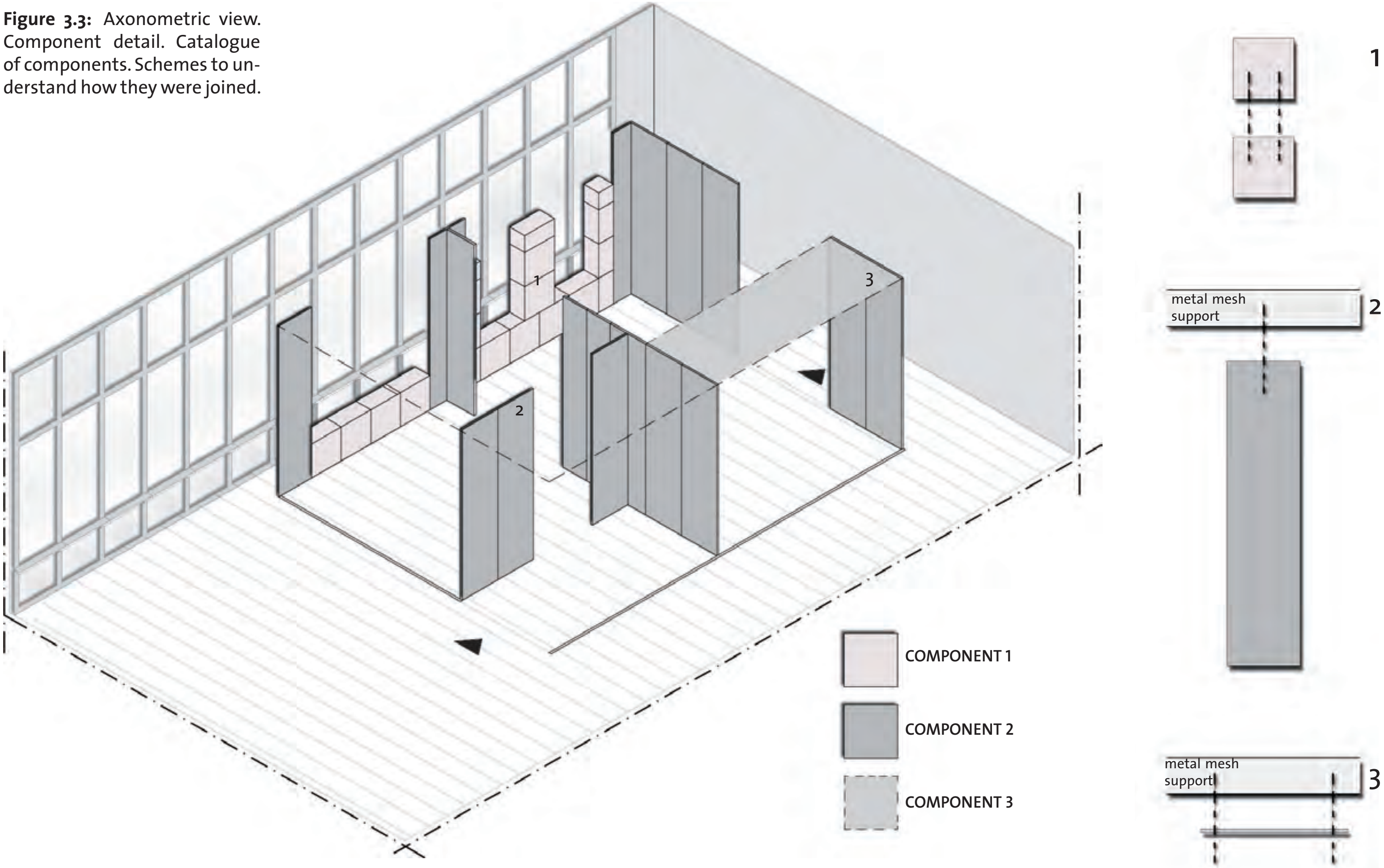


Figure 3.2: Route description

Figure 3.3: Axonometric view. Component detail. Catalogue of components. Schemes to understand how they were joined.



The interior design was studied to simulate, in the best way, the home environment; consequently it was planned and built in order to be suitable for the performance of the different everyday activities. Hereinafter description detailed.

Hall

In this experimental room, the first test comparing two artificial light solutions was carried out; the participants had to recognize and pick out some books, which differed in the covers' contrast, from a small library. For this reason, a bookcase using nine black boxes *(Internal light brown. 50x50x25cm. Figure 3.4)* was assembled, thus creating three shelves where the 39 books *(3x20cm)* were arranged.

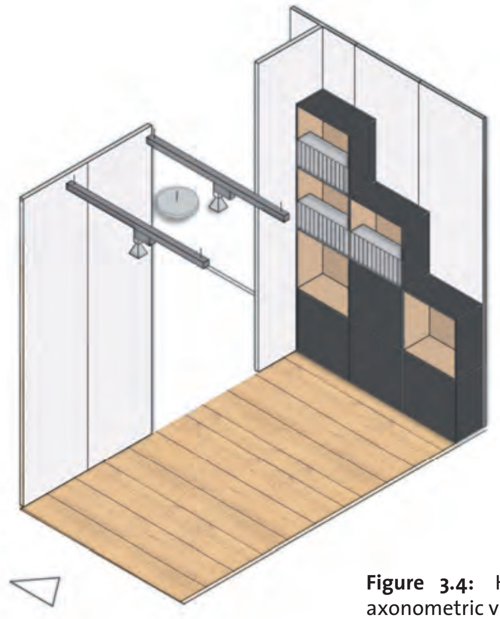


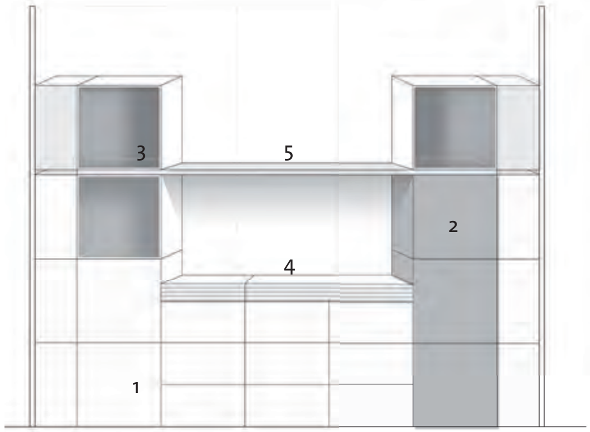
Figure 3.4: Hall axonometric view

Kitchen

In this room, also two experiments were performed: the Reading Test and the Object Recognition Test; the first evaluated a natural lighting device under two sky conditions, while the other one compared two artificial lighting solutions. The main aim was to simulate a real kitchen where different activities were carried out; the furniture were designed to be compatible for both tasks, in natural and artificial light conditions.

Next to the external wall, a wooden dining table with iron legs *(85 x 120 cm)* was placed with four gray plastic chairs around. On the opposite wall instead, the kitchen furniture was assembled with twenty-four white boxes *(50x50x25 cm Figure 3.5 Component 1)*, six gray boxes *(50x50x25 cm Figure 3.5 Component 2)* to simulate a fridge and three white boxes *(50x50x25 cm, internal: dark blue. Figure 3.5w Component 3)* for the kitchen cabinets; finally, were arranged fourwhite wood pa-

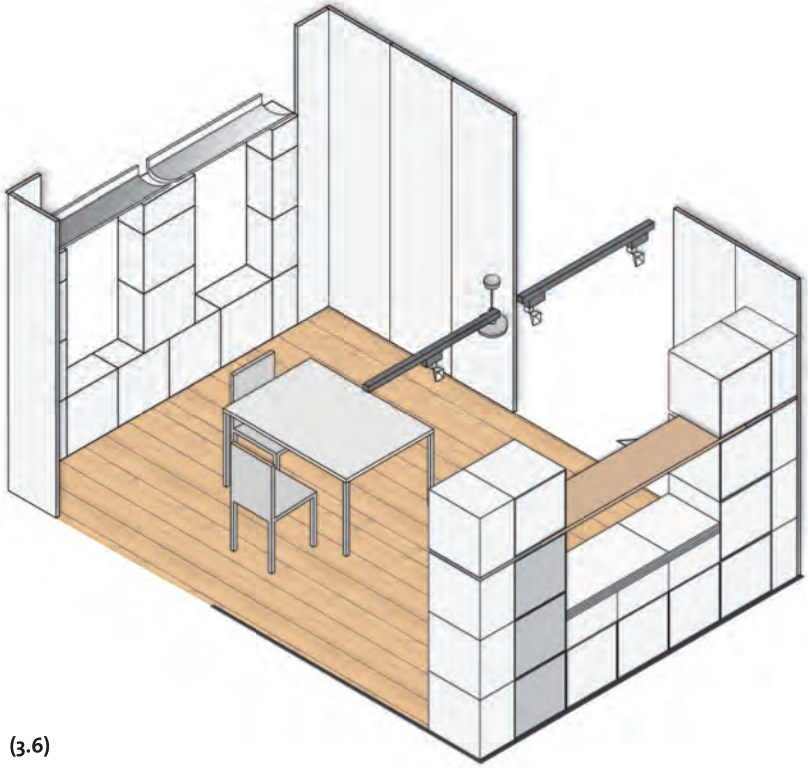
Figure 3.5: Kitchen furniture's front view. **Component 1:** white box(50x50x25 cm). **Component 2:** six gray box (50x50x25 cm). **Component 3:** white box with internal: dark blue (50x50x25 cm). **Component 4:** white wood panel (150x55x3 cm). **Component 5:** dark brown wood panel (250x30x3 cm).



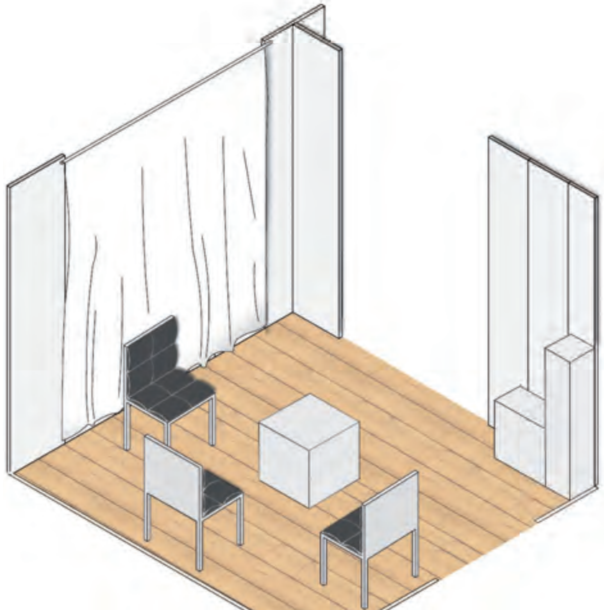
nels (150x55x3 cm. Figure 17. Component 4), one above the other, to create the work plane and one dark brown (250x30x3 cm. Figure 17. Component 5) which was used like a shelf to 1.50 meter high.

Living Room

Here were performed two experiments: the reading test and the watching TV test, the first evaluated *two natural lighting devices under two respective sky conditions*, while the other one compared *two artificial lighting solutions.* Regarding the furniture, they were unchanged during the execution of all experiments and it happened for one main specific reason. Since the purpose was to simulate domestic environment, artificial-natural lighting and furniture should be flexible and regulated enough to satisfy a variety of needs. An example could be the key role of the *chandelier* placed in the Living Room: even if it was designed for the watching TV experiment, it was very important also in the reading test, particularly because it creates the atmosphere typical for living room environment in many *Nordic homes.* In fact, in the Nordic climate, the use of gold or other shiny materials is a solid answer to add sparkling and luminance contrast, and a wider spread of light, to an otherwise dull setting of dark skies. The interior design of the living room was therefore organized with three armchairs around a TV table. During the reading test three different alternatives were created in relation with the window: one easychair was in front of the aperture, another one was on the side and the last was back to the window. Whereas for the Watching TV experiment, only the armchair disposition was changed: all the three seats were in front of the TV table, with the window on the left side in order to not produce glare or reflections on the screen *(Figure 3.7-3.8)*.

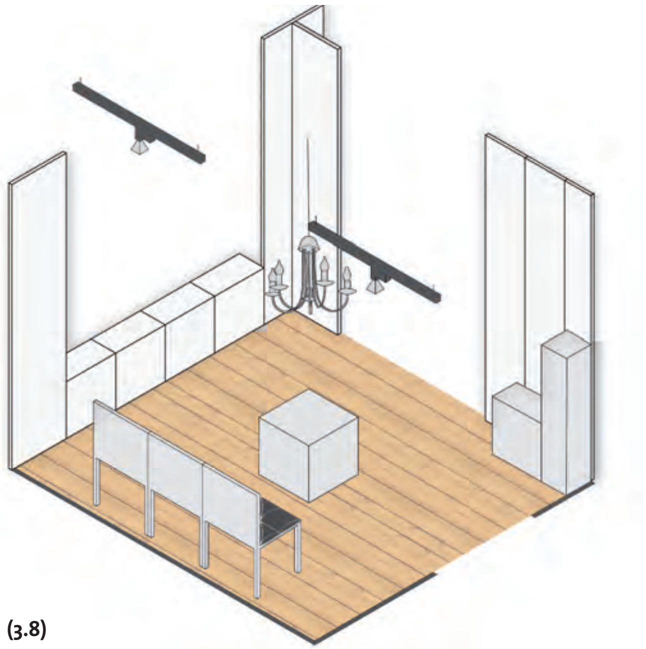


(3.6)



(3.7)

Figure 3.6: Kitchen axonometric view. **Figure 3.7:** Living Room axonometric view _ Reading Test. **Figure 3.8:** Living Room axonometric view_ Watching TV Test.



(3.8)

7.2.3 Experiments description

Experiment n°1:
Pick out books from the library
This first experiment was a colour discrimination test and it took place in a full-scale experimental room set up in the Romlab to simulate a hall in an apartment; the participants had to recognize book covers with different contrast levels *(from the easiest to the most difficult)* and pick them out in the library. The main aim of the test was to compare two different artificial lighting scenarios, **a conventional evenly lit solution** *(a compact fluorescent source)* against a **directional lighting solution** *(halogen sources)*, and to define what type of *Artificial Lighting Scenarios subjects preferred to complete their task, by examining visual comfort qualities and participants' feelings*.

The issue of contrast in coloured texts was then addressed. Luminance contrast, unlike chromatic contrast, is independent from brightness and refers only to the comparison of saturated colours *(See" Visual and Colour Perception" in Chapter 4)*.

People with vision impairments, partially sighted and elderly people, often have chromatic deficits which reduce their ability to recognize colours. On the other hand, the skill of luminance contrast is much less damaged; so we need to focus on this aspect, making high-contrast products available to many of them as possible. In general an abundant brightness difference between the letter and the background should be guaranteed. In this regard the **environment lighting** plays a key role, it can reduce, or even eliminate, problems of contrast.

The study intended to show that higher luminance contrast allows better vision and is of great importance for visually impaired people, especially for the colour combinations more difficult to recognize. Luminance level is in fact affected by a source's characteristics *(CRI, CTT, etc..)*, which influence the participants' response times and their number of errors.

Keywords: *Brightness , Colour Combination, Luminance contrast, general-task/accent lighting.*

Procedures and materials
Before starting the experiment, the participants stayed in the hall for about 10 minutes to adapt the to luminance; at the same time they could become familiar with the environment and observe the objects position in the library.
39 books were placed on three of the library's shelves: 13 were used for some trials before the test itself, in order to make the subjects more aware about the task to perform; the other 26 were employed for the real test. These books were made with the purpose of creating three different levels of luminance contrast: High, Medium and Low depending on the title's colour, the background colour and the lighting type. In this way five colour combinations were defined, with high, medium or low luminance.

	Colour Background	Colour Title	Number of Books	SOLUTION I Luminance Contrast Level	SOLUTION II Luminance Contrast Level
1	White	Black	6	High	High
2	Black	White	5	High	High
3	Blue	Yellow	4	Medium	Medium
4	Blue/Violet	Red	5	Medium	Medium
5	Red	Light Green	5	Low	Low

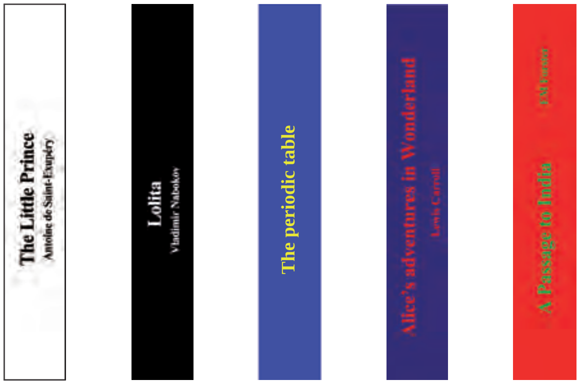


Table 3.1- Figure 3.9: Covers type. The choice of combinations was not random; three special pairs of colours were selected: neutral *(White/Black, Black/White)*, extreme of the visible spectrum *(Violet/Red)* and complementary *(Blue/Yellow, Red/Green)* depending on their different components of brightness. Under the two experiment's different artificial light scenarios, the various colour luminances were measured *(See Chapter 7.3 for Luminance Values in detail)*.

The test was done twice by subjects; the first part tested the 1^ Artificial Light Solution and the second part evaluated the 2^ Artificial Light Solution. In both of them the participants were asked to find five books with different *cover types*: *number 1, 2, 3, 4, 5 (see tables 3.1)*; the order was randomized in each session for every participant to avoid bias connected to the context effect as well as the sequential contraction.
Valuation
Performance was evaluated in terms of correctness and speed for the two lighting conditions: the *Accuracy Score* represented the number of the books that the subject was able to find, while the S*core of Speed* was the time employed *(expressed in seconds)* for picking out each book *(Table 3.2)*.

	Title (English or Norwegian)	Pick up V(YES) or X(NO)	Errors	Seconds
1				
2				
3				
4				
5				

Table 3.2: Model of evaluation table

The questionnaire, filled out at the end of experiment, constituted another evaluation element, especially to understand the subjects' real needs and preferences.

(Please fill in with your data each sheet)

CANDIDATE N° 1

Age: ....

Date: ....

MALE ○ **FEMALE** ○

VISUAL IMPAIRMENT:

○ Macular Degeneration

○ Cataract

○ After cataract surgery

○ No visual Impairment

Experiment Questionnaire n°1:

Pick out a book from the library

PRIVACY

These questionnaire answers will be anonymous and used only for the following study. By signing the candidate accepts the terms of the following activities of research.

SIGNATURE ....

1 Which artificial light solution do you prefer?

○ Solution 1 (ceiling lamp)

○ Solution 2 (spot lamps)

2 Rate from 1 to 4 the Solution chosen by you, based on your aptitude in the task's performance: (1= the worst; 2= quite good; 3= good; 4= very good)

○ 1

○ 2

○ 3

○ 4

2 Why did you choose this solution?

○ Absence of shadows between the shelves

○ Better contrast and, as a consequence, I found it easier to recognize books

○ Other...
....

4 Which book's cover was, for you, easier to recognize? (also more than one answer)

- ◯ White on Black
- ◯ Black on White
- ◯ Black on Yellow
- ◯ Blue on Yellow
- ◯ Green on Red
- ◯ Red on Blue

5 Which book's cover was, for you, more difficult to recognize? (also more than one answer)

- ◯ White on Black
- ◯ Black on White
- ◯ Black on Yellow
- ◯ Yellow on Bright Blue
- ◯ Green on Red
- ◯ Red on Blue

6 What kind of luminaire do you have in your hall?

- ◯ Ceiling lamp
- ◯ Wall lamp
- ◯ Floor lamp
- ◯ Spot lights

7 What kind of bulbs lamp do you have?

- ◯ Incandescent
- ◯ Florescent
- ◯ Halogen
- ◯ LED

Master Thesis on:"Light and health for visually impaired people" - Students: Francesca Borra, Laura Cane - Supervisor: Barbara Matusiak.

Figure 3.10: Model of English Questionnaire, which was also translated in Norwegian to facilitate the participants.

Lighting scenarios

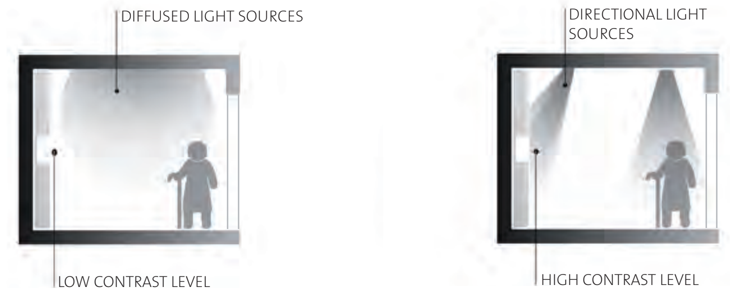


Figure 3.11: I and II Artificial Light Solutions. Lighting Concepts.

This experiment was carried out under **two artificial lighting scenarios** *(Figures 3.10 and 3.11)*: to shelter completely the room from the daylight sun proof roller blinds were used.
The purpose was to compared a "*traditional*" light solution *(surface-mounted fixture in the centre of the ceiling is used to be placed in many homes)* and a solution which we considered "*more performing*" thanks to the deepen analyzes carried out *(See Chapters 1.1 and 2.1)*.

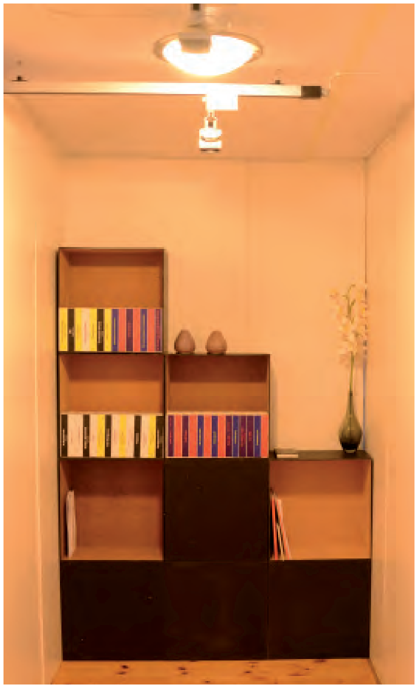


Figure 3.12: Photos of 1° and 2° artificial lighting solutions.

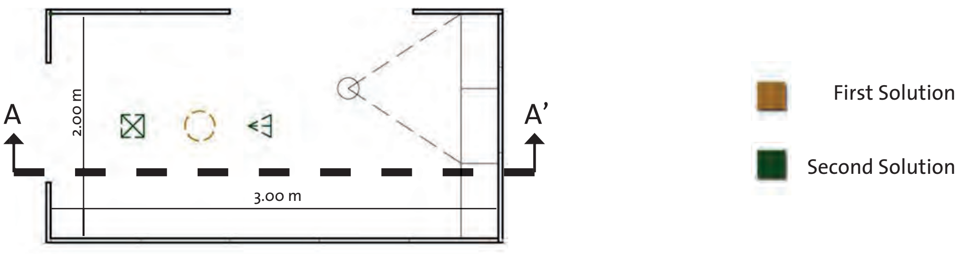


Figure 3.13
Lighting Plan and lighting cross Section (A-A') of the Hall, I and II Solution electrical light, Scale 1:50.

N° scenario	Lamps	Comment
1	One Ceiling Lamp (100%) with a compact fluorescent bulb	Even luminance distribution
2	Two halogen Spot Lamps (100%)	Focused luminance distribution (large difference between the luminance of directly and indirectly lighted areas)

(3.3)

N° scenario	The Lamp	CCT (K)	CRI
1	Linear Fluorescent Lamp, 14 W Dimmable: NO Base: E27 Energy Class: A	2700 K	80
2	Halogen Spot Lamp, 50 W Dimmable: YES Base: GUS.3 Energy Class: B	3000 K	100

(3.4)

As a consequence, lighting variables of the experiment differ in the first and the second light solution are:
- *the lighting type:* general ambient lighting - task/accent lighting *(See Chapter 3.1: The function of Illumination)*;
- *the lighting sources:* compact fluorescent lamp - halogen lamp *(See Chapter 6)*
- *the CRI: 80-100 (See Chapter 4, Paragraph: Lamp and Colour)*

Table 3.3: Lighting Scenarios.
Table 3.4: Lamp type and its CTT (in cold climates a warmer light colour appearance is preferred EN 12464.1:2011), CRI.

Experiment n°2:
Reading

The Reading test started with the consideration of three main factors: the first is the **interaction between a person and the environment** which is a key point to understand how illumination could affect people; the second is that people are most acutely aware of light when there is either not enough or too much of it to be able to comfortably do what they want to do; the third is the consciousness that *people with vision impairments, partially sighted and elderly people*, **need more light and more time to perform visual tasks with the same accuracy and speed than normal people**: *reading is preminently one of these visual tasks*.
The test took place in the same 1:1 scale purpose-built apartment in the Rom-Lab to simulate a domestic environment. The test had to be done twice by the subjects: both in the Living Room and in the Kitchen, equipped with **two different sun shading devices**. The main purpose was primarily to evaluate the *presence or not of direct sunlight* effects on the task performance and, as a consequence, **two different conditions of only natural lighting**: *sunny and overcast skies (See Chapter 1.1)* being aware that other factors, such as the style of written text, its height and spacing should be considered in each reading performance *(See Chapter 1.1, Chapter 2.1).*
Skies in northern countries, as in Norway where the experiments took place, are predominantly overcast, light is often dull and grey. Where light is prized , the conflict between protecting an exterior area from rain and yet admitting light is one that can be resolved through the use of glass but, in designing a window, we have the opportunity to do much more than offer a view or let daylight come into the building. Its size and position are important factors which determine where in the room light will settle and what its character will be. As a consequence, the perception of light-quality is intwined both with people's response to the local climate and built-environment as well as with the task in hand.

Keywords: *daylight, sun shading devices, visual tasks, written text, window's role, visual impairments.*

Procedures and materials

Before to start, subjects were welcome to come in the first experimental room*(the living room)* to adapt their eyes to luminance level. During this time of luminance and environment adaptation it was explained in detail how to carry out the experiment. Participants were free to choose their most comfortable sitting place and two/three trials were conducted to help them to become familiar with the visual task. The test then started in the position that the subjects chose as the most suitable for them.

The Reading test was divided into *two sections*: the first section took part in the Living Room and the second in the Kitchen.
Single words or 10 lines of words were printed on each sheet. Words belonged to the English and Norwegian vocabularies and were both short *(4-5 letters)* and long *(8-10 letters)* words, both high and low frequency of use. Subjects could choose in which language perform the test.

Sheets' Composition:

Four key variables were defined to affect the readability of the written text:
- *font size*
- *font type*
- *all capital letters*
- *text spacing and page's organization*

According to what has been said above, the five sheets were listed in the following order of presentation to the subjects, from the easiest to the more difficult to read:
• Preliminary test words: it consisted in five capital letters' words ordered in a column
  • First words' sheet: ten short capital letters' words ordered in a column;
  • Second words' sheet: ten long capital letters' words ordered in a column;
  • Third words' sheet: five lines with four spaced capital letters' words each one, both short and long and with no contextual connection between them;
  • Fourth words' sheet: five lines with four spaced lower

case letters' words each one, both short and long and with no contextual connection between them;
• Fifth words' sheet: five lines with four closed lowercase letters' words each one, both short and long and with no contextual connection between them.

Sheets were presented one by one placing them on the plane where the subject picked them up and held them in a centred position with respect to the reader axis.
Dealing with unreleased words, some fonts could be difficult to recognize and is therefore more advisable to use font that set them apart clearly, especially when the context did not provide sufficient evidence to overcome uncertainties. For this reason **serif-font** was used *(Times New Roman)* in this experiment *(Lucia Baracco et al, Questione di Leggibilità, Progetto lettura Agevolata, Venezia, 2005.)*. The decision to include both capital and lowercase letters was due to the legibility which varies greatly depending on the size of the stroke character *(See Chapter 1.1: Vision and Age)*.

Valuation:
Each subject performance was evaluated in terms of speed and accuracy, separately for the two light conditions; the reading time was registered for each sheet of words.

Score of Speed: is the total time employed *(expressed in seconds)* for reading each set of words.
Score of Accuracy: is the number of the words read correctly *(% per cent)*.

N° Words	Preliminary Test	I Sheet	II Sheet	III Sheet	IV Sheet	V Sheet
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
	Errors:					
	Seconds:					

Table 3.5: Model of evaluation table

When the experiment was done, the participants received and filled out a written questionnaire which contained four closed questions. In addition, there was space for them to write their spontaneous observations of the room's character and atmosphere, and final comments.

CANDIDATE N° 1
Age: ....
Date: ....

MALE ○ **FEMALE** ○

Experiment Questionnaire n°2:
Reading

VISUAL IMPAIRMENT:

- ○ Macular Degeneration
- ○ Cataract
- ○ After cataract surgery
- ○ No visual Impairment

PRIVACY

These questionnairE answers will be anonymous and used only for the following study. By signing the candidate accepts the terms of the following activities of research.

SIGNATURE ....

1 Which sun shading device do you prefer?

- ○ Venetian blinds with lightshelves
- ○ Textile curtains

2 Why did you choose this sun shading device? (also more than one answer)

- ○ Great amount of natural light
- ○ Even light
- ○ No glare on the working plane
- ○ No shadows on the working plane
- ○ Possibility to watch outside

3 Which is the better sitting position both in the livingroom and in the kitchen?

- ○ On the coffee table (back to the window)
- ○ Sit on the armchair (with the window on one side)
- ○ Sit on the armchair (in front of the window)
- ○ On the kitchen table position 1 (back to the window)
- ○ On the kitchen table position 2 (with the window on one side)
- ○ On the kitchen table position 3 (in front of the window)

4 Why did you choose this position? (also more than one answer)

- ◯ No glare
- ◯ Greater amount of light
- ◯ View of the outside
- ◯ Better environment's control
- ◯ Other...
....
....

5 Which words did you find most difficult to read? (also more than one answer)

- ◯ Capital written
- ◯ Small close written
- ◯ Small spaced written

6 Which words did you find more easy to read? (also more than one answer)

- ◯ Capital written
- ◯ Small close written
- ◯ Small spaced written

7 Which device do you have in your livingroom?

- ◯ Light thin curtains (partial view towards the outside)
- ◯ Light thick curtains (no view towards the outside)
- ◯ Dark thin curtains
- ◯ Dark thick curtains
- ◯ Venetian blinds
- ◯ Shutters

8 Which device do you have in your kitchen?

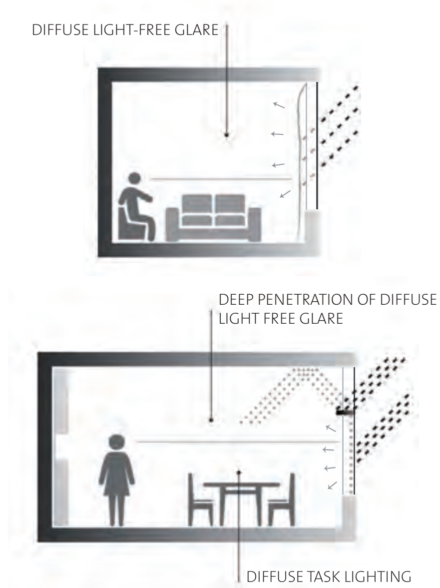
- ◯ Light thin curtains
- ◯ Light thick curtains
- ◯ Dark thin curtains
- ◯ Dark thick curtains
- ◯ Venetian blinds
- ◯ Shutters

Master Thesis on:"Light and health for visually impaired people" - Students: Francesca Borra, Laura Cane - Supervisor: Barbara Matusiak.

Figure 3.14: Model of English Questionnaire, which was also translated in Norwegian to facilitate the participants.

Figure 3.15: Daylighting Devices. Photos of First and Second Solution. **Figure 3.16:** I and II Natural Light Solutions. Lighting Concepts.

(3.15)



(3.16)

Daylighting systems

The two experimental rooms have windows which are:

• In the Living Room: one window 2m x 2m at a height of 50 cm from the floor;
• In the Kitchen: two windows 0.75 m x 1.25 m at a height of 50 cm from the floor and another one 2 m x 0.75 of size at a 1.80 m height from the floor.

Two of the most used, simple and cost-effective daylighting systems were selected: thin Linen Blinds in the Living Room and Venetian Blinds plus Light Shelves in the Kitchen*(Figures 3.16)*. Although Venetian Blinds are originally considered a shading system, when they are modified regarding the reflectivity of its slat surface and the orientation of the curvature of the slats, they acquire a daylight redirection property that can qualify them as a daylighting system.

As the Kitchen is deeper than the first room, besides the presence of the Venetian blinds, it has also two Light Shelves. By varying the height, angle and internal or external projection of a light shelf, it was possible to control the pattern, intensity and depth of penetration of natural light *(including sunlight)* within the room: light shelves were therefore placed internally with respect to the window frame and at a height of 1:80 m from the floor to ensure light

reflection on the ceiling further from the middle line of the room.
Light shelves reflect daylight to penetrate deep into a building and they are suitable for north and south elevations but not the flat sun angles of east and west *(See Chapter 5.2)*; that's why all the daylighting systems were analyzed close to 4:00 pm, when, on a sunny day, the sun entered straight into the room (facing west) as if it was facing south.
Bearing in mind the difficulty due to the control of natural light, such variance in illuminance values not only during the year but also in just a few hours, special care was therefore paid to the time variable in order to get comparable results(*See Chapter 7.2.4).* As a consequence, the Reading test session was planned so that all the participants could perform the test in the same time range *(in June, from 4:00 to 4:30 pm)*.

Sky conditions:
Both Daylighting systems were tested under clear and overcast sky conditions; as a consequence the total amount of light scenarios studied in this experiment were four:
- Living Room in condition of clear sky;
- Living Room in condition of overcast sky;
- Kitchen in condition of clear sky;
- Kitchen in condition of overcast sky.

As a consequence, the experiment lighting variables which differ from the first to the second light solution are:

• different sky conditions *(sun and overcast)*
• daylighting systems *(thin linen blinds - light shelf plus venetian blinds)*

Figure 3.17.

No	**Daylighting Systems**	Comment
1 (Living Room)	**White thin linen blinds**	Great illuminance level in the room, focus especially near the window; even lighting distribution and possibility to see the outside. Clear double-glazing: 4-16-4 mm (Air), Light Reflection (LRe)= 12%, Ra= 98.
2 (Kitchen)	**White venetian blind plus Mirror light-shelf**	Great amount of light at the bottom of the room and light reflections on the ceiling. More even light at the top of the room and harsh shadows on the working plane. White venetian blinds: the spacing to width ratio was of 0.8, and the slat overlapping fraction of 20%. Both slat sides had a diffuse reflectance of 0.7. Mirror Light Shelves: the total dimensions were 0.30x1.15 m; the mirror had a thickness of 4 mm and a reflectance of 0.94. The two Light Shelves were installed at each window in a horizontal position at 1.80 m from the floor. Clear double-glazing: 4-16-4 mm (Air), Light Reflection (LRe)= 12%, Ra= 98.

Table 3.6: Daylighting device tested

Figure 3.17: Daylighting Devices Front View. Living Room: White Thin Curtains. Kitchen: Venetian Blinds plus Light- Shelf. Scale 1:50. **Table 3.6:** The features of the Daylighting Systems utilized for each solutions.

Experiment n°3:
Object Recognition

This study was aimed at comparing users satisfaction for *two different artificial lighting concepts, a conventional evenly lighting solution against a different type of directional lighting (both halogen solutions), which had to embody (supplement) an inadequate amount of natural light in the built environment*. The test was performed in the kitchen: a full-scale experimental room realized in the Romlab to simulate a domestic environment where commonly two of the **iADL** *(Instrumental Activities of Daily Living)*: food preparation and taking medicines are carried out. By asking the participants to perform these two relevant tasks: to recognize objects *(kitchen objects)* from a distance and to read the expiry date on medicine boxes, the experiment was then designed to facilitate the development of both activities and to show the best lighting conditions.

Lighting in the indoor environment is essential: daylight is always the best although it needs to be integrated with an artificial one; especially in a climate such as the city of Trondheim, where the hours of direct sunlight are the only 30% of the total amount that it could have during the year. For the remaining part of the time instead the sky shown as overcast; in this case the levels of illumination recommended for different spaces and required for the performance of specific activities aren't then satisfied.
The aim was both to identify which *Natural +Artificial Solution was rated as most preferred by the test subjects and to provide solid answers about Light Level, Colour, Quality, Details and Preferences*. People with poor eyesight, caused from old age or from macular degeneration, in order to have proper lighting should use more direct lighting and with more intensity lighting sources; as a consequence, **the experiment wanted to show that too indirect bulbs** *(that flatten the three-dimensional objects and the room)* **make perception difficult as, in a different way, direct but too strong light** *(with deep shadows or glare)*; **for this reason light intensity should be set by the user through a switch or a "dimmer" according to his/her personal needs**.

The perception of three-dimensional objects is given by a good contrast of luminance, that is why a correct focused lighting is essential to recognize objects in a room. The best solution is therefore a kind of illumination with a correct mix of light and shadows: trying to avoid both sharp and dark shadows, which arise from the use of too directional light and with narrow beam angle lamps, and an illumination with low shadows, where forms are no longer recognized and situations are not perceived in the correct way.

Keywords: *Domestic lighting, focused and even light, "dimmer", light and shadows balance, colour and luminance contrast.*

Procedures and materials

Before starting, the subjects were welcome to come into the experimental room *(the kitchen)* to adapt their eyes to the room's luminance level, which was higher or lower compared to the luminance level in the rest of the Rom-Lab.

After about 15 minutes of environment and luminance adaptation, each participant received practical and detailed information about the experiment he/she was going to perform. In addition, before the test itself, the subjects could became familiar with the task carrying out 2/3 trial tests: the goal was to avoid incomprehension in order to have test results as reliable as possible. In this case, the Object Recognition Test was divided into two sections, first the task was illustrated, where the trials were to be performed and consequently the real test for the part one started; then the same procedure was repeated for the second one.

SECTION I

The participants had to sit around the table, from there they were asked to recognize some kitchen stuff from the given distance: 1.50 m. The colourful objects and other objects with neutral colours *(opal white/black)* were organized in two cabinets *(dark background)* and on two shelves *(light background)*. The aim was to create three levels of luminance contrast: **High, Medium and Low** depending on the objects colour, the background colour and the lighting solution type *(Figure 3.18)*.

The experiment started with the first scenario; objects were pointed out randomly one by one; accordingly every subject had to give a description, as detailed as possible, of the objects pointed out *(containers for food preparation, boxes containing food, ect..)* trying not to make mistakes. Afterwards, for the second solution, only the items which were not recognized in the first scenario were indicated: the participants had to try to define them and to add, if possible, details to the objects previously identified. The test relied on the assumption that the second lighting solution was better than the first one; both illuminance values and luminance contrast between the object and its background were increased according to the current European Lighting Guidelines for elderly and visually impaired people *(See Chapter 1.1 and 2)*. This procedure went to show the effectiveness of the Accessible Design "*advices*" put in practice in the second solution.

During the experiment, both solutions could be dimmed by 50% based on the subjects' preferences to avoid glare and negative reflections.

Figure 3.18: Object location on Kitchen shelves and cabinet

Object Number	Object Name	SOLUTION I Luminance Contrast	SOLUTION II Luminance Contrast
1	Pulverkaffe	Medium	Medium
2	Torrgjaer	Medium	Medium
3	Bowl	Medium	Medium
4	Plastic cont.	Medium	Medium
5	white Dish	Low	Low
6	Notte Sjoko	High	High
7	Fond cups	Low	Low
8	Plastfolie	Low	Low
9	Blue Bottle	High	High
10	Gold Dish	Medium	Medium
11	Apple juice	Medium	Medium
12	Hamburger S.	Low	Low
13	Sjoko Duo	Medium	Medium
14	Cup	Medium	Low
15	Nescafè	Medium	Medium
16	Nescafè Gull	High	High
17	Black glass	Medium	High
18	Nugatti	Medium	Medium
19	Ferskere Bakst	Medium	Medium
20	Torrgjaer	Medium	Medium
21	Kakao	Medium	Medium
22	Black glass	Medium	Low
23	Cup	High	High
24	Plasfolie	Medium	Medium

Table 3.7: The 24 Objects tested

9 10 11 12 13

22 23 24

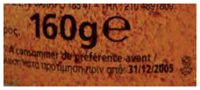
Valuation

The performance was evaluated in term of correctness, separately for the two lighting scenarios: the Accuracy Score was represented by the number of objects recognized; in the evaluating table, it was specified which contrast level it belonged to and if such items had been identified in general or in detail *(Table 3.8)*.

	Kitchen: far Objects	High Contrast	Medium Contrast	Low Contrast	Objects Recognized V(YES) or X (NO)	Ob. Recognized in detail, V(YES) or X (NO)
1						
...						
24						

Table 3.7: Model of evaluation Table

(1)



(2)

(3)

Figure 3.19: Typologies of label design

SECTION II

This section was focussed on the recognition of specific objects: medicinal products. The participants had to stand in front of the kitchen and to identify three medicine boxes from a distance of 30 cm and then reading correctly the expiry date printed on the same.The medicines were in fact displaced on two different kitchen surfaces: a cabinet with dark background and a shelf with light background. The boxes were selected and displayed in order to recreate possible situations in real life; as regards the expiry date indeed, three types of labels with a varied luminance contrast were chosen; depending on the written date color, the background color, the box's design and the lighting solution type. The first kind of label *(High Contrast)* included a small white square which was very obvious and arranged to accommodate the expiry date; in the second one *(Medium Contrast)*, the date was instead printed directly on a background composed of images and finally, in the third *(Low Contrast)*, the dates were plotted for the only imprint, without the use of ink *(Figure 3.19)*. As for the Section I, given the first lighting scenario, the experiment started; participants were told the names of three medicines, one for each type of luminance contrast: *High, Medium, Low*. The subjects had then to search for them, one by one, on the kitchen shelves and to read, as quickly possible but trying to not make a mistake, the expired date. At a

later stage, the same procedure was repeated for the second lighting solution; they were asked to find three other medicine boxes which similarly, as the previous case, had different *“expiry data labels”(High, Medium, Low luminance contrast).*
During the experiment, both solutions could be dimmed by 50% based on the subjects’ preferences to avoid glare and negative reflections.

Table 3.8: Model of evaluation Table.

Valuation
The performance was evaluated, separately for the two scenarios, in term of correctness and of speed: the Accuracy Score was given by the number of due dates read properly, while the Speed Score was the time employed for reading each of them *(Table 3.8).*
The questionnaire, filled out at the end of experiment, constituted another evaluation element, in particular to understand the subjects’ real needs and preferences.

	Close Objects: Medicinal Products	Expiry Date Recognized v(YES) or X(NO)	Errors	Seconds
1				
2				
3				

CANDIDATE N° 1
Age: ....
Date: ....

MALE ○ **FEMALE** ○

Experiment Questionnaire n°3:
Object Recognition

VISUAL IMPAIRMENT:
○ Macular Degeneration
○ Cataract
○ After cataract surgery
○ No visual Impairment

PRIVACY

These questionnaire answers will be anonymous and used only for the following study. By signing the candidate accepts the terms of the following activities of research.

SIGNATURE ....

1 Which artificial light solution do you prefer?

○ Ceiling lamp

○ Spot lights

2 As regard question number 1, Why did you choose that scenario? (also more than 1 answer)

○ It was enough for me to recognize detail objects

○ It gave me a better view between the shelves

○ Stronger contrast, so it was easy for me to find the objects

○ No harsh shadows between shelves so I got confused less

○ Labels and written words appeared clearer and more readable

3 As regard far objects: which seemed to you to be easier to recognize?

○ Objects in contrast with their background (dark on light backgrounds / light on dark background)

○ Objects not in contrast with the background

4 As regard far objects: which seemed to you to be easier to recognize?

○ Colorful Objects

○ Objects with neutral colours (opal white / black)

5 As regard close objects (medicines), Which of them did you find easier to find?

○ On dark background in the cabinet

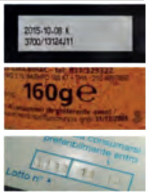
○ On light background on the shelf

6 MEDICINES: Which expiry dates did you read easily? (also more than one answer)

○ With white rectangle as a background

○ Words printed directly on a background composed of images

○ Words plotted for the only imprint



7 MEDICINES: Which expiry dates did you read with more difficulty? (also more than one answer)

○ With white rectangle as a background

○ Words printed directly on a background composed of images

○ Words plotted for the only imprint

Figure 3.20: Model of English Questionnaire, which was also translated in Norwegian to facilitate the participants.

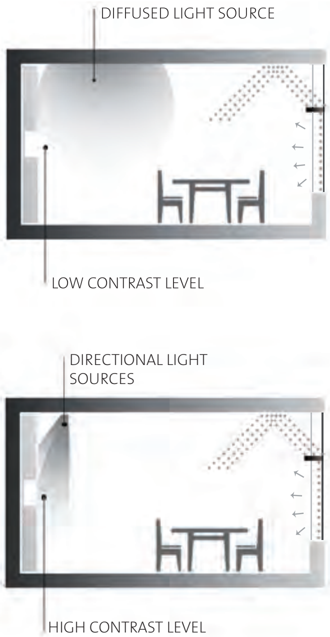


Figure 3.21: I and II Natural plus Artificial Light Solutions. Lighting Concepts.

Lighting scenarios

Due to the experimental room's geographical location and orientation, the weather conditions, and the environment's depth, the two artificial light solutions had to supplement a natural light quantity *(in overcast sky conditions)* which was lower than 20% of the amount required to ensure the task's performance. To assure these conditions, one had to keep in mind the difficulty due to natural light control, for such variance in illuminance values not only during the year but also in just a few hours, special care was therefore paid to the time variable in order to get comparable results *(See Chapter 7.2.4)*. As a consequence, the Object Recognition test session was planned so that all the participants could perform the test in the same range time *(in July, from 6:30 to 7:00 pm)* when possible direct sunlight penetration was in any case avoided from the adjacent building's shadow. This experiment compare two artificial lighting scenarios *(Figures 3.21 and 3.22)*: to partially shelter the room from the daylight sun proof roller blinds were used, ensuring a natural light amount lower than 20%. The purpose was to compared a "*traditional*" light solution *(one pendant fixture)*, usually still used today in many homes, and a solution which we considered

Figure 3.22: Photos of 1° and 2° artificial lighting solutions.

N° scenario	Lamps	Comment
1	One Pendulum Lamp (100%) with a halogen bulb, it could be dimmed by 50% by subjects.	Even luminance distribution. Clear double-glazing: 4-16-4 mm (Air), Light Reflection (LRe)= 12%, Ra= 98.
2	Three Halogen Spot Lamps (100%), which could be dimmed by 50% by subjects.	Focused luminance distribution (large difference between the luminance of direct and indirect lighted kitchen areas). Clear double-glazing: 4-16-4 mm (Air), Light Reflection (LRe)= 12%, Ra= 98.

Table 3.9: Lighting Scenarios

N° scenario	The Lamp	CCT (K)	CRI
1	Halogen Pendulum Lamp, 46 W Dimmable: YES Base: E27 Energy Class: D	2700 K (Warm White)	100
2	Halogen Spot Lamp, 50 W Dimmable: YES Base: GUS.3 Energy Class: B	3000 K (Warm White)	100

Table 3.10: Lamp type and its CTT (in cold climates a warmer light colour appearance is preferred EN 12464.1:2011), CRI

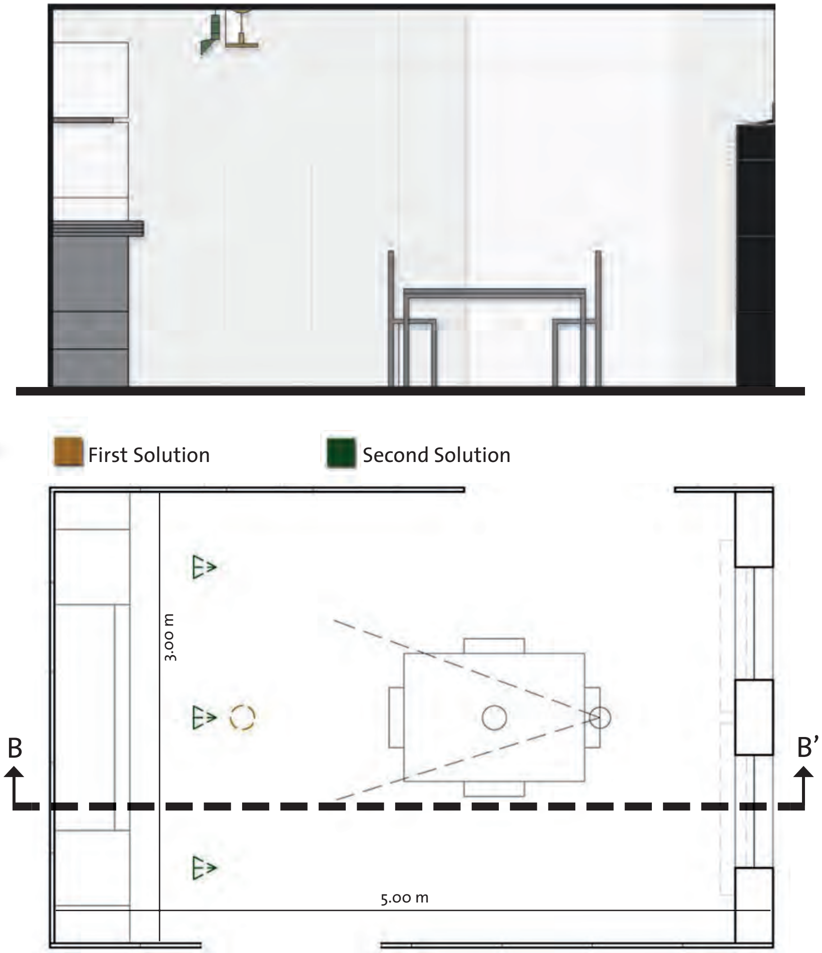


Figure 3.23:
Lighting cross Section (B-B') of the Hall, I and II Solution electrical light, Scale 1:50.
Lighting Plan and of the Kitchen, I and II Solution electrical light, Scale 1:50.

As a consequence, the experiment's lighting variable which differ from the first to the second light solution is:

• the type of lighting: general ambient lighting - task/accent lighting;

Lamps were chosen to have the same CCT*(3000 K)* and CRI*(100 - for specialized tasks in fact where color is very important, such as the food preparation, it is advisable to select lamps with a CRI above 90).*

"*more performing*" thanks to the deeper analyzes carried out *(See Chapters 1.1 and 2.1)*.

Experiment n°4: Watching TV

J.E.H. Gordon wrote in her book in 1891: "*electricity can aid us in hours of work and conduce comfort and peace in our hours of rest and recreation*". This objective is still relevant today, even more for visually impaired people, and provides the focus for the topic discussed in this last experiment. The test took place in the same full-scale experimental room created in the Rom-Lab to simulate a residential living room in **conditions of only artificial lighting**: *the aim was both to identify which Lighting Concepts were rated as most preferred by the test subjects and, at the same time, to provide answers about the Light Level, Visual Comfort, Screen Reflections, Glare and Personal Preferences*.
The living room is the place where different hobbies and activities are carried out; these tasks can include: holding a conversation with guests, painting, reading, sewing TV, playing the piano, or playing cards and games. For all of them, lighting should be as flexible as the rest of the home component, regulated enough to satisfy a variety of needs and it must be planned to avoid glare. Another key component kept in mind for this experiment is the increasing use of electronic devices in elderly everyday life and, as a consequence, screen *(television or laptop)* viewing could represents a lighting problem in multipurpose spaces such as the living room so for this reason among the many activities which may take place in it, it was decided to examine in depth the theme of "*Watching TV*".
Originally, to distribute the highest illumination level possible throughout a room, gas pendant luminaires were frequently placed in the centre of a ceiling. This practice continued with the invention of electricity and had negative consequences. Many homes today still have a surface-mounted fixture in the centre of the ceiling and as a result, to provide an adequate level of illumination in the room, the lamp became a "*glare bomb*"; TV viewing, on the other hand, presents unusual lighting requirements because the rest of the lighting in the living room is unwanted and detrimental for the purpose.
The definition of both scenarios has then come out its own: a conventional and very popular lighting solution is with a fixed chandelier placed in the middle of the room and two wall lamps located behind the armchairs, followed by a second solution with a couple of fixed spot lamps on both sides of the chandelier.

Keywords: *multipurpose spaces, flexible lighting, single pendant fixture, down-lights as accent lighting*

Procedures and materials

Before starting, the participants were welcomed in the experimental room for about ten minutes to adapt their eyes to the environment's luminance level, which was lower compared to the rest of the Rom-Lab. During this time of luminance adaptation, where the participants were free to choose their position in the room, it was explained in detail how to carry out the experiment and two/three trials were conducted to help them become familiar with the visual task and understand better what were the main activity goals . The test then took place in the position that the subject chose as the most comfortable.

Video presentation

The selection of the aesthetic attributes, especially light fixtures, was based on the literature review done before the study *(See Chapter 2.1: ISO/IEC Guide 71)*. The laptop was located on the coffee table in the middle of the room, taking into account the proportion of 1:5 existing between the screen's main diagonal line and the subject's distance from the screen itself, in order to enjoy good vision.
After the adaptation and explanation steps, the "*Watching TV*" test has to be done twice by the subject under two different artificial light scenarios. Given the first one, the experiment started with a video approximately five minutes long shown on the computer screen. Once the first part of the video was finished,

the same procedure of adaptation, explanation and video viewing was carried out for the second concept scenario for a period of another five minutes.

Summarizing, the two part of the experiment were performed in the following order:

1) Preliminary test *(adaptation and explanation)* first lighting scenario
2) Part I Test- first lighting scenario
3) Preliminary test *(adaptation and explanation)* second lighting scenario
4) Part II Test- second lighting scenario

Participants were then asked to sign a consent form and to fill out a written questionnaire.

Valuation

Participants evaluated each luminous scenario using a written questionnaire; in addition, there was space for them to write their spontaneous observation of the room's character and atmosphere, and final comments.

There are no Speed or Accuracy scores as in the previous experiments. Just to compare questionnaire results and establish which artificial light solution was preferred by the subjects.

CANDIDATE N° 1
Age: ....
Date: ....

MALE ○ **FEMALE** ○

Experiment Questionnaire n°4:
Watching TV

VISUAL IMPAIRMENT:
○ Macular Degeneration
○ Cataract
○ After cataract surgery
○ No visual Impairment

PRIVACY

These questionnaire answers will be anonymous and used only for the following study. By signing the candidate accepts the terms of the following activities of research.

SIGNATURE ....

1 Which lighting scenario allows you a better vision?

○ Widespread light solution (wall lamps and chandelier)
○ Varied light solution (spot lights)

2 Check positive points regarding your previous answer (also more than one answer):

○ No screen reflections
○ No glare
○ A more even illuminance in the room allows me to concentrate more
○ A greater amount of light and it's easier for me to have control of the environment also in the room corners.

3 Which sitting position on the armchair do you prefer?

○ Position 1 (on the right)
○ Position 2 (on the left)

4 Why did you choose this position? (also more than one answer)

○ No glare
○ Greater amount of light
○ No screen reflections

Master Thesis on:"Light and health for visually impaired people" - Students: Francesca Borra, Laura Cane - Supervisor: Barbara Matus

Figure 3.24: Model of English Questionnaire, which was also translated in Norwegian to facilitate the participants.

Lighting Scenarios

This experiment was carried out under two artificial lighting scenarios *(Figures 3.25 and 3.26)*, every opening *(windows and skylight)* was covered by dark roller blinds. The purpose was to compare a "*traditional*" light solution *(general pendant fixture with two wall luminaires)*, usually used in many homes still today, and a solution which we considered "*more performing*" to carry out the specific task *(Watching TV)* thanks to the deeper analyzes carried out *(See Chapter 2.1: LIGHTING GUIDE 9:2013)*.

The features of the lighting type and sources utilized for each solutions are illustrated in the Tables 3.11 and 3.12. Each luminaire position, shown in the following plan and cross section(Figure 3.27), was defined to prevent both Disability and Reflected Glare in the visual place(Chapter 2. EN 12464.1:2011).

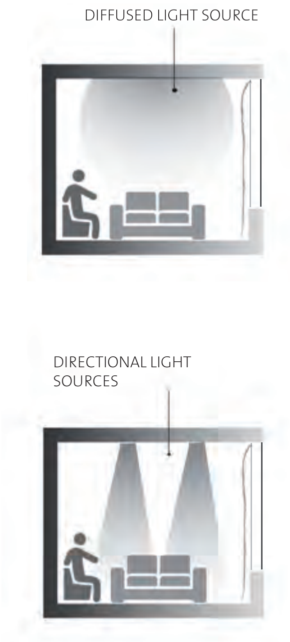
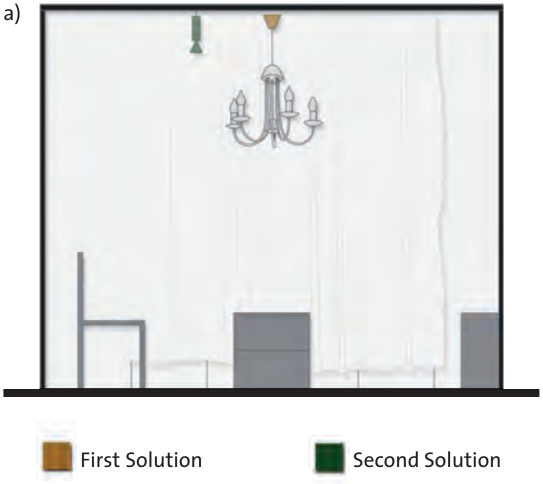


Figure 3.25: I and II Artificial Light Solutions. Lighting Concepts.

Figure 3.26: Photos of 1° and 2° artificial lighting solutions.

a)

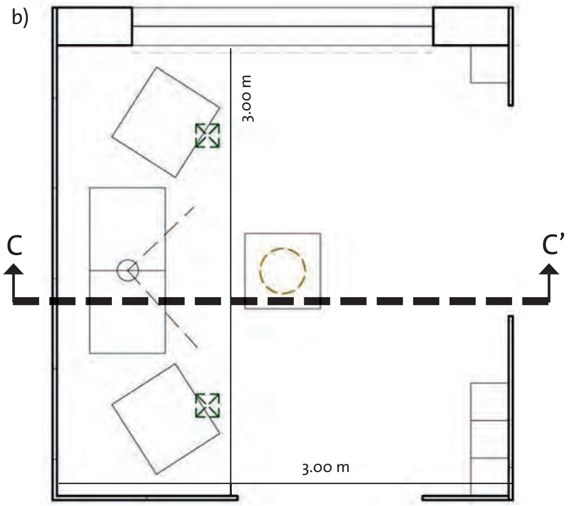


N° scenario	Lamps	Comment
1	Chandelier five-armed with five candle halogen bulbs in the middle of the room and two wall lamps behind the sofa.	Room lighted very strongly, very even luminance distribution; the chandelier introduces a very strong luminance contrast.
2	Two halogen spot lamps towards the floor: one between the chandelier and the door, the other between the chandelier and the window.	Low illuminance, focus points only between coffee table and the armchairs; the rest of the room rather darker, very uneven luminance distribution.

(3.11)

Table 3.11: Lighting Scenarios. **Table 3.12:** Lamp type and its CTT (in cold climates a warmer light colour appearance is preferred EN 12464.1:2011), CRI.

b)



N° scenario	The Lamp	CCT (K)	CRI
1	Chandelier five-armed, 40 W Dimmable: YES Base: E14 Energy Class: D	2700 K (Warm White)	100
2	Halogen Wall Lamp, 25 W Dimmable: YES Base: GY6.35 Energy Class: C	2850 K (Warm White)	100
3	Halogen Spot Lamp, 50 W Dimmable: YES Base: GU5.3 Energy Class: B	3000 K (Warm White)	100

(3.12)

Figure 3.27:
a) Lighting cross Section (C-C') of the Hall, I and II Solution electrical light, Scale 1:50. *b)* Lighting Plan and of the Hall, I and II Solution electrical light, Scale 1:50.

Only halogen lamp bulbs where chosen because they are able to simulate in the best way the sunlight spectrum and then the most suitable in environments, like the living room, where several activities are held during the whole day.
As a consequence, the lighting variable experiment which differ from the first to the second light solution is:

• *the type of lighting*: general ambient lighting - task/accent lighting *(Chapter 3.1: The function of Illumination).*

2.4 Measurements

Due to equipment availability, measurements in the experimental rooms were performed between June and August 2015. All the equipment used during the monitoring procedure were provided by the Faculty of Architecture and Fine Art of the Norwegian University of Science and Technology. The instruments used to perform the essential monitoring procedure were:

• 1 hand-held lux meter for interiors
• 1 hand-held luminance meter;
• 1 Nikon D700 digital camera;
• Software to upload the digital camera luminance pictures
• 1 laptop
• tripod.

Illuminance values
Since illuminance values depends on the point where they are measured, it was necessary to primarily elaborate a grid to identify exactly where to take the measurements: in both horizontal and vertical planes due to the kind of visual task performed in each experiment.

a. Experiment n°1: in the Hall a six point vertical grid was defined at a distance of 8 cm from the bookcase.
b. Experiment n°2-4: in the Living Room a nine point horizontal grid was defined at a distance of 80 cm height from the floor level; in the Kitchen a twelve point horizontal grid was defined at a distance of 80 cm height from the floor level.
c. Experiment n°3: in the Kitchen six point horizontal grids were defined at a distance of 8 cm from the cabinet planes and three point horizontal grids were defined at a distance of 8 cm from the shelves' planes.

All the illuminance values were taken with a hand-held lux meter for interiors at the specific points given by each grid. To verify the reliability of the measurements, values were taken more than once and are shown in the Table ..(See Chapter 7.3.Results)

Luminance values
All the luminance measurements, in every experiment, were registered with luminance pictures taken with a Nikon EOS350D camera, specially chosen according to the sky conditions or to the type of illumination (lighting sources) in each room. Thank to the Web-HDR software, luminance values were then obtained through False colour images and Interactive luminance maps; to ensure their accuracy, some points were also measured, under the same lighting conditions, using a Minolta LS-100 Luminance Meter and checked with the previous ones. To verify the reliability of the measurements, values were taken more than once*(See Chapter 7.3.Results)*.

It had to bear in mind the difficulty due to natural light's control, such variable not only during the year but also in just a few hours. Special care was therefore paid to the time's variable in order to get comparable results.
Particular consideration have been necessary for the natural light measurements:
in the Reading Test performed in only natural light conditions, illuminance and luminance values both of the room and of the paper sheet were checked before to start *(See Chapter 7.3.Results)*. The experimental session was planned so that all the participants could perform the test in the same range time*(in June, from 4:00 to 4:30 pm).*
For this main reasons similar considerations have been addressed also in the Object Recognition Test, where the artificial light supplemented an inadequate amount of daylight*(<20%. See Chapter 7.2.3 Experiments' description)*. The experimental session was planned so that all the participants could perform the test in the same range time*(in July, from 6:30 to 7:00 pm)* in order to ensure the lighting condition before mentioned.

7.3.1. Experiment 1: Pick out books from a library

7.3.1. 1 Illuminance and luminance values

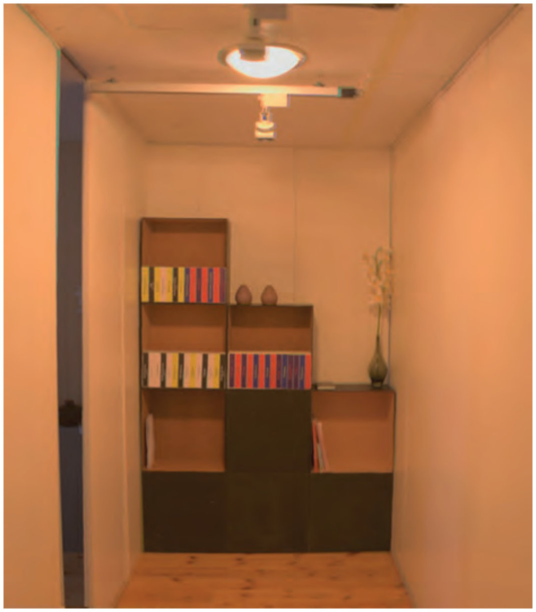


Figure 3.28 : First Artificial Light Solution. Even Solution. Lighting Type: General. CRI:80.

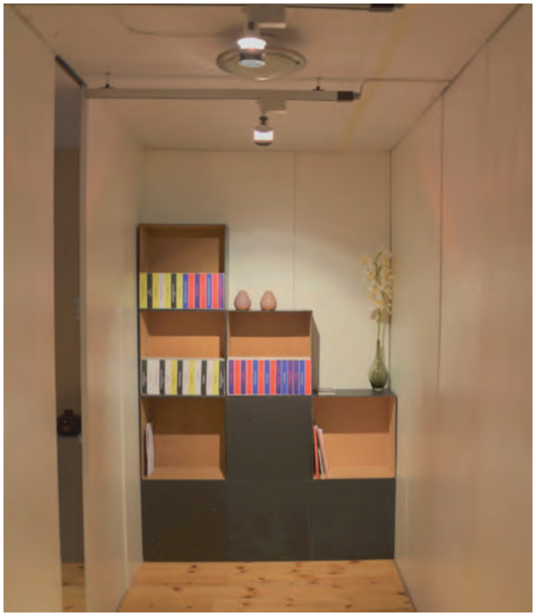


Figure 3.29 : Second Artificial Light Solution. Directional Solution. Lighting Type: Task/Accent. CRI:100.

7. 3 Results

Results were achieved through two different valuations: one more “impartial” and another more “individual or personal”. For each test, a score by the examiner in terms of accuracy and speed was assigned and the answers given by the subjects filling a questionnaire were analyzed. Conclusions drawn from these valuations want to highlight how the type of illumination and the luminance values affect the results obtained through each experiment.

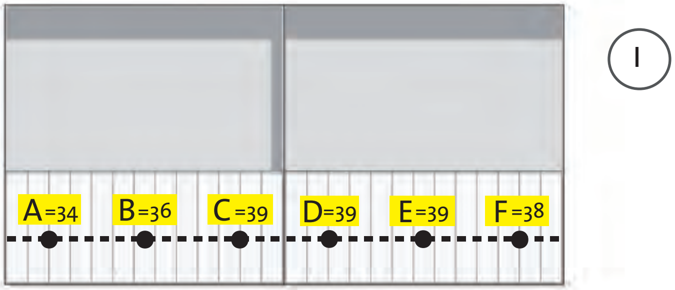


Figure 3.30: E values on the vertical grid at a distance of 8 cm from bookcase. I Artificial Lighting Solution.

	1^ Solution[lux]	2^ Solution[lux]	Standard
Em[lux]	**40**[lux]	**200**[lux]	**200**[lux]

Table 3.13: E_m of both Artificial Lighting Solutions compared with Standard(EN 12464.1:2011)

Figure 3.31: E values on the vertical grid at a distance of 8 cm from bookcase. II Artificial Lighting Solution.

Illuminance values on visual task plane were taken on a vertical grid system at a 8 cm distance from the bookcase*(See Chapter 7.2.4.Measurements)*,both for the first and second artificial light solution. All the values are shown in Figure 3.30 and 3.31. As regards the minimum illuminance level *(Em)* to be guaranteed on the bookshelves, relevant legislation still does not exists with regard to the residential field. It was therefore decided to refer to EN 12464_1 Standard: *Light and Lighting_ Lighting for workplaces where, in clause number 5_Table 5.33 (Places of Public assembly_ Libraries)*, minimum levels of illumination and color rendering index are respectively: 200 lux and CRI=80.
Referring to these values, the first lighting solutions, with an illumination level *(Em)* of 40 lux, is placed far below the minimum Standard requirement. On the other hand, the Accent/task lighting shows, on the vertical grid, illuminance values equal to those expressed in the EN 12464_1.*(Table 3.13).*

As can be noticed from the Figure 3.28 and 3.29, the first lighting scenario displays illuminance values, due to a general/ambient type of lighting, equally distributed in the vertical plane and, on average, very close not only to the other measured points *(between 34 and 39 lux. Figure 3.30)* but also to the background ones.

A very different behaviour occurs in the second solution where, unlike the previous one, some illuminance values differences are noticeable: the range is from 120 lux to 250 lux*(Figure 3.31)*. The highest lighting values can be found in points straight from the accent light sources but moving a little out from it, they slightly decrease until they reach the lowest value of 120 lux on the left end of the bookcase. The second artificial light solution, compared to the previous one, produces higher illuminance differences between the object in the visual task and its background, making it more recognizable.

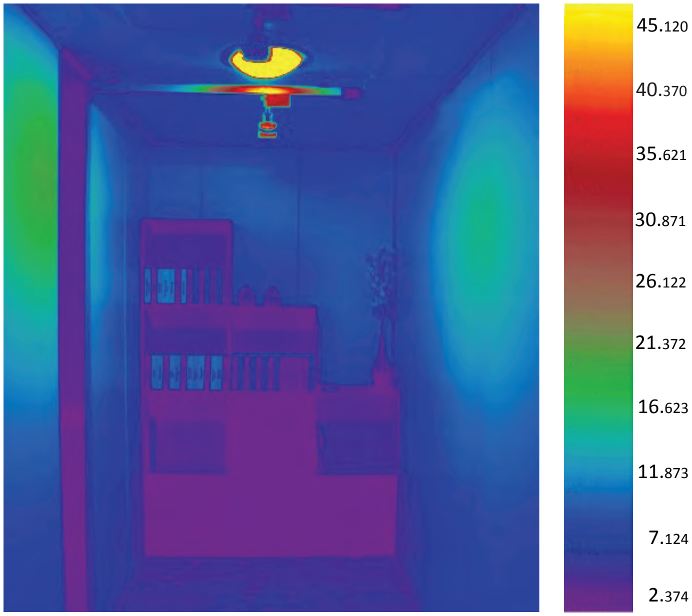


Figure 3.32: First Artificial Light Solution. False colour image with luminance values.

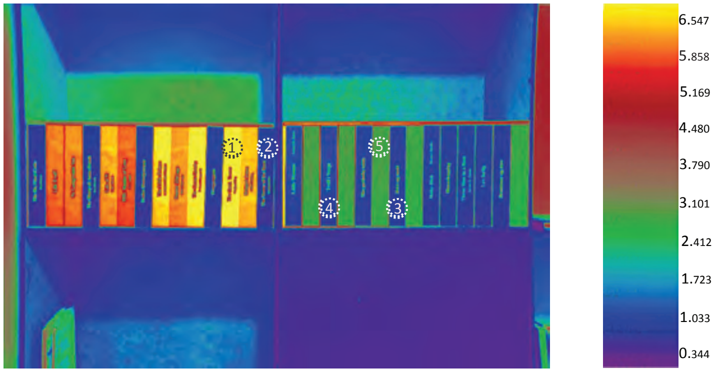


Figure 3.34: Zoom showing in detail cover books' luminance values(*I Lighting Solution).*

N	Source	Reg.	Unit	Count
1	Luminance image	1	L cd/mq	11
2	Luminance image	2	L cd/mq	0.7
3	Luminance image	3	L cd/mq	1.2
4	Luminance image	4	L cd/mq	0.7
5	Luminance image	5	L cd/mq	3.5

Table 3.14: Luminance values of five points taken with the Luminance meters *(I Lighting Solution).*

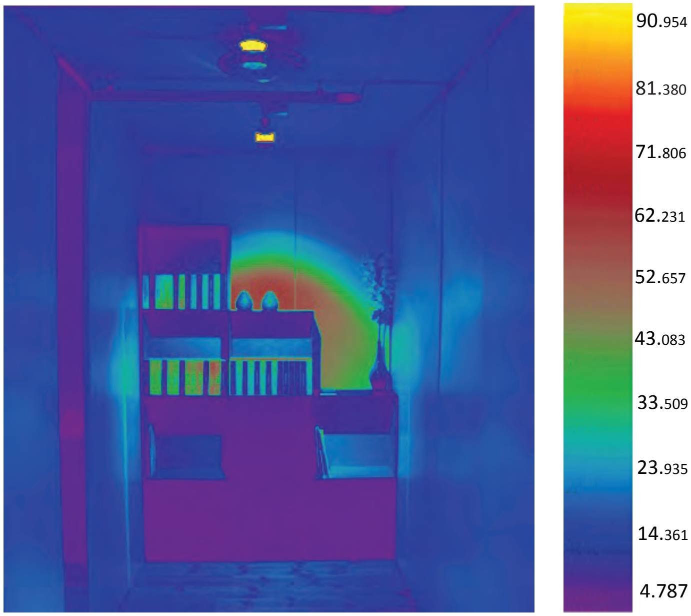


Figure 3.33: Second Artificial Light Solution. False colour image with luminance values.

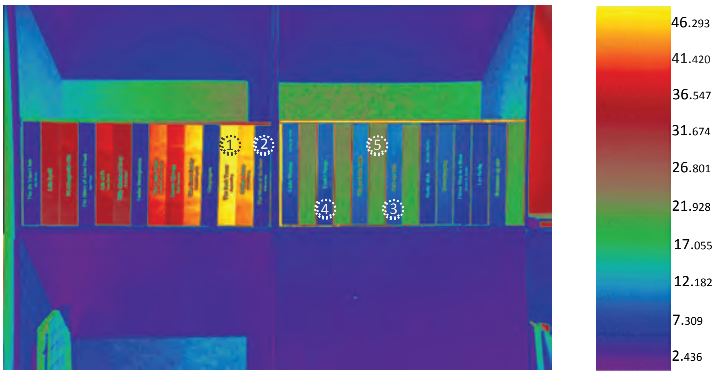
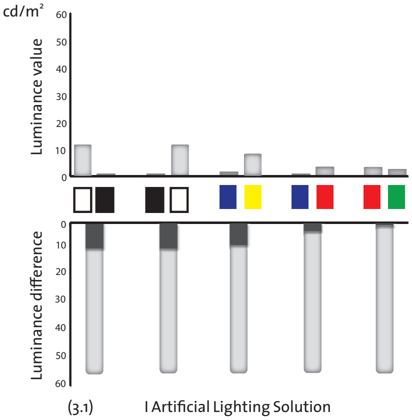


Figure 3.35: Zoom showing in detail cover books' luminance values(*II Lighting Solution).*

N	Source	Reg.	Unit	Count
1	Luminance image	1	L cd/mq	55
2	Luminance image	2	L cd/mq	2.6
3	Luminance image	3	L cd/mq	6.6
4	Luminance image	4	L cd/mq	4
5	Luminance image	5	L cd/mq	20

Table 3.15: Luminance values of five points taken with the Luminance meters *(II Lighting Solution).*



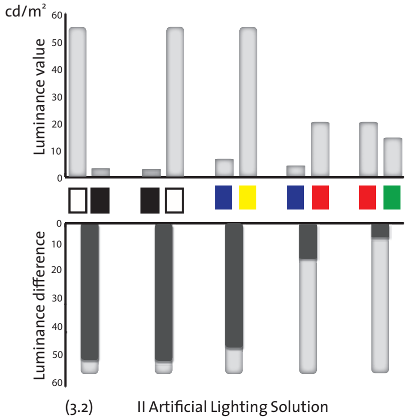


Chart 3.1(I Solution) and 3.2(II Solution): Luminance value of each colour pair and relative difference luminance. For each pair,the Pantone on the left refers to the Background colour, while the Pantone on the right represents the title colour.

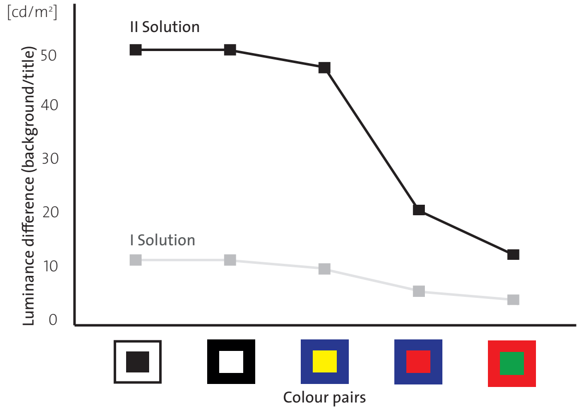


Chart 3.3: Luminance difference values for each colour pair recorded under first *(grey line)* and second *(black line)* lighting scenario. It is plain to see the considerable gap between Black/White couples and the Red/Green one which is decidedly the least recognizable one.

Similarly, also luminance pictures reinforce what has been said in the previous paragraph with regard to the illuminance values. The two images *(Figures 3. 32 and 3.33)*, after being compared and checked through five points taken with the Luminance meters *(Tables 3.14 and 3.15)*, are evidence that an accent lighting with an higher CRI produces higher luminance levels on the book covers. In fact it moves from a range between 0.7 and 11 cd/m² in the first solution to another between 2.6 and 55 cd/m² in the task/accent one.

The luminance values of each cover, given by a colour pair (Background and title colour), were taken according to this specific procedure: the relative Pantone was placed on the corresponding bookcase's shelf and then measured with the Luminance meter under both artificial lighting solutions (See 7.2.4 Measurements).

The luminance difference was then carried out between the background and the title written on it. Chart 3.3 compares the luminance differences of the two lighting solutions. As a consequence the luminance contrasts of each cover was calculated. Figure 3.36 shows the relative luminance contrasts, values do not change in both solutions.

Regarding lighting devices, the material and colour of furniture can also play a role in the decision to use warm or cool lights, since the variation of lighting colour can make room colour appear very vibrant or dull. The colour of the library within the experimental room is better suited to accent lighting type Colour Rendering Index= 100 that give greater plasticity and not a slightly flattened effect as in the first scenario.

To conclude, another important issue concerns shadows created in the second lighting scenario: even if more pronounced than the previous solution, they do not represent a stumbling block for the visual task performance and strengthen the Modelling effect already provided by the halogen lamps CRI and CTT.

Figure 3.36: Colour pair Luminance contrast for each cover book. The Luminance Contrast has been calculated through this formula:

$$C= (L_{max} - L_{min}) / L_{max}$$

Each contrast value was then converted into a percentage; it follows that, according to the picture, the lowest is constituted by the pair red-green and the higher by the pair white-black and viceversa.

Figure 3. 37: Upper part: first light solution. Lower part: second light solution

7.3.1. 2 Speed Score and Accuracy Score

As one can clearly deduce from the charts on the previous page, the Red/Green pair shows luminance difference values much lower than the White/Black, Black/ White and Yellow/Blue pairs. **Chart 3.4 shows**, very simply, colour pairs which were identified by the subjects during the test without taking into account in this case the time variable; *the only couple not found, by subjects suffering from macular degeneration, was that of the Red/Green under the first light scenario*. Assuming that no colour can be seen without light and that the brain, the eyes and the age of the individual are physiological factors that affect colours perception, among people with visual impairment there are often serious problems in the design of a proper illumination able to eliminate these personal barriers. Reference is not only to colour blindness *(defined as absolute blindness to certain colours),* but also to the visually impaired and many elderly with chromatic deficits, perhaps significantly, those that reduce their ability to capture colour differences. Much less compromised, fortunately, is the ability to grasp the brightness contrast. For more clarity, before

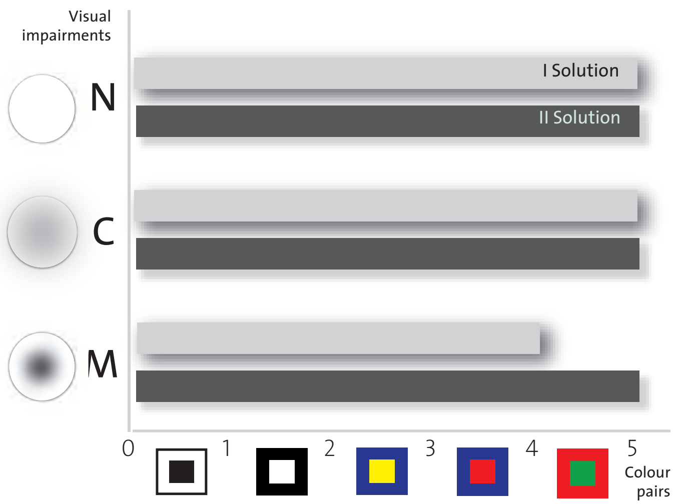


Chart 3.4: On the vertical axis are place the three subject categories: N= subjects with normal vision, C= cataract and M= macular degeneration, further subdivided in the first *(light grey bar)* and second *(dark grey bar)* lighting scenario. On the horizontal axis instead, there are the five colour pairs.

analyzing the following chart, what is meant by brightness contrast and colour contrast it will be defined *(See Chapter 4. Vision and Colour Perceptions)*:

***Colour contrast**: it refers to the comparison between saturated colours, and it is substantially regardless of the brightness.*

***Luminance contrast**: as opposed to the above this is light-dependent: each colour has a different reflection capacity driven by a different amount of white and black more or less marked, which makes them more or less dark.*

Graph n° 3.5 introduces *the time dependent variable* to evaluate the accuracy in the task performance; **each radar chart**, in turn, **represents** *a pair of colours with different luminance contrast(See Figure 3.)*. The three axes, one for each category of analyzed individuals, express in seconds, the time taken to identify that particular cover type. The evaluations resulting from the first lighting solution to the second one are clearly different *(two different area pattern in the radar charts)*. The time for carrying out the performance increases in the last two covers, especially in the latter. It should be noted that red and green, while at opposite ends of the hue spectrum, are only one degree away in terms of value *(See Chapter 4: Colour Theory)*. This would make red very difficult to read on a green background due to the low luminance contrast in the pair.

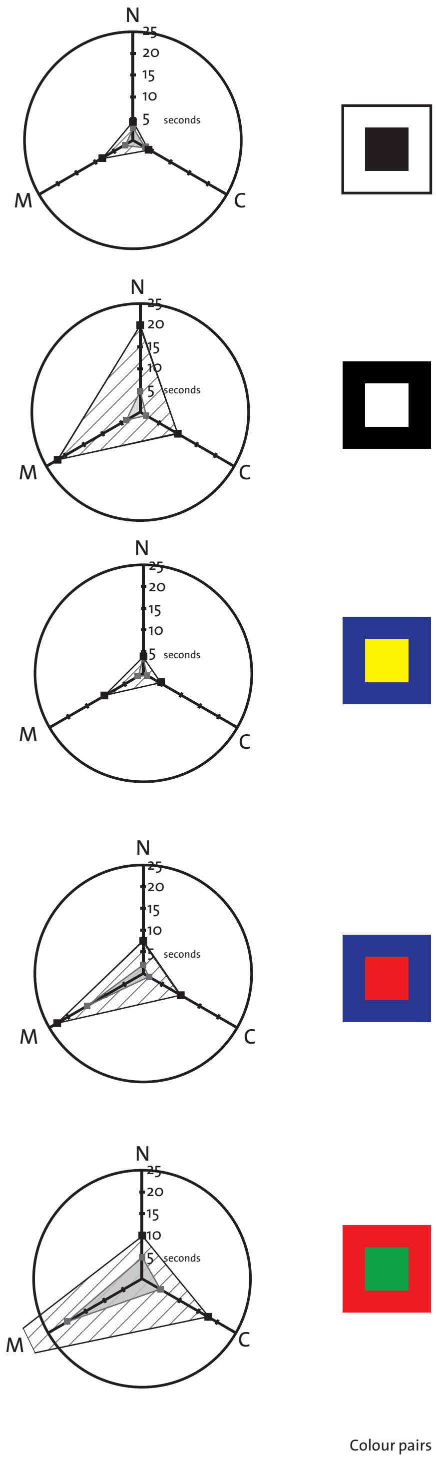
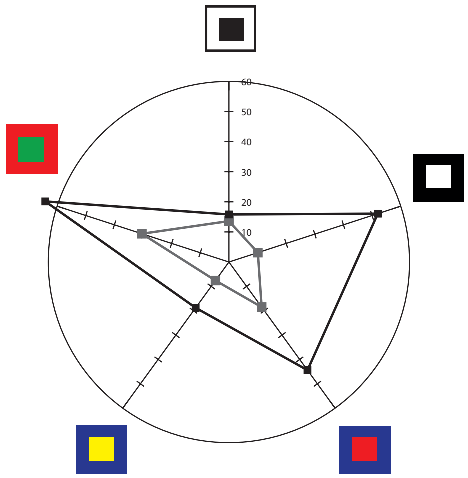


Chart 3.5: Speed and Accuracy evaluation. This confirms that most of the subjects need higher luminance levels to carry out the performance or to do it more comfortably. The first solution better suited the task. Striped pattern represents the first solution, light grey the second one.

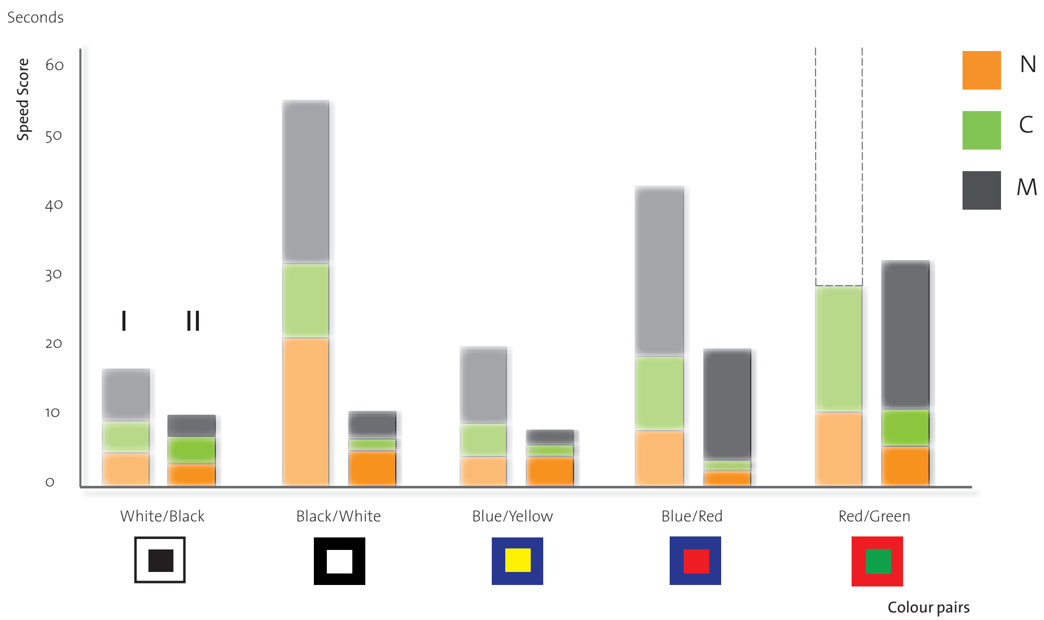


(3.6) Area with black boundaries represents the first solution, light grey boundaries: second light solution. The five axes show **the global Speed Score** *(N+C+M)* for each colour pair *(Seconds)*.

Evaluation results, in **charts numbers 3.6 and 3.7**, for subjects with normal vision differed *(in terms of speed)* from both groups of visually impaired subjects, followed shortly after by people with cataracts.

Both for subjects without sight problems and for those suffering from cataracts, these challenges in colour discrimination can be partially overcome with the aid of new lenses; for people suffering from macular degeneration however, this is not possible. The macular damage causes an altered colour and contrast vision, while the remaining peripheral parts of the retina continue to operate normally; this is clear in the last cover case when, increasing the brightness contrast in the second solution, they are able to locate it too.

Chart 3.6 and 3.7: Show both generally and in detail the time taken to carry out the task by the three categories of visual impairments. The Results confirm that accent lighting *(more opaque columns)* is better compared to a general environment lighting both as regards the rapidity of performing the task especially for the pathology of macular degeneration.



(3.7) The global Speed Score was split up into time employed by each category *(N, C and M)* to find book covers. For each colour pair, the column on the left *(more opaque column)* gives the results of the first lighting solution, while the column on the right represents the second lighting solution.

7.3.1.3 Questionnaire

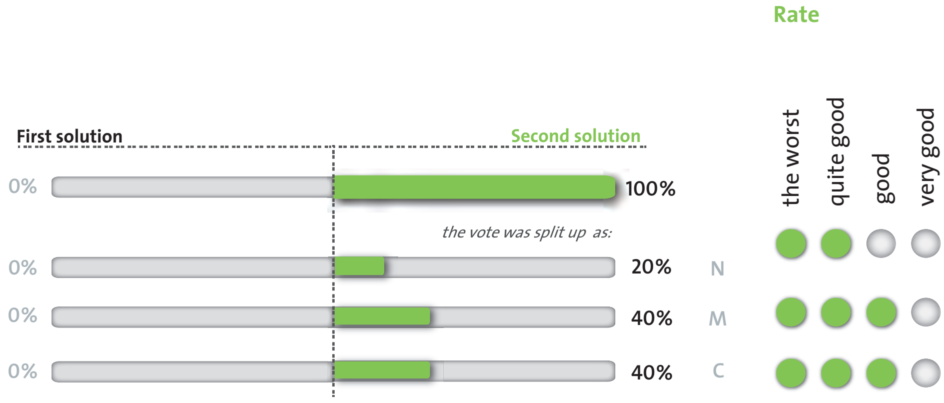


Chart 3.8 and 3.9: Quality valuation of the two lighting scenarios and rate from 1 to 4.

Chart 3.10: shows previous answer motivation:
- Absence of shadows between shelves
- Better contrast
- other...

The second answer show the total score possible.

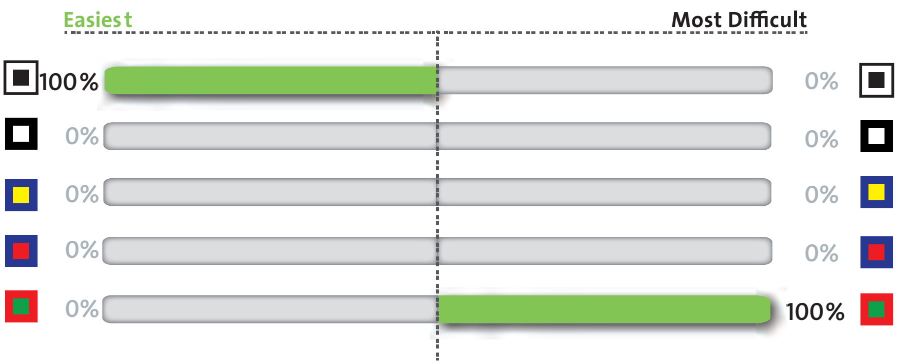


Chart 3.11: Colour and Luminance contrast valuation both for the easiest and for the most difficult.

In the Questionnaire the selection of the aesthetic attributes *(Dependent Variables)* was based on the literature review done before the study. The evaluated attributes were: Unpleasant - Pleasant *(the room was perceived as agreeable or enjoyable)*, Legible-Illegible *(it was clear for the observer to see all the books covers)*. **First Solution,** having the lowest luminance and illuminance level, was liked the least by the subjects; **the Second Solution**, as a consequence, was evaluated as the best with the 100%. The partial votes are represented by 20% of the total for people without visual decifits and by 40% for both cataract macular degeneration subjects. *(Chart 3.8)*. When they were asked to give a score from 1 to 4 on the quality of the solution they had just chosen, the visual unimpaired people defined the solution “quite good” compared to the first, on the grounds that they did not consider as essential higher levels of illumination for the performance of the task. On the other hand both cataract and macular degeneration people assigned a rating of 3 out of 4.*(Chart 3.9)*. During the discussion with some of them in the laboratory we learned that they do not like dark spaces so much, for example in the corner interiors, but they are aware that the Halogen solution allows them a better view than the fluorescent one. As regards **graph n ° 10**, to the question: *Why did you choose this solu-*

tion?. All of the participants responded with: *"There was better contrast and, as a consequence, I found it easier to recognize books".* Even if Halogen Spots at 100% are a very modern lighting pattern in modern interiors *(second solution)*, most of the elderly do not have them in the hall of their homes yet.

Finally, as it has already been seen from the results shown above, the question *"Which book cover was the easier/more difficult to recognize?"(**Chart 3.11**)* , the entire score was given in the first case, in the Black on White pair, while in the second, it was the Green on Red pair. Interestingly, on equal luminance contrast between the pairs: Black on White and White on Black, the subjects chose the first. In general it was observed that the dark text on a light background got increasingly higher scores than the similar opposite couple; the black background in this case tends to absorb some character edges which did not make the recognition as quickly.

7.3.1.4 Conclusion
new recommendations for visually impaired people

The study brought some notions on how elderly and visually impaired people manage artificial lighting distribution in their indoor environments. Talking with the subjects, they confirmed that all of them were limited, especially in the evening in conditions of only artificial light, in finding out books in their home due to careless lighting design in the room. All of them indeed, stated they lived everyday in lighting conditions not far from the first experimental solution: a fixed ceiling lamp coupled if necessary with wall or floor-standing luminaires.

"My son installed an additional light in the kitchen." [Female, 78 years old]

Such a lighting design provides a satisfying level of general/ambient lighting in the room but does not help visually impaired people in performing a visual task such as the one described in the experiment. On the other hand, lighting fixtures like pull down accent, which are more suitable for this purpose are hard to find in their homes.

***Improvements and advices** that should be taken into account are:*

- *Accent/Task Lighting*: Guidance on housing design *(ISO Guide 71:2011)* for people with loss of sight indicates that artificial light should be well distributed and local areas of higher illumination can be introduced, as this will assist partially sighted residents by enabling them to suit the lighting to their own clinical conditions. Some bulbs have a *"reflector"* coating on the top, which helps directs the light to where you want it. A 50-to 65-watt bulb may be adequate, depending on the task.

- *a high CRI:* The higher the CRI rating, the more natural the colors look. For visually impaired subjects it is advisable that the "CRI" number is at least 91.

- *the arrangement of the luminaire position*: should be defined with respect to the task to be performed; avoiding both the direction of the light beam straight to the head of the subject forcing him to carry out tasks in his own shadow and Disability Glare in the eyes due to a bad inclination of luminaire on the working area.

- *title-background contrast*: this is important, especially for subjects with vision loss, for ease of recognition and ease of seeing. Some colour combinations are also more effective. For example, black on white or yellow on blue are general purpose combinations which provide strong definition without too much glare *(ISO Guide 71:2011)* .

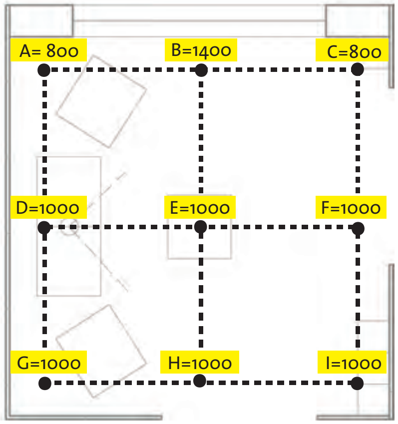
However our findings need to be confirmed by other real experiments since there is still no uniform practice to design and quantify it with respect for visually impaired people's needs.

7.3.2. **Experiment 2: Reading Test**

7.3.2.1 Daylight Factor(DF) Illuminance and luminance values

In order to define the overall amount of daylight, in both experimental rooms, the daylight factor *(DF)* was calculated: the function of the angle of sky visible from the centre of the window, the glazing area and transmittance and the area of all the surfaces in the room *(ceiling, walls, floor and windows)* and their average reflectance. The DF value is respectively **4%** for the Living Room and **3%** for the Kitchen. The DF values of the Reading Test are compared with the Standard minimum requirements *(Norway)* ***2%*** and the recommendations given by the Lighting Guide 9:2013 *(See Chapter 2.1)*, which suggests, for best practice, a DF value of **5%** for the Lounge and of **3%** for the Kitchen.

All the illuminance and luminance values were taken simultaneously in the Living Room and in the Kitchen, under two sky conditions: ***clear sky*** *and* ***overcast sky.*** After the setting of each stimulus, luminance pictures of the two experimental rooms were taken. Due to the highly variability of daylight *(pictures were taken during the summer season)* and the selection of the sky type *(clear and overcast sky)* there were long periods of waiting, sometimes even days, for the appropriate weather conditions, to take the pictures. *(See chapter 7.2.4. Measurements).* **Figures 3.40 and 3.41 show** how in



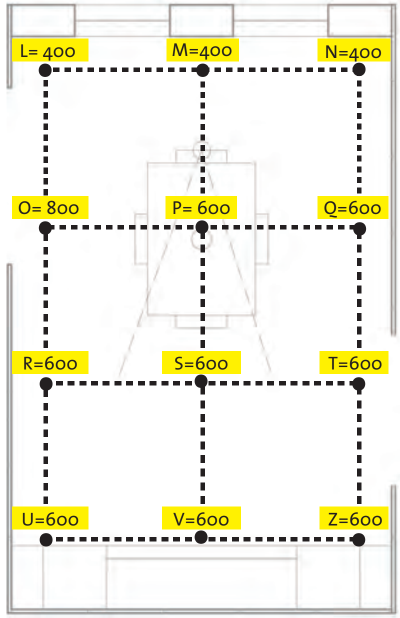
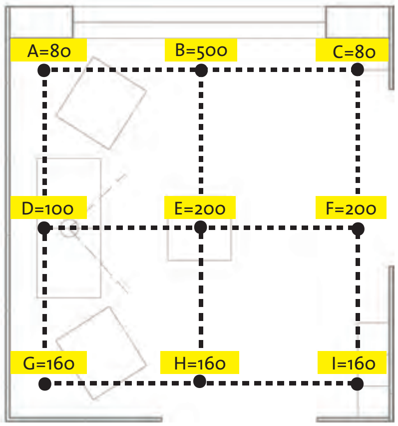


Figure 3.38: E values taken on the horizontal grid at a height of 80 cm from the floor level. I Natural Lighting Solution: cloudy sky condition.



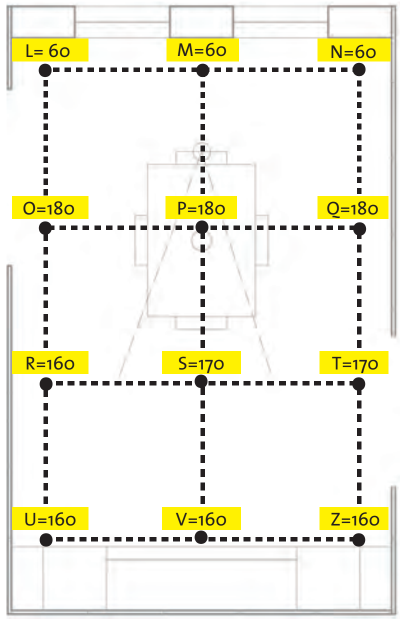


Figure 3.39: E values taken on the horizontal grid at a height of 80 cm from the floor level. I Natural Lighting Solution: sunny sky condition.

Figure 3.40: First Natural Light Solution: cloudy sky conditions. Daylight devices: Blinds. Living Room false colour image with luminance values.

Figure 3.41: First Natural Light Solution: cloudy sky conditions. Daylight devices: Venetian Blinds and Light Shelf. Kitchen false colour image with luminance values.

overcast conditions it is possible to find, in both rooms, luminance values almost homogeneous and the most even light distribution. In the living room luminance values are slightly higher than those of the kitchen: the luminance of the sky seen through the window was in the range 180-550 cd/m2, to reach values even under the 50 cd/m2 in places where daylight is obstructed: in the corners, under the window and in the furthest points from it; at the height of the work plan values are found around 100 cd/m^2. Corresponding to the ceiling chandelier *(See also the ceiling)* luminance values rise slightly thanks to its own capacity to reflect light. In the kitchen both the light-shelf and venetian blind design lead to higher values at the top of the walls and of the ceiling: very minimal improvements to witness the fact that they both work at their best potential in the case of direct light. The function of the light shelf can be detected in the narrow blue-coloured area in the part of the ceiling immediately above the window. The task performance area does not benefit from these enhancements from the two devices and has values around 40 cd/m^2.

The reverse is the behaviour of such lighting devices in clear sky conditions: **the two pictures*(Figure 3.42 and 3.43)* show** very large luminance differences in both rooms. In the living room the highest values are found in close proximity to the window *(the first armchair and coffee*

table) and are included in a range from 1400 to 2600 cd/m2; as you move away from that area values decrease uniformly to reach values around 100 cd/m^2 in places where daylight is obstructed.
In the kitchen, the uneven distribution of luminances reveals the characteristics of both the light shelf and blinds. Their presence causes luminance values greater between each slats, thanks to their reflection properties, and sharp shadows on the work surface. The upper part of the walls show higher values than the lower part until reaching maximum values on the ceiling *(between 4920 and 5570 cd/m^2)*, for a depth equal to the half of the room.

What was stated above is supported by the luminance values measured on the sheet of paper during the oral reading test: **Figure 3.44 shows** luminances of 1680 cd/m^2, 2050 cd/m^2, 1430 cd/m^2, 1890 cd/m^2 and 1790 cd/m^2 *(in points 2, 3 and 5 respectively)* in the Living Room near the window while in the Kitchen ***(Figure 3.45)***, luminances range between 770 cd/m^2 and 947 cd/m^2 *(Point 1)*. Both Pictures were taken in conditions of clear sky. On average, these points gave a higher mean value in comparison with the same daylighting systems under an overcast sky. In the Living Room in fact, luminances obtained were between 200 cd/m^2 and 56 cd/m^2 while in the Kitchen a range from 40 cd/m^2 to 100 cd/m^2.

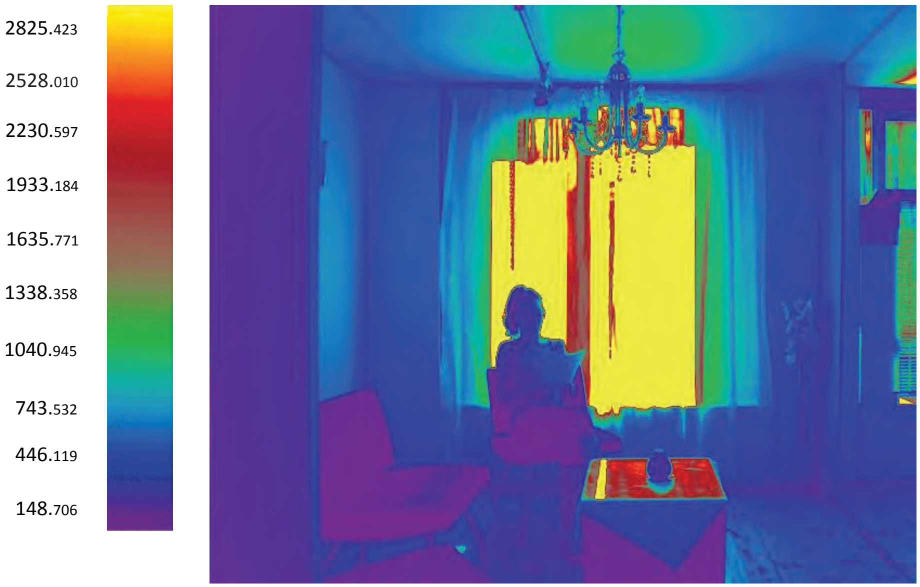


Figure 3.42: Second Natural Light Solution: sunny sky conditions. Daylight devices: Blinds. Living Room false colour image with luminance values.

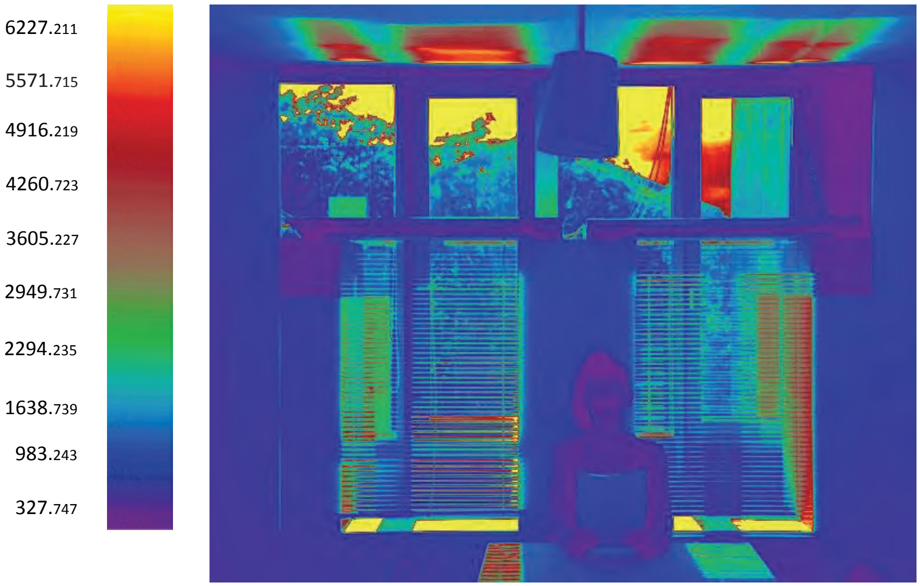
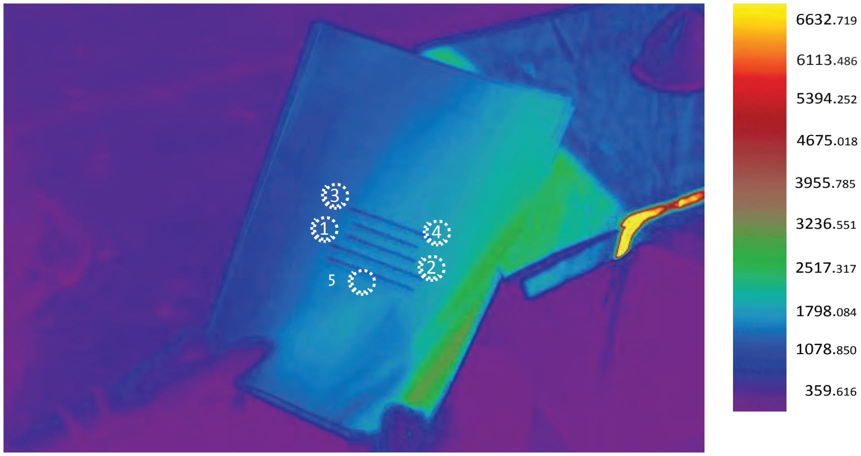


Figure 3.43: Second Natural Light Solution: sunny sky conditions. Daylight devices: Venetian Blinds and Light Shelf. Kitchen false colour image with luminance values.



(3.44)

N	Source	Reg.	Unit	Count
1	Luminance image	1	L cd/mq	1680
2	Luminance image	2	L cd/mq	2050
3	Luminance image	3	L cd/mq	1430
4	Luminance image	4	L cd/mq	1890
5	Luminance image	5	L cd/mq	1790

(3.45)

N	Source	Reg.	Unit	Count
1	Luminance image	1	L cd/mq	947
2	Luminance image	2	L cd/mq	770
3	Luminance image	3	L cd/mq	785
4	Luminance image	4	L cd/mq	780
5	Luminance image	5	L cd/mq	930

Zoom showing in detail luminance values on paper sheet (visual task plane).
Figure 3.44: Second Natural Light Solution: sunny sky conditions. Daylight devices: Blinds.
Figure 3.45: Second Natural Light Solution: sunny sky conditions. Daylight devices: Venetian Blinds and Light Shelf.

7.3.2.2 Speed Score and Accuracy Score

Another independent variable to appear in this section is that of character type with its height and spacing, combined with the influences that these aspects have for the various “categories” of readers. As mentioned previously, visually impaired people and elderly need more light and more time to perform visual tasks with the same accuracy and speed: reading is pre-eminently one of them and it is important to consider the specifics of the users and the metering modes provided. Both for white linen blinds and for light-shelves with venetian blinds, in clear sky conditions, scores obtained by the subjects in terms of speed and accuracy were almost similar; the same for those with an overcast sky.

After this initial analysis of the data obtained, it was decided to represent in the graphs a comparison between clear sky and overcast sky where the differences were larger, rather

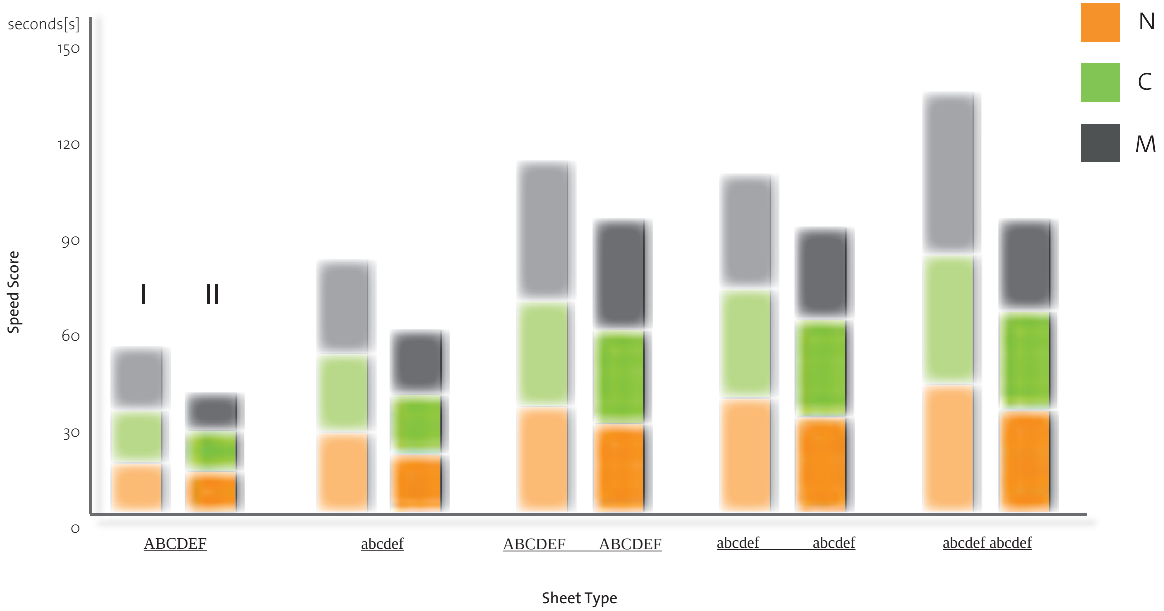


Chart 3.12 : Shows in detail the time taken to carry out the task by the three categories of visual impairments. Results confirm that clear sky conditions *(more opaque columns)* is better compared to a overcast sky condition both as regards the rapidity of performing the task and the accuracy, *(as it can be seen in the following chart 3.13)* especially for the pathology of macular degeneration. Cataract and visually unimpaired people results are almost similar in each type of sheet.

than the two daylighting devices.

Chart 3.12 shows on the x-axis five different sheets submitted to the subject during the test; the order followed is the one that goes from the easiest to the most difficult although during the experiment sheets were presented completely at random, in order to achieve results as objective as possible and to avoid any external references. Each type has two columns, the first referring to the overcast sky and the second at the clear sky. On the y-axis is reported the time employed, in seconds, is noted. The results show that for both daylighting systems *(White Linen Blinds-Light-shelves+Venetian Blinds)* subjects took less time to perform the test under clear sky conditions than under an overcast sky. For each type of sheet introduced, the category of subjects suffering from macular degeneration took more time in the reading than the other two; In fact, with advancing age and progression of the disease, the printed text looked distorted and seemed to lack segments of words, colour vision is less sharp and there is a greater need for light.

Chart 3.13 details *the five types of text submitted and their accuracy scores* of the three subject categories. Despite overall very high scores, some of them, always in overcast conditions, may draw the attention: the third sheet, in which words ap¬pear spaced and all uppercase, the subjects with cataracts have read correctly 80% of words while subjects with macular degeneration 70%; the highest number of errors committed, especially with regard to macular degeneration, may be due to two main reasons: less sharp vision and less automatic reading and immediate with written texts in all capital letters.
The lowest score recorded was 60% of M during the fifth point of the sheet. The central part of the retina being damaged complicates the reading of sentences with words which were very close together, which appearing distorted, do not allow the understanding of others that are located in the peripheral area

of the retina and therefore, clearly recognizable. As confirmation of the above, we find 80% accuracy in sheet 4 where words in lowercase letters *(which is usually found in the texts)* and spaced from each other so allow the individual with macular degeneration to focus better on the content of the text.
The time taken and the number of mistakes made by participants with cataracts were slightly higher than people without visual impairment. Subjects suffering from this pathology are able to overcome almost all of the obstacles with the aid of new lenses.

Finally, it can be seen how independent variables, in particular the sky and text condition, are fundamental for a person with sight problems in the performance of usual activities of daily leisure.

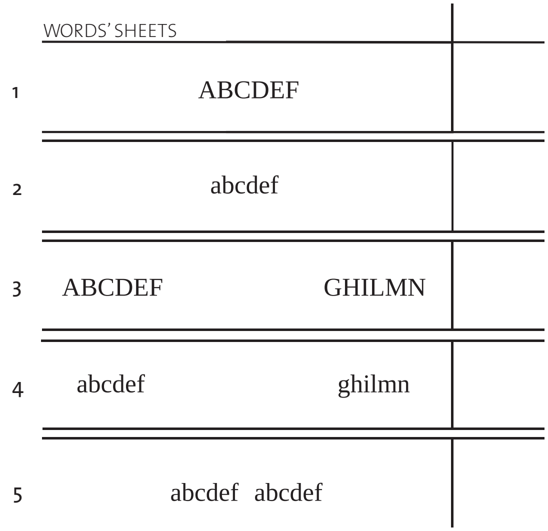
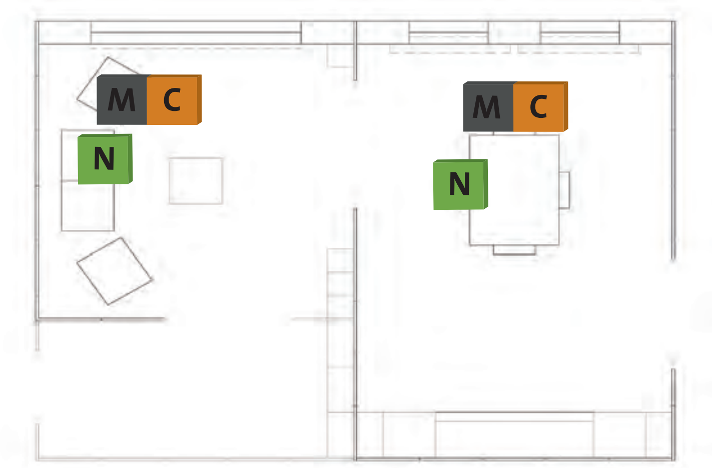


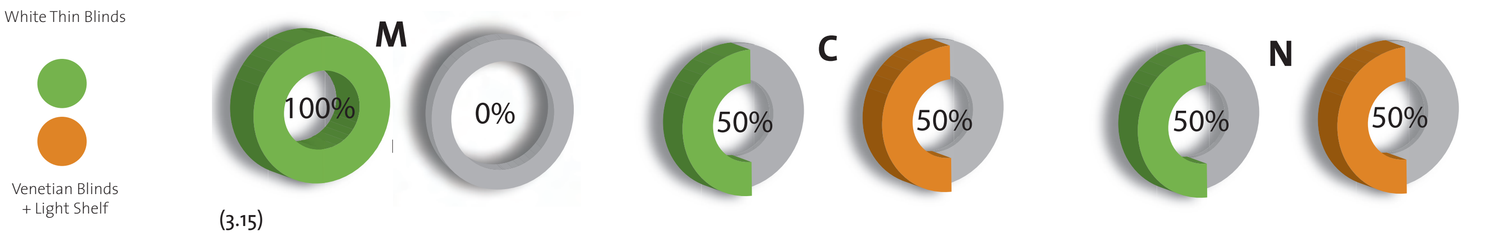
Chart 3.14: Preferences for sitting and reading position. **Chart 3.15:** Daylighting Devices preferences for the three categories of subjects. **Chart 3.16:** Type of written text valuation by the three categories of subjects.



(3.14)

7.3.2.3 Questionnaire

In this Experiment the aesthetic attributes *(Dependent Variables)* were evaluated: **Thin linen blinds-Light-shelves** and **Venetian blinds**. As could be expected, the sitting position for reading was very similar for all participants, only for subjects with normal vision their position, being indifferent to them to perform the required task, was, in both rooms, the sit to the left and in a distance greater than 1 meter from the window *(See **Chart 3.14**)*. The rest of participants *(Cata-*

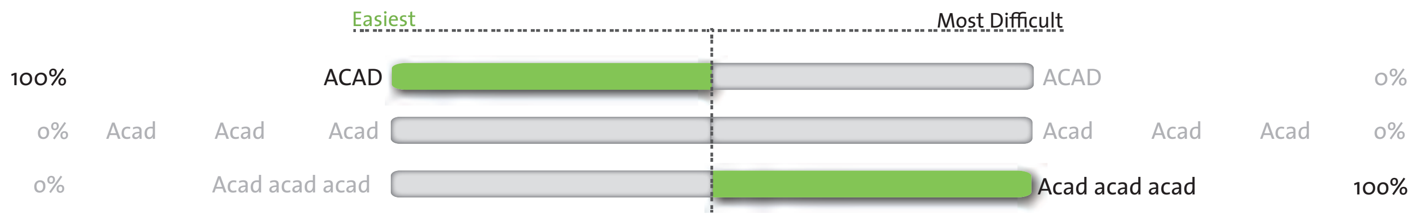


(3.15)

FONT SIZE	CAPITAL(C) LOWERCASE(l)	WORDS' SPACE			
12	C	-	>90%	>90%	N
			>90%	>90%	C
			>90%	>90%	M
12	l	-	>90%	>90%	
			>90%	>90%	
			>90%	>90%	
12	C	YES	>90%	>90%	
			>90%	80%	
			>90%	70%	
12	l	YES	>90%	>90%	
			>90%	80%	
			>90%	80%	
12	l	NO	>90%	>90%	
			>90%	80%	
			>90%	60%	

Chart 3.13. Accuracy Score: percentage of words read correctly, both in clear sky and overcast conditions.

ract and Macular Degeneration) preferred to sit close to the window on their back where there were very high illumination values. Some of the visually impaired subjects*(M)* moved the armchair as close to the window as possible to get more light and higher luminance values on the paper sheets; a small change of the position made the difference, especially as regards to the possible shadow on the paper made by their own head. **Chart n°3.15 shows** how the rooms/two different daylighting systems were evaluated: partly on the basis of how easy it was to do the reading task, partly of an overall impression. The preferred daylighting system was the Thin Linen Curtains in the Living Room: all the subjects affected by M rated the first solution as the best while for Cataract and Visually unimpaired the two solution were equal; one explanation could be that this device allowed both a stronger and a more diffuse light in the room than the second solution, so the light seemed to be better distributed and well reflected down to the working area. Additionally, responses from the participants in the written comments from the questionnaires indicated two possible causes over the preferences *(for M subjects)* of thin linen curtains over the light-shelves. It was noted that the second solution produced disturbing light patches in the working area and annoying reflections from the ceiling. As regards the last **chart 3.16**, we tried to find out which was the easiest and the most difficult type of written text to read for all the participants, considering both the reading times employed and the accuracy of the performance. It was shown from the graph that: all capital letter single words were the easier while the most difficult were lowercase non spaced words, especially in overcast sky conditions.



(3.16)

cially those affected by macular degeneration.

Many participants felt that having lots of daylight was important during the experiement, either because it improved the feeling of a home or because it enabled them to undertake tasks requiring close vision, in this case: Reading.

'I can see a bit better in normal daylight than artificial lighting.' [Male, age 75 years]

***Improvements and advice** that should be taken into account are:*

- *quality daylight*: if planned carefully, it is an excellent light source for almost all interior spaces; being aware both of its advantages and disadvantages is fundamental. Current specialist guidance *(ISO/IEC Guide 71, LIGHTING GUIDE 9:2013, See Chapter 2.1-2.2)* on design for people with sight loss includes recommendations that natural light be maximized in spaces of circulation and task areas, particularly in kitchens and Lounges and focuses on the need to enable occupants to control the amount of sunlight that enters their home through the use of blinds, in order to reduce glare.

- *the high Daylight Factor*: besides being a consequence of large openings, as reported also from the ISO/IEC Guide 7 and the LIGHTING GUIDE 9:2013, high Daylight factor *(3% in Kitchen and 4-5% in Lounges)* ensures visually impaired subjects a high level of visual performance in daily home tasks.

- *the type of window*: its size depends on the type of climate where it is located, in places such as Norway, large

7.3.2.4 Conclusion

new recommendations for visually impaired people

The study helps in understanding how elderly and visually impaired people manage natural lighting distribution in their indoor environments, especially in living spaces such as Lounges and Kitchens, where most of daily home tasks are carried out. Participants were asked about their experiences of undertaking everyday activities such as reading, talking with other people, etc. as a way of exploring their views on the design of their home in relation to daylight, visual task's aspect and layout, etc. The decision to hold the experiment in two different rooms equipped with different daylighting devices, revealed how difficult it could be to provide an appropriate illumination levels for the Reading Task in visually impaired people' dwelling. All of them confirmed that they lived everyday in daylighting conditions not far from the first experimental solution: a large window coupled with thin linen blinds. This statement was not surprising being the provision of large windows, in order to ensure good daylight penetration especially in winter, a part of the Nordic architectural culture. As it has been seen from the questionnaires responses, blinds in the Living Room are preferred over venetian blinds+light shelf in the kitchen by almost all participants, espewindows or dwellings having windows on two sides are preferred because of their potential in bringing extra light into the rooms or because of increasing of the amount of direct sunlight in the indoor environment. Another important challenge lies in the height of the window sill: different lighting guidelines point out that the recommended minimum sill height of 800mm is too high to permit a seated person a good view out *(visual contact with the outside is very important for visually impaired people)*; a minimum sill height is still difficult to obtain due to Building Regulations and to the need in some housing schemes to allow space for radiators under windows.

- *the type of device*: in the design for elderly and visually impaired people, the use of blinds over venetian blinds or light shelves is preferred. Blinds ensure a great amount of even light equally distributed in the whole room unlike venetian blinds or light shelves which, in the case of sunlight, produce disturbing light patches on the wor¬king plane and annoying reflections from the ceiling, particularly annoying for people with vision loss.

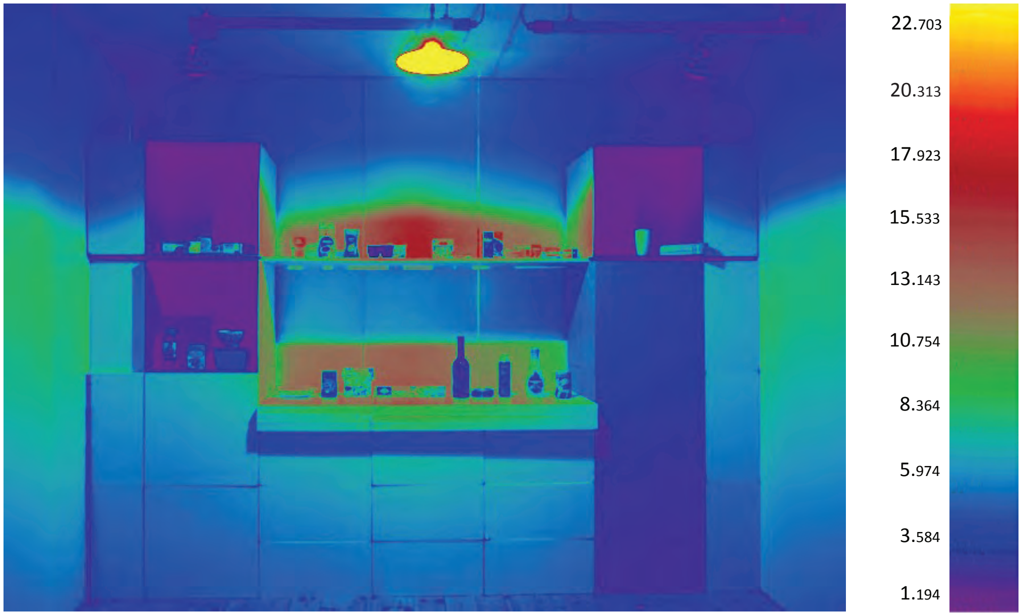
- *the type of written text:* Appropriate font size and font type, and lighting as well, should be designed for older people and people with low vision. However, there seems to be no systematic method. The principle factor to determine the legible font size is visual acuity. If the acuity is good, small font size is sufficient to read, and if the acuity is worse, the size should be larger. The actual problem is that the visual acuity changes in our daily conditions such as luminance levels, viewing distances as well as age and type of visual loss of the observer. One should be bear in mind that a type of written text can be readable by an individual with cataracts but not by one with macular degeneration disease.

However our findings need to be confirmed by other real experiments since there is still no uniform practice to design and quantify it with respect for visually impaired people's needs.

7.3.3. Experiment 3: Objects Recognition

7.3.3.1 Illuminance and luminance values

(3.46)



(3.47)

1° SOLUTION *(Figures 3.46 and 3.47)*: The illumination appears scattered and uniform. The source creates in fact low shadows which tend to flatten the objects three-dimensions; at the same time the device itself, not being directed, causes negative shadows in some points like inside the right cabinet.

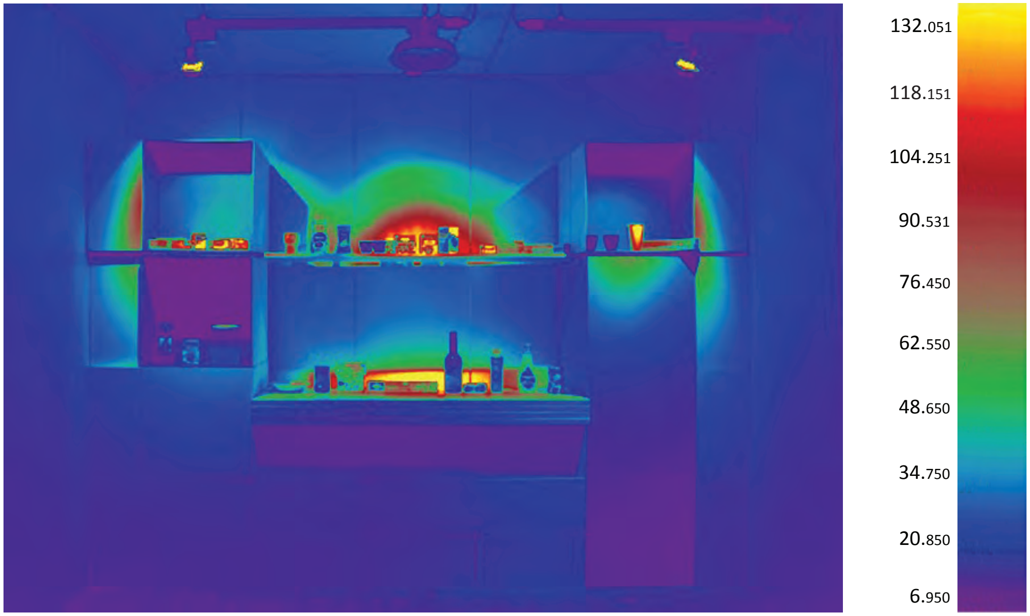
2° SOLUTION *(Figure 3.48 and 3.49)*: The ac¬cent lighting was directed to illu¬minate the specific vision task. The sources create a varied illuminance that, through the control of light and shadow give a better luminance contrast; on

Figure 3.46: First Artificial Light Solution. Lighting Type: General. Source: Halogen CRI:100. CCT:2700. Not Dimmed *(100%)*
Figure 3.47: False colour image with luminance values.

the other hand the same devices, not being dimmed, define areas of glare on the upper shelf(objects with reflective surfaces).

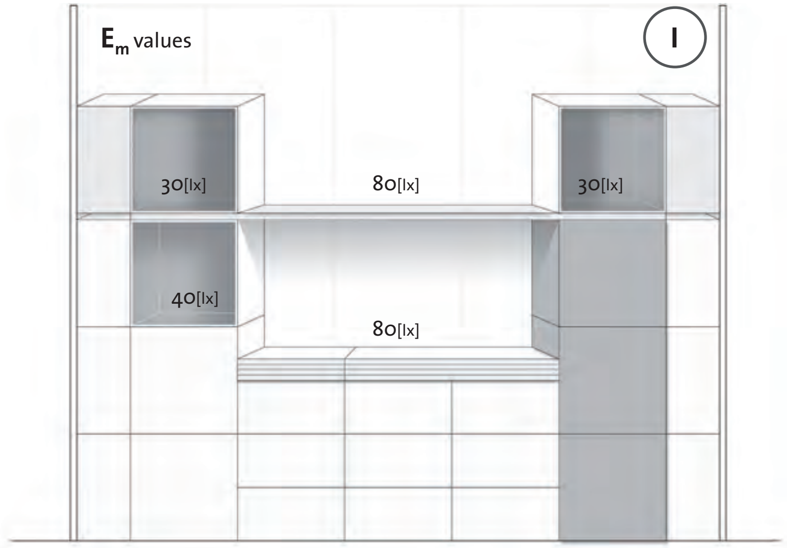
Each kitchen object has a level of luminance contrast *(High, Medium or Low. Table 3.7 Figure 3.18)* depending on the object colour, the background colour and the type lighting solution. The Solution 2, with a more correct mix of lights and shadows, determines a higher luminance difference between the object and the background and as a consequence, a greater contrast of visibility.

(3.48)

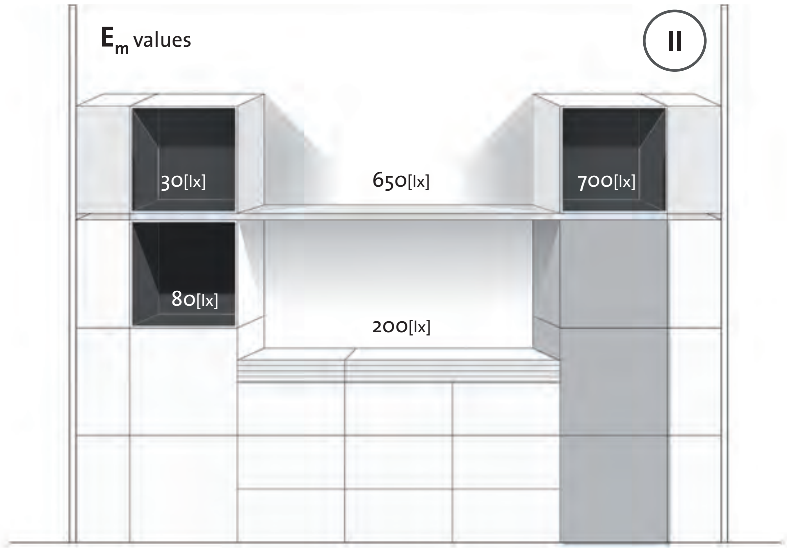


(3.49)

Figure 3.48: Second Artificial Light Solution. Lighting Type: Accent/Task. Source: Halogen. CRI:100. CCT:3000. Not Dimmed *(100%)*
Figure 3.49: False colour image with luminance values.



(3.50)



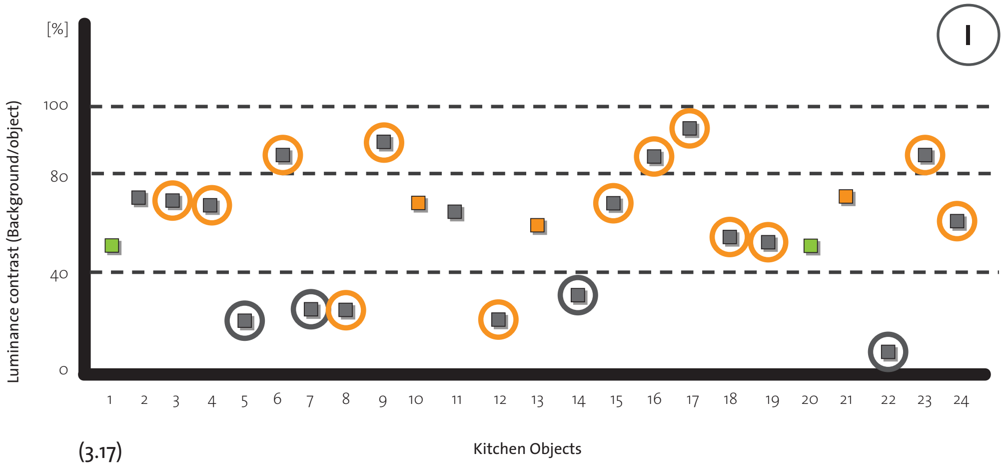
(3.51)

Figure 3.50 and 3.51: Em values are given by six E values measured on the horizontal grid in the cabinet planes and by three E values taken on the horizontal grids in the shelf planes. *(See 7.2.4 Measurements)*

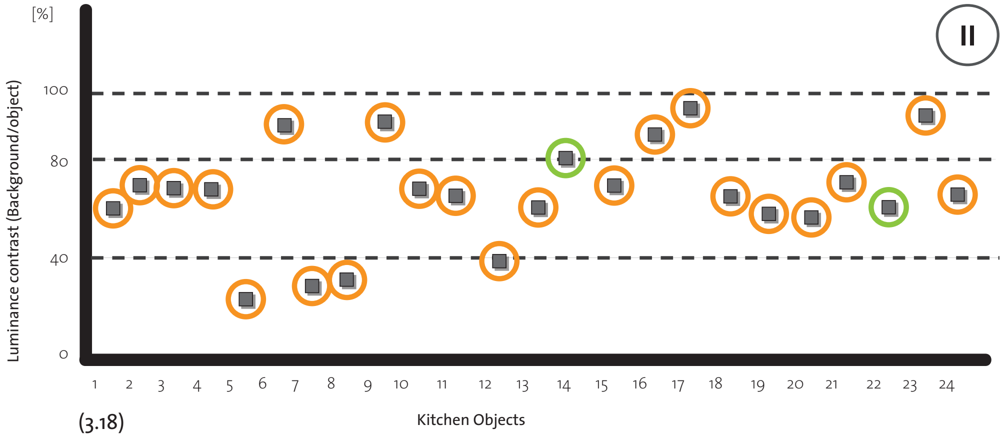
The range of illuminance values is varied for both solutions, especially the second one, based on the kind and position of visual task plane, for this reason only a general illuminance value*(E_m)* can not be meaningful to describe the totality. A specific Em was therefore calculated for each plane where the objects were placed; the values are respectively 30-80-30-40-80 lux*(Figure 3.50)* for first solution and 500-650-700-80-200 *(Figure 3.51)* for the second one.

The Standard doesn't define the lighting requirements as regards to the task performed in the residence building but only for working places. The values obtained in the experimental room(kitchen) were therefore compared to the recommendations given by EN 12464.1:2011 about working places where similar tasks(cooking) are carried out, such as restaurants(12464.1:2011.Clause 5. Table 5.29) and food stuffs and luxury in the food industry(12464.1:2011. Clause 5. Table 5.12). In the public restaurant kitchens 500 lux on the working plane is necessary, while 200 lx is recommended for cooking in factories.

NOTE: the symmetric illuminance distribution reflects the light output from the general/ambient lamp used in the First Solution*(Figure 3.50)*.



(3.17)



(3.18)

- Object recognized by all category of subjects
- Object recognized by all category of subjects
- Object recognized by N and C subjects
- Object recognized by C and M subjects
- Object recognized by only C subjects
- Object not recognized

Chart 3.17*(First Lighting Scenarios).* Chart 3.18*(Second Lighting Scenarios).* Each kitchen objects is linked to its luminance contrast level; the vertical axis shows the three ranges: low*(0-40%)*, medium *(40-80%)* and high *(80-100%)*, while the horizontal ones indicate the number of objects which had to be recognized. The order*(1-24)* followed is based on the objects position as it is illustrated in Figure 3.18, each cabinet and shelf was cataloged from left to right.

<u>SECTION I</u>

The Score Accuracy indicates the number of objects recognized by each category of subject: N*(with normal vision, after cataract surgery), MD(with macular degeneration) and C(with cataract).* **Charts 3.17 and 3.18 summarize**, separately for the two lighting scenarios, the results obtained; we can clearly see, by comparing the graphs, that *the Score increases in the Second Solution(the directional light type)* where all participants are able to recognize completely the kitchen objects.

Going into detail, **the first solution shows** 6 items in the low contrast*(0-40%)* range, 13 in the medium one*(40-80%)* and 5 in the high one*(80-100%).* All participants had no problems in recognizing objects with high contrast, but they were not capable of identifying the low contrast ones with exception of two items: numbers 8*(Parchment Paper)* and 12*(Sauce for Burgers)* were in fact easily distinguishable thanks to their particular colour and specific form. The medium contrast range, instead, doesn’t define a uniform trend for the three groups; the objects identification was heavily varied and influenced by subjective experiences, for instance the experiment shows that women had less difficulty than men in recognizing the yeast because it was a well known object. *(**Colour constancy.** Chapter 2. Colour and vision perception).*

In the second solution than the first, each luminance contrast value increased until arriving, in some cases, at upper range. The low contrast objects in fact decrease to 3, while the medium and high ones increase: the first move from 13 to 15 and the second one from 5 to 6. The two largest increments are given by the items number 14*(white cup)* and 22*(black glasses)* depicted by the green colour in graph 3.18; both constitute critical cases: the objects colour was almost equal to the background one, this entails the same luminance and therefore a low contrast which may be emphasized, only by an appropriate lighting design. **The task/accent solution achieves the purpose through the right mix of lights and shadows, Figure 3.52** makes the concept clear comparing the first and second lighting solution.

As a consequence, **the better results were obtained by the Directional Lighting Scenario*(II Lighting Solution)* but dimmed 50%**; the participants preferred to reduce the amount of light in order to avoid negative reflections which cause glare points especially for subjects with macular degeneration. *(See objects number 19-20-21. Figure 3.49-Upper shelf).*

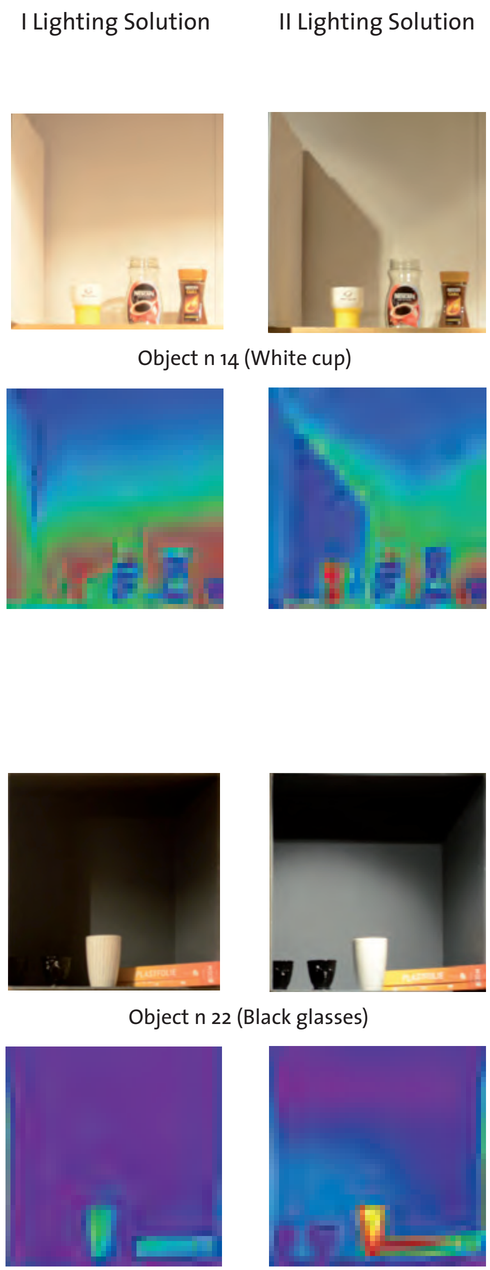


Figure 3.52: Comparison between I and II Solution, focused on two object: white cup*(n°14)* and black glasses*(n°22)*. II Scenarios: for the object n° 14 the back shadow is essential to accentuate its three-dimensionality and increase the luminance contrast with the background, while for item n° 22 the absence of shadow makes the object recognizable.

7.3.3.2 Speed Score and Accuracy Score

SECTION II

The Speed Score is the employed time, by each subject category, to read correctly every label type*(Luminance contrast: n°1-High, n°2-Medium, n°3-Low. See 7.2.3. Table 3.19)*; **the Chart 3.19** makes clear the two essential variables tested: the label design and the lighting type; increasing in fact the luminance contrast*(expiry date-background)* and using task/accent sources*(II Solution)*, the required time to recog-nize the label decreases sharply. On other hand decreasing the luminance contrast and using a scattered lighting*(I Solution)*, the results get worse; as evidenced by **Chart 3.20** through **the Accuracy Score**, the subjects with macular degeneration in fact are not able to read the third labels in the First Lighting Scenarios.

One can deduce: a careful design of the light and the context avoids errors that for normally sighted are almost imperceptible but are crucial for visually impaired people, especially the subjects with MD.

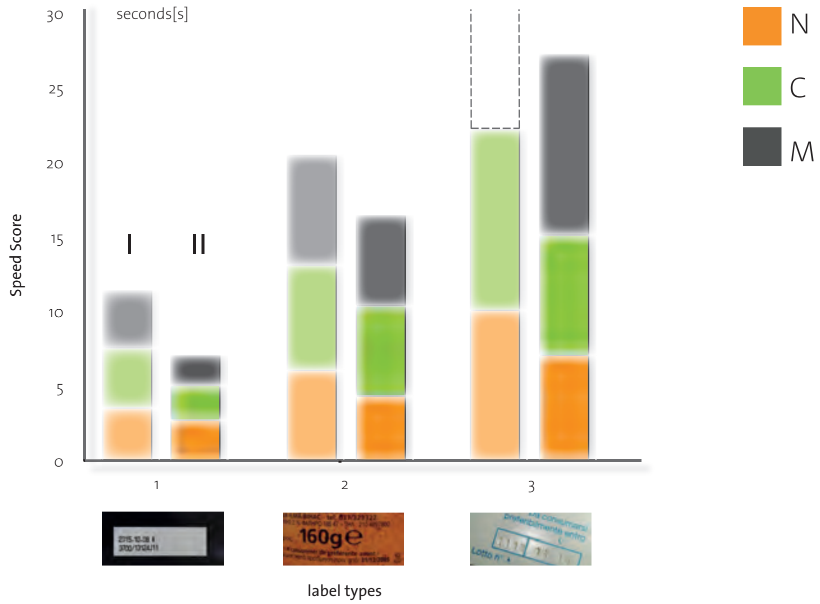


Chart 3.19 sums up **the Speed Score** showing the partial time of each subject category in the First *(less opaque Column)* and Second *(more opaque Column)* Solution. The vertical axis indicates the time (seconds), while the horizontal one the label types *(1: high contrast, 2:medium contrast, 3: low contrast).*

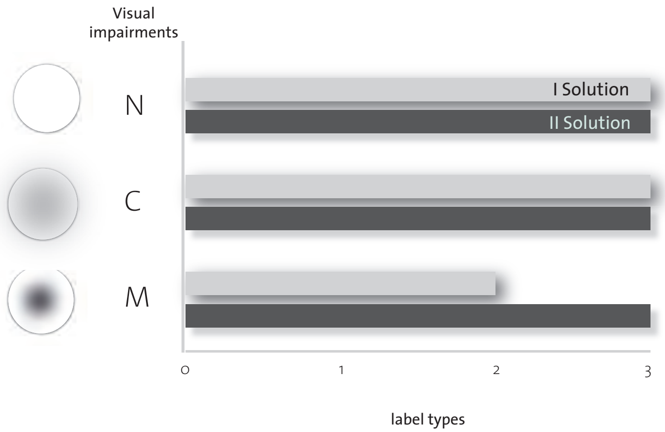


Chart 3.20 Accuracy Score. On the vertical axis are the three subject categories: N=subjects with normal vision, C=cataract and MD=macular degeneration, further subdivided in the First *(light grey bar)* and Second *(dark grey bar)* Lighting Scenario; on the horizontal axis instead, the numbers *(1-2-3)* symbolize the label types from the highest contrast.

7.3.3.3 Questionnaire

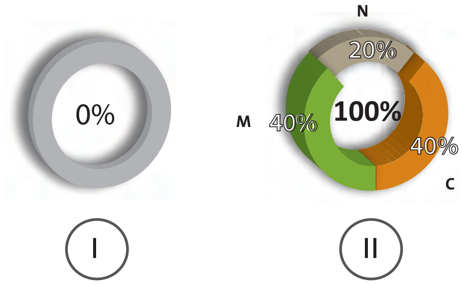


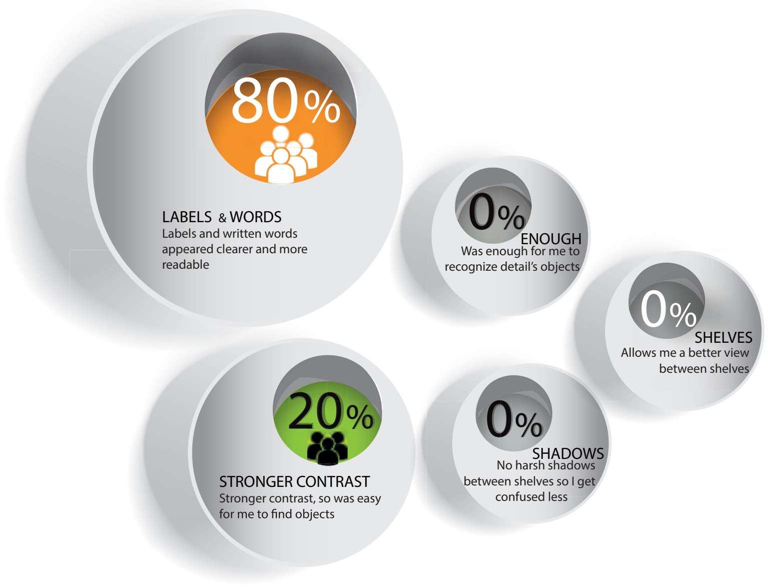
Chart 3.21*:* to the question *"Which Artificial Light Solution did you prefer in both Section of the experiment?"*, **all participants chose the Second Scenario**: accent light ing's type. The 100% were represented by 20% of the total for people without visual deficit and by 40% for both cataract and macular degeneration subjects.

Lighting scenario 1, having the lowest luminance and illuminance level, was liked least by the subjects; the second solution indeed was evaluated as the best with 100%. The vote was split up as 20% of the total for people without visual deficit and by 40% for both cataract and macular degeneration subjects. *(**Chart 3.21**)*. To the question: *"Why did you choose this solution?"*, the participants explained their choice by answering: *"The stronger contrast allowed me to find the objects more easily"* and *"Labels and written words appeared clearer and more readable"*. *(**Chart 3.22**)*. Accordingly, the subjective preferences reflect and confirm the results obtained in the experiment itself.

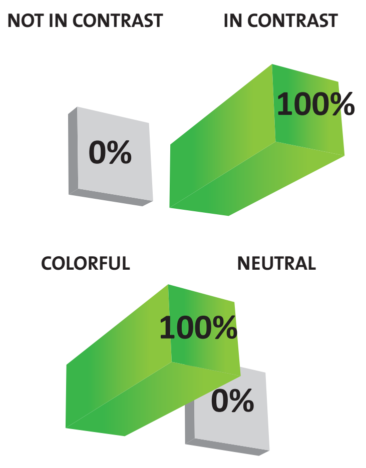
The participants, after filling out the questionnaire, reaffirmed some essential elements, in addition to their preference on the light's design, to improve the daily activity performance:

As regards Section I, the results show unanimity among the participants, all of them had less trouble in identifying objects in contrast with the background and colourful items *(Chart 3.23)*; these last were especially easy to recognize when they are well known ob¬jects of daily use such as a particular choco¬late jar *(called "Nugatti", typical in Norway).* Regarding Part II, as it has already been shown from the results shown above, the question "Which label was easier/more difficult to read?", the entire score went in the first case, in the 1° label type *(high contrast)*, while in the second, for the 3° label type *(low contrast).* See **Chart 3.24**. During discussion in the laboratory with some of visually impaired subjects, it was interesting to discover their real problem was reading the expiry dates with low contrast at their homes, especially when the date was printed directly on a background composed of images or were plotted for the only imprint, without the use of ink.

Chart 3.22 shows why the subjects preferred the Second Scenario: accent lighting's type. 80% answered: *"Labels and written words appeared clearer and more readable"*, while 20% replied *"The stronger contrast allowed me to find the objects more easily ".*

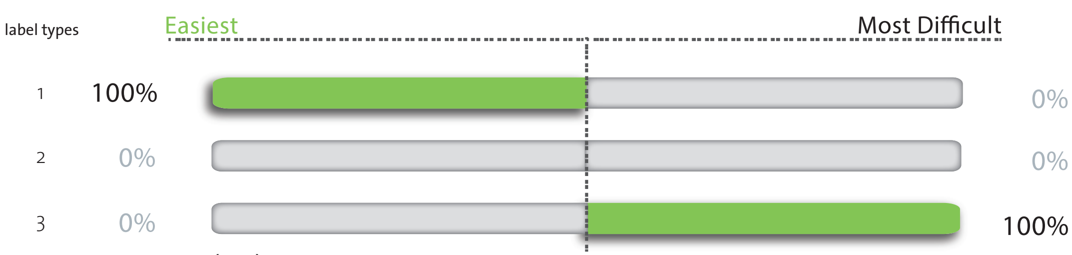


(3.22)



(3.23)

Chart 3.23, regarding Section I, shows the subjective preferences to easily recognize an object from a distance. **Chart 3.24** summarizes the results about the question: *"Which expiry date type was easier/more difficult to read?".* The label types are three *(from top to bottom in the graph)*: the first kind *(High Contrast)* included a small white square, very obvious, arranged to accommodate the expiry date; in the second one *(Medium Contrast)*, the date was instead printed directly on a background composed of images and finally, in the third *(Low Contrast)*, the dates were plotted for the only imprint, without the use of ink.



(3.24)

7.3.3.4 Conclusion
new recommendations for visually impaired people

The study brought some notions on how elderly and visually impaired people manage artificial lighting distribution in their Kitchen environments in order to implement an amount of natural light. After the experiment performance, the subjects expressed their consideration through the questionnaire and an informal discussion about their homes. 100% of the entirety of participants said they were limited in the performance of visual tasks on cloudy days, especially in late afternoon when the daylight is much lower; subjects in fact used to carry out particular activities, such as cooking, before sunset.
All of them confirmed they lived everyday in lighting conditions not far from the first experimental solution: a fixed pendant luminaire or a chandelier in the middle of the kitchen ceiling.

Improvements and advice *that should be taken into account are:*

- *Layered lighting*: design environments by integrating and layering light into the entire composition. A careful design of artificial layered light solutions should allow the activity performances by visually impaired people even in conditions of limited natural light.

- *Directional lighting*: light from a specific direction increases the visibility of the task, making the performance easier.*(12464.1:2011.4.6.4. Directional lighting of the visual tasks)*. Some shadows help to increase the luminance contrast, while low shadow, created by the general ambient sources, tend to flatten the objects' three-dimension.

- *Reflected glare*: unintended veiling reflections given by bright surfaces should be avoided *(12464.1:2011.4.6.4. Directional lighting of the visual tasks),* especially for people affected by macular degeneration. The lighting systems should be dimmable in accordance with people's needs.

- *Labelling of controls*: the required size of font for information relates to the probable viewing distance, level of illumination and colour contrast of the text against its background*(ISO/IEC Guide 71)* in order to make a visually impaired person more independent.

Our findings need however to be confirmed by other real experiments since there is still no uniform practice to design and quantify it *(luminance thresholds, observer position for luminance values, etc)* with respect for visually impaired people needs.

7.3.4. **Experiment 3: Objects Recognition**

7.3.4.1 Illuminance and luminance values

Illuminance values, which were taken both for the first and second artificial light solution *(See Chapter 7.3.4)*, are shown in Figures 3.53 and 3.54. Every solution was de-

I

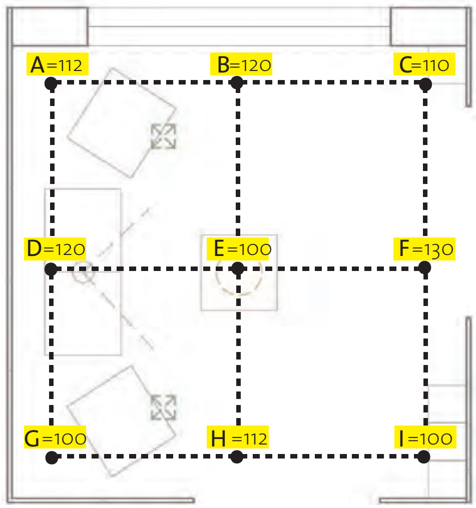
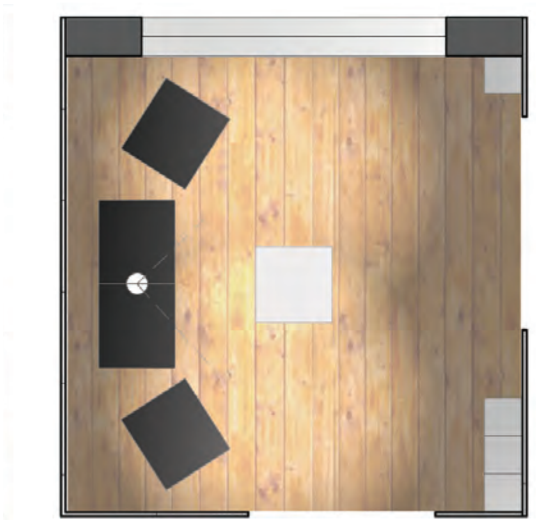


Figure 3.53: E values taken on the horizontal grid at a height of 80 cm from the floor level. I Artificial Lighting Solution.

	1^ Solution[lux]	2^ Solution[lux]	Standard
Em[lux]	100[lux]	66[lux]	50[lux]

Table 3.16: E_m of both Artificial Lighting Solutions compared with European Standard (EN 12464.1:2011)

II



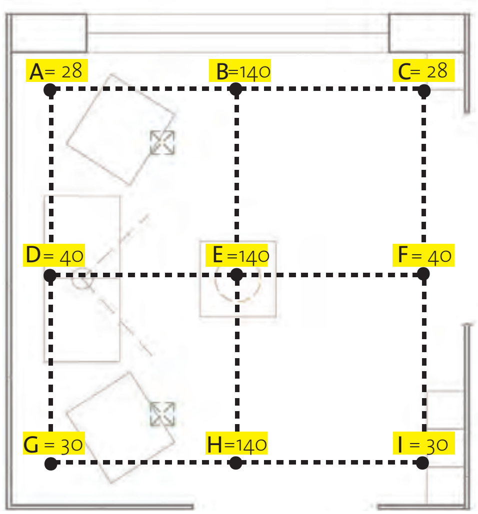
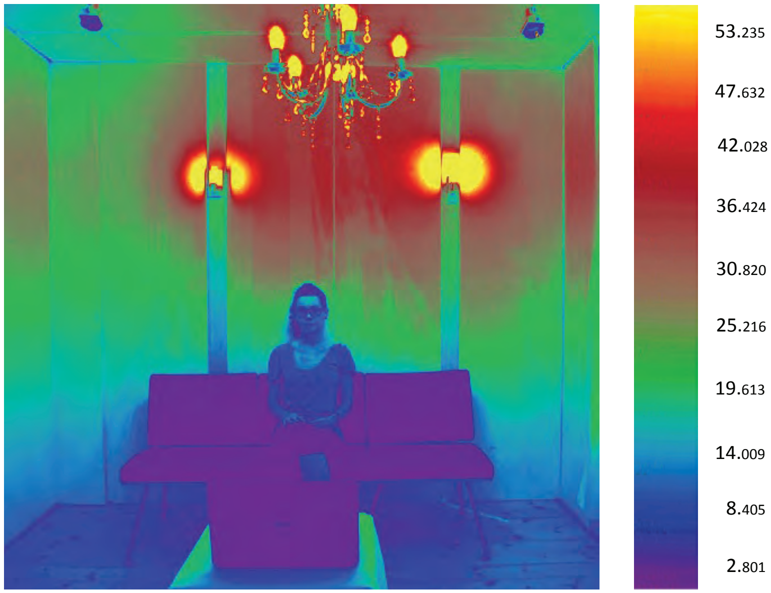


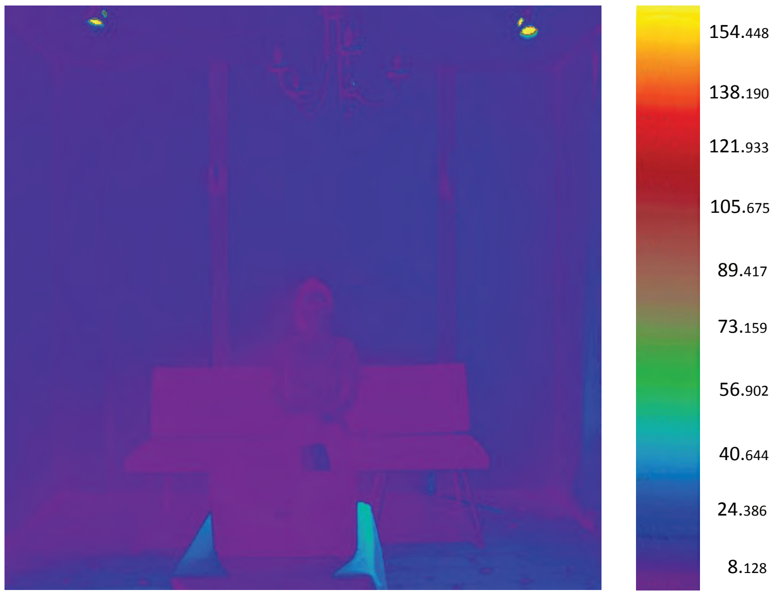
Figure 3.54: E values taken on the horizontal grid at a height of 80 cm from the floor level. I Artificial Lighting Solution.

signed in order to reach the minimum illuminance *(E_m)* requirement detailed by the Lighting Guide 9: 2013 *(See Chapter 2.1)*. Respectively illuminance values in our experiment are: 100 lux in the first solution and 66 lux in the second one. The standard stated before indicates a Em recommended value of 100 lux for general living room considered as a place where different hobbies and activities are carried out and a value of 50 lux for the specific TV watching task *(See Table 3.16)*. As can be noticed from the Figure 3.53 and 3.54, **the first lighting scenario shows,** on average *(between 100 and 130 lux)*, illuminance values equally distributed in the horizontal plane; a minimum illuminance of 100 lux is guaranteed for each point of the measuring grid, including even the corner of the room. A very different behaviour can be noted in the second solution which shows, unlike the previous one, strong illuminance value differences: it ranges between 28 lux and 140 lux; the highest light level can be noticed in points under the light sources but moving a little away from the sources, it decreases quikly resulting in very low values especially in the corners. Similarly, also luminance pictures reinforce what has been said in the previous paragraph with regard to the illuminance values:
Figure 3.55 shows further luminance values in the medium to upper part of the walls, distributed in a uniform way and without large luminance differences, in a range between 20 cd/m^2 to 53 cd/m^2. In the lower part, in correspondence with the working plane and the floor, the values go further down. The chandelier and the two wall-mounted fixtures provide general lighting which radiates a comfortable level of brightness in the whole room. The second solution, as shown in Figure 3.56, consists of two spots oriented towards the floor. Compared to the first solution there are wide luminance differences in the room: spots create luminance variation in the room allowing both to focus on the visual task through the low luminance values around the task place and to orient themselves in the new environment *(thanks to the orientation of the spotlights)* being the corners of the room being already quite dark. Here luminance values go from 30 cd/m^2 to values of 140 cd/m^2 under the spotlights.

Figure 3.55 (First Artificial Lighting Solution) and 3.56 (Second Artificial Lighting Solution): Living Room false colour image with luminance values.



(3.55)



(3.56)

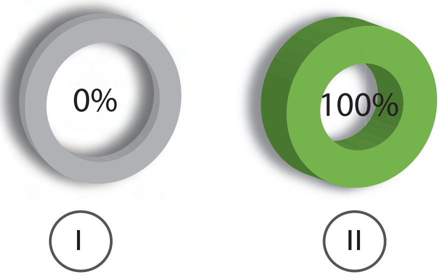


Chart 3.25: Lighting scenarios valuation

As **chart 3.25 shows**, even in the latter experiment, the dependent variable of type of lighting which has earned the total number of votes is that of Accent Lighting. An interesting aspect, skipped from conversations with the subjects after the experiment, is about the two lighting scenarios: all the participants stated a preference for the second light solution. As reported by them in the open comments of the questionnaire, they used to pull down the curtains to eliminate any reflections caused by natural light preferring therefore, to carry out this visual task with ambient lighting values very low. The two halogen spots allow them to focus better on the visual task thanks to the presence of high levels of illuminance only circumscribed to the table and to the screen but at the same time, they said they did not appreciate dark spaces, for example below the doors or in the corners of the room: a type of illumination not suitable for carrying out any other activity.

In fact, most rooms need two types of lighting: general lighting and task/accent lighting and to use different lamps and light fittings for each purpose. Aesthetically and for its ability to ensure lighting levels more or less homogeneous throughout the room, a kind of general lighting as on the first solution, is considered more suitable to their homes being aware that it does not provide the

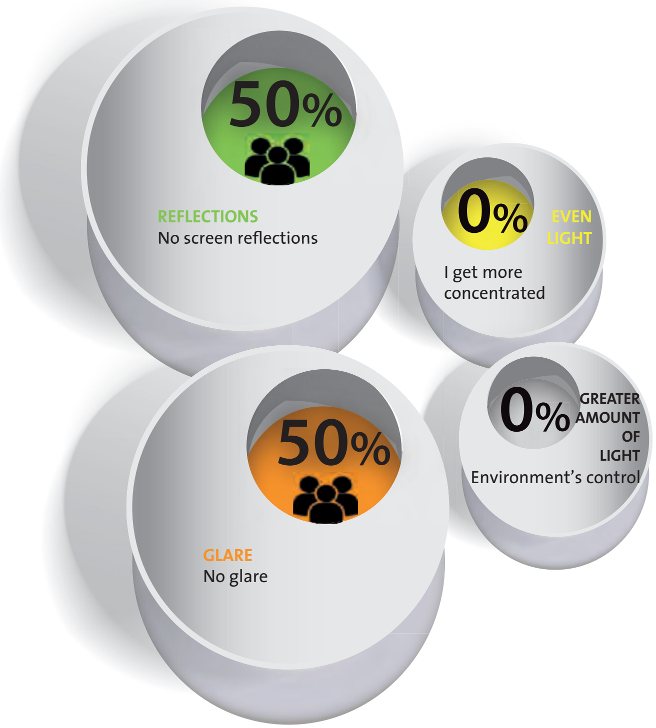
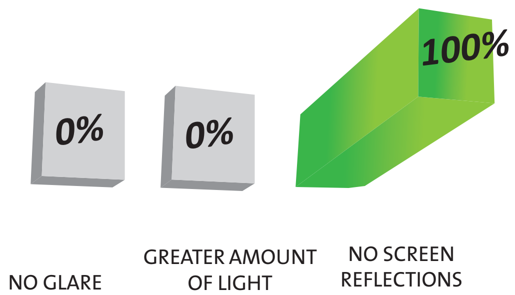


Chart 3.26: shows why the subjects preferred the Second Scenario.

Chart 3.27: Explanation related to the sitting position choice.



same level of visual comfort as the latter solution. The frontal position *(chosen by all parties)* is that which undoubtedly is easier on the eyes and the body and the distance to be kept, compared to the sessions, varies depending on the size of the screen: in general, is equal to the screen's diagonal size, in centimeters, multiplied 5 times. For these reasons, the table was positioned at that precise point inside the room. It is well known that the most suitable light for a good vision is undoubtedly the natural one, side device *(aspect respected in the definition of the interior design)*, since place the TV in front of a window, with the light entering behind the viewers could produce annoying reflections on screen. The challenge of this experiment was precisely to create the best conditions for visual comfort even under artificial light scenarios by keeping the same arrangement of furniture.

The target is confirmed in **Chart 3.26** where 50% of respondents said that they had not found any problems related to reflections on the screen and the other 50% had not suffered from glare. Finally, **Chart 3.27** shows that all of the subjects stated that they have not noticed reflections on the screen from the frontal position taken during the experiment.

7.3.4.3 Conclusion

new recommendations for visually impaired people

The study brought some notions on how elderly and visually impaired people manage artificial lighting distribution in their Lounge environments. The responses questionnaires reveal that 100% of the subjects/the entirety of participants said they were limited in the performance of this specific visual task in their home because of lighting problems/ due to careless lighting design on this specific task. All of them indeed, confirmed that they lived everyday in lighting conditions not far from the first experimental solution: a fixed pendant luminaire or a chandelier in the middle of the ceiling coupled to wall or floor-standing luminaires; such a lighting design allows them for further variation in the lighting plan in order to suit their own eye conditions and to carry out the activities of their choice. On the other hand, lighting fixtures like pulldown accent or downlights, suitable for watching TV, are more complex changes in a single switch lighting plan and in most cases a general ambient type of light is also employed to watch tv.

***Improvements and advices** that should be taken into account are:*

- *lighting installation*: minimal lighting level*(Em=50lx_See chapter 2.1 LIGHTING GUIDE 9:2013)* with strong illuminance differences between the surrounding and background area*(Background area: 1/3 surrounding area_Chapter 2.EN 12464.1:2011.Illuminance).*
- *Layered lighting*: design environments by integrating and layering light into the entire composition. Such areas benefit greatly from the interest and flexibility provided by a combination of different types of lighting. Combine at least two lighting types with separate switches, so residents can select between two lighting levels is desiderable.
- *and the task position arrangement:* it should be defined with respect to luminaires, windows and roof lights, trying to avoid Disability Glare , Discomfort Glare and Reflected Glare *(See Chapter 2. EN 12464-1:2011. Glare).* The frontal position is that which is undoubtedly easier on the eyes and the body.

Our findings need however to be confirmed by other real experiments since there is still no uniform practice to design and quantify it *(luminance thresholds, observer position for luminance values, etc)* with respect for visually impaired people needs.

Conclusion

The study was set out to explore the need of a new Accessible Design for older people with visual impairments. The reason and motivation of the issue is the problem situation in Europe which has to be addressed for the first time: the increasing number of people over age 65 and the resulting loss of specific abilities of the visual system.
As people age, older people become more dependent on their environment to compensate for increasing frailty and sensory loss. Typical residential home lighting is inadequate to meet the lighting needs of their residents; it is clear that the physical environment does not often meet the needs of the people they are built to serve. The goal for all new construction and renovation of existing homes must go beyond shelter and provide for lighting to meet both the visual and the photo-biological needs of older people.
The study sought to answer this question:
Is it possible, through careful natural and artificial lighting design, to safeguard the same accessibility both for normal and visually impaired elderly in daily home task performance(cooking, reading, take medicines, watching tv, etc.)?

The main empirical findings are described within Section III*(Full-Scale Study in a Room Laboratory)*, each experiment provides and/or confirms recommendations for visually impaired people about accessible/lighting design. The empirical conclusions answer the study research question; factors, which the designer should consider to provide quality lighting design, are synthesized in the following list*(a-l)*.

a) The ophthalmic capacity of the person ***(visual acuity, depth perception, colour perception)*** which is an essential part of the illumination design system. Environments with quality lighting are specifically designed for the users.

b) The minimal lighting level*(Illuminance values)* given by European Standard and/or Lighting Guidelines; “traditional” lighting design in residential buildings generally provides lower illuminance values which do not allow the good performance of everyday activities by older people with visual impairments.

c) The luminance adaptation*(Luminance values);* the elderly have difficulty in moving suddenly from bright to dark lighting conditions, as a consequence different rooms of an apartment should not have strong differences of luminance level.

d) The quality of daylight, an excellent light source for interior spaces; natural light should be maximized in spaces of circulation and task areas, particularly in Kitchens and Lounges. Occupants should be able to control the amount of sunlight through the use of blinds in order to reduce glare and negative reflections on the visual task plane.

Daylight systems/devices; the use of thin white curtains is preferred to the use of venetian blinds or light shelves. Curtains ensure a greater amount of light equally distributed in the room unlike venetian blinds or light shelves which, in the case of sunlight, produce disturbing light patches on the visual task plane and annoying reflections from the ceiling, which is particularly annoying for impaired people with macular degeneration.

e) The layered lighting which include natural light and multiple electrical light sources; residential rooms should have a combination of artificial lighting types(general and accent/task) which integrate the daylight and provide different lighting levels to perform different task/activities(reading, cooking, playing cards, socializing, watching TV etc..). Artificial lighting should be controlled with separate switches and also dimmed by visually impaired based on their needs avoiding glare and negative reflections.

f) The accent/task lighting: light from a specific direction increase the visibility of the task, making it the performance easier. The visual perception is given by a good luminance contrast, for this reason focused lighting is essential especially for visual impaired people.

An additional illumination(ambient/general lighting) beyond accent lighting is also needed to help reduce eye fatigue, thus cutting the contrast in the overall environment.

g) The high contrast marking; human visual perception is based on the existence of contrasts of light and shade and contrast of colour. The term contrast involves the assessment of the difference in appearance of two or more parts of the visual field seen simultaneously or successively, for example brightness contrast, colour contrast, successive contrast in dynamic lighting situations involving movement. The contrast level is essential for visually impaired people to perceive the three-dimension of objects/obstacles of the environment and influences also the readability of texts and labels. A range of 50-80% of luminance contrast permits a good perception, while a range of 80-100% ensures the best performance.

h) A good CRI, which makes objects appear and is able to show the true colour compared to daylight itself. For visually impaired subjects it is advisable that the “CRI” number is at least 91.

i) Disability, Discomfort and Reflected glare; glare annoys the task performance of visually impaired people, especially those affected by macular degeneration. Glare should be avoided through a correct arrangement of the lamps and visual task position.

The accent/task lamps position and inclination: veiling luminance directly into eyes and veiling reflections on the visual task should be avoided. The optimal task light is located between your head and the work surface.

The task position: it should be defined with respect to luminaires, windows and roof lights, trying to avoid Disability Glare , Discomfort Glare and Reflected Glare.

l) The intrinsic task properties: size, shape, position, colour and reflectance properties of detail and background. For instance, the readability of labels, books, magazine etc is dependent on the intrinsic properties of the written text.

Once minimal levels of illumination have been achieved, additional light is generally not the most effective means of increasing visibility and visual comfort. Absolute luminance levels do have a relationship to sensations of glare and distraction, but it is *the patters of light sources and the nature of their relationship to other elements in the visual field* which largely *determine the overall quality of the luminous environment*.

To implement the accessible design in homes for the elderly, all spaces should be designed and lit to satisfy specific needs of older people, not just engineered to meet code requirements – different lights, as it were, for different activities.

The study has offered an evaluative perspective on European lighting design with the purpose of improving the accessibility in older people's residential buildings. The findings were deducted through four experiments which tested older people with normal sight and with visual impairments. The experiments were conducted in the RomLab of the Faculty of Architecture at the NTNU *(Trondheim, Norway).* As a direct consequence of this methodology, the study encountered two limitations which need to be considered. The first is the limited number of older adult participants in the experimental research: study results do not provide data which represent a generalization of older people with visual impairments, but refer precisely to that group of subjects analyzed. The second limit is given by daylight which depends on local light and sky conditions: results refer to that specific geographic area.

Environments with quality lighting are specifically designed for the client, users, architectural features, site and location. *"**Lighting design**" is one of the architect's most useful and potent design tools; the design of human environment is, in effect, the design of human sensory experience; all visual design is de facto also lighting design.*

Bibliography

Books

Benya J. and Karlen M. , Lighting Design Basics , John Wiley & Sons Inc, 2004
Borasi G. and Zardini M. , Imperfect health, CCA, Montreal, 2012
Boyce P. R. , Human factors in lighting, CRC Press, 2014
Evans B.H. , Daylight in architecture, McGraw-Hill Inc. ,US, First Edition, August 1981
Harleman and Maud, Daylight Influence on Colour Design: Empirical Study on Perceived Colour, Axl Books, 2007
Lam W. M.C. , Perception and Lighting as Formgivers for Architecture , McGraw-Hill Inc.,1977
Miller Mary C. , Color for interior Architecture, Wiley, 1 Edition, 1997
Ronchi Lucia R. , Visione e Illuminazione alle soglie del 2000 , Vol.I,2000
Smith A. , Lighting for Health and Safety , Routledge, 2000
Whitehead Randall, Residential Lighting. A Practical Guide , John Wiley & Sons Inc, 2004
Winchip S. M., Fundamental of lighting, Fairchild Books, 2011
Winchip S. M., Designing a Quality Lighting Environment , Fairchild Books, 2004

Journal articles

Baracco Lucia et al, Questione di Leggibilità, Progetto lettura Agevolata , Venezia, 2005
Boyce P. in: Thomas Pocklington Trus, GOOD HOUSING DESIGN_LIGHTING, Good Practice Guide 5, 2010.
Chain C. , Public Lighting specification for visually impaired people: results from an experiment , 26th Session of the CIE Beijing, 2007;
Cook G.K. , Innovation in light reflectance value - measurement and application , 26th Session of the CIE Beijing
Geerdinck L. et al. , Comfortable lighting for seniors: the effect of illuminance and colour temperature on the visual acuity in later life , Session of Lux Europe, Istanbul, 2009
Lasagno C.M. et al, Transitional spaces from exterior to interior as functional vision barriers in ageing, Lighting Res. Technol. 2014, 46: 706-715
Lewis A. , Daylighting in older people's housing: Barriers to compliance with current UK guidance, Lighting Res. Technol. 2015, 47: 976-992;
Lewis A. - Torrington J. , Extra-care housing for people with sight loss: Lighting and design, Lighting Res . Technol. 2013, 45: 345-361;

Lewis A. , Evaluation of Older People's Living Environments (EVOLVE), University of Manchester, Housing LIN Extra Care Housing Conference, 2011 Rosemary Bakker, Household Tips for People with Low Vision, Cornell University, 2011
Logadòttir A., Comparison of user satisfaction with four different lighting concepts , Session of CIE, 2013
Pocklington Trus Thomas, GOOD HOUSING DESIGN_LIGHTING, Good Practice Guide 5, 2010
Sagawa K. , Vision of the elderly and visually impaired -for Accessible Design in Light and Lighting , 26th Session of the CIE Beijing, 2007
Tenner A. , Activity light for the elderly , 26th Session of the CIE Beijing, 2007
Torben Dahl , The architectural potential of climate in: Climate and Architecture , Routledge, November 2009
Vidovszky-Németh A. et al, Brightness, Visual comfort and Task Performance , 27th Session of the CIE Sun-City, 2008
Wei M. and Houser K.W. , Colour discrimination of seniors with and without cataract surgery under illumination from two fluorescent lamp types , Session of the CIE, 2012
Werner Wahl Hans, **Oswald Frank** and **Zimprich Daniel** , Everyday Competence in Visually Impaired Older Adults: A Case for Person-Environment Perspectives , The Cerontologist, Vol. 39, No. 2, 140-149, 1999
Wienold J., Quantification of age effects on contrast and glare perception under daylight conditions ,Session of CIE, 2012
Youko I. , Emergency lighting with considering adaptation of eyes , 26th Session of the CIE Beijing, 2007
Zhang Y. , Experiments and researches of reading lighting for the elderly , 26th Session of the CIE Beijing, 2007.
Barbara Matusiak, **Per Fosse**, Daylighting Preferences for Subjects with Visual Impairment and for Subjects with Normal vision, a Full-Scale Study in a Room Laboratory, Session of Lux Europe, Istanbul, 2009;

Standards

EN 12464-1: 2011"The Lighting of Workplaces"
UK LIGHTING GUIDE 9:2013 "Lighting for communal residential buildings"
ISO/IEC Guide 71 "Guidelines for standards developers to address the needs of older per-

sons and persons with disabilities”

Websites

http://www.cibse.org/society-of-light-and-lighting-sll/about-sll
http://www.cencenelec.eu/standards/Sectors/Accessibility/Pages/default.aspx
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1447157/
http://www.who.int/publications/en/
http://www.worqx.com/color/itten.htm
http://www.dueffetecnovision.it/test-della-sensibilita-al-contrasto/
http://www.cultorweb.com/Color/CC.html