

**THE INFLUENCE OF THE APPEARANCE OF WORK  
POSITIONS ON THE OCCURRENCE OF EYE  
SYMPTOMS IN OFFICE BUILDINGS**

by

**NOR HALIZA BTE MADROS**

This thesis is submitted in fulfilment of the requirements for the  
Degree of Doctor of Philosophy from the University of London

VOLUME 1  
(TEXT)

**BARTLETT SCHOOL OF GRADUATE STUDIES  
UNIVERSITY COLLEGE OF LONDON  
1998**

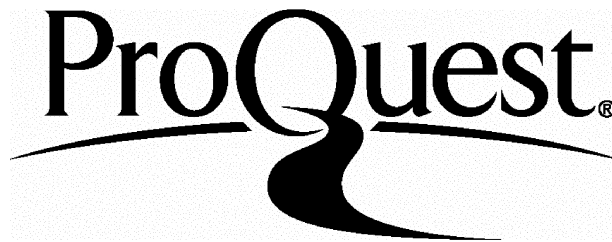
ProQuest Number: U642957

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



ProQuest U642957

Published by ProQuest LLC(2016). Copyright of the Dissertation is held by the Author.

All rights reserved.

This work is protected against unauthorized copying under Title 17, United States Code.  
Microform Edition © ProQuest LLC.

ProQuest LLC  
789 East Eisenhower Parkway  
P.O. Box 1346  
Ann Arbor, MI 48106-1346



To my daughter.....

**IZALEA.**

## ABSTRACT

This study examines the relationship of occupants perception of appearance of their work positions in commercial offices on the occurrence of eye symptoms.

The study was carried out in collaboration with the health hazards in buildings research group also known as the LINK programme. Three office buildings with uniform lighting were selected from the LINK programme for investigation. They are Pearl Assurance Building in Cardiff, ODA Building in London, and the Sapphire Building in Reading. The survey was conducted in 1995 over a period of 2 months. In each case study, employees were selected randomly and asked to complete a questionnaire over the period of a given week. A month after the questionnaires were completed, physical lighting measurements were made in the relevant offices.

The study concludes that;

- i. the occurrences of eye symptom are related to the occupants perception of the appearance from the work position. The mean analysis shows that occupants with better perception of the appearance from the work position experience fewer eye symptom occurrences.
- ii. the number of eye symptoms that an occupant experiences does not vary significantly with the occupants orientation with respect to the window,
- iii. the perception of appearance from the work position does not vary significantly with the occupants orientation with respect to the window,
- iv. occupants in work positions facing the windows do not have a significantly better perception of their work positions appearance,
- v. occupants seated facing window do not have a significantly better physical light attributes,
- vi. occupants in work positions facing the windows do not have significantly fewer symptom occurrences.
- vii. the appearance from the work position is not influenced by the physical lighting attributes.

In essence, this study concludes that any work position can be satisfactory. The requirement for a satisfactory work position is a good light pattern which projects good perception of the appearance of the field of view, resulting in fewer occurrences of eye symptoms.

## ACKNOWLEDGEMENTS

I would like to thank Professor P. O'Sullivan for giving me the opportunity to conduct this research with the LINK. Their collaboration in this research has made possible what was otherwise impossible. Much of the work load that was necessary has been simplified, thus enabling me to focus on my area of concern. Therein, I would like to thank the researchers both in the Welsh School of Architecture and Bartlett Graduate School, University College of London for all their assistance in my work. I would like to particularly thank Dr Gradjewski for familiarising me with the use of statistics in social science studies. He has been a tower of strength and an invaluable adviser and friend. I would also like to thank Dr Young for the supervision that led me to understand how research on the environment works and the options available on how the data gathered can be analysed. I would also like to thank Mr Vaughan for running through my eye health questionnaire and teaching me the process and considerations embedded therein. The three had been important interdisciplinary advisers. I would also like to thank Mr Patel who had gone out of his way, allowing for the extra visits where necessary to make my field study possible. I would like to thank Mr Jenkins for all his assistance and advice.

My special thank to Mr. Loe, Mr Mansfield, Dr Stone and the lecturers in the Light and Lighting course at the Bartlett for allowing me to attend all the MSc lighting classes which gave me the chance to familiarise myself with all the necessary lighting works, technical methods, research and development. These lecturers had also very kindly made themselves available for all the brainstorming sessions and discussions throughout the study which enable me to formulate my research.

I would also like to take this opportunity to thank Dr Weale of Kings College, London and University College Hospital for finding time to advice me regarding ophthalmology, methods of examination and the problems associated in eye health studies.

I would like to express my appreciation to the staff of Kendal, Pearl, Reading, Glasgow, ODA and Plymouth who so kindly allowed me to conduct my study along side the LINK research group, and to all my friends at the Bartlett Graduate School for their assistance, support, encouragement and the numerous discussions.

Finally, my study here in United Kingdom would not have been possible without the financial support from the government of Malaysia. In particular, I am grateful to the Public Service Department of Malaysia and the University Technology of Malaysia for

providing not only the scholarship but also the financial support for the numerous conferences that I had to attend.

# TABLE OF CONTENT

	Page No
DEDICATION .....	i
ABSTRACT .....	ii
ACKNOWLEDGEMENTS .....	iii
TABLE OF CONTENTS .....	v

## Chapter 1

<b>INTRODUCTION</b> .....	1
---------------------------	---

## Chapter 2

### **THE EFFECT OF THE LIT ENVIRONMENT ON SICK BUILDING SYNDROME (SBS) AND THE IDENTIFICATION OF A NEW STUDY AREA**

2.0 INTRODUCTION .....	6
2.1 SICK BUILDING SYNDROME (SBS) .....	6
2.2 THE SYMPTOMS ASSOCIATED WITH SBS .....	8
2.3 THE EFFECT OF THE LIT ENVIRONMENT ON THE OCCURRENCES OF SBS SYMPTOMS .....	9
2.3.1 Availability Of Daylight .....	9
2.3.2 Glare .....	12
2.3.3 Flicker .....	13
2.3.4 Illuminance Level .....	14
2.3.5 Uniformity Of The Lit Environment .....	16
2.3.6 Summary .....	19
2.4 REASONS THAT SUGGEST THAT OCCUPANTS OCCURRENCES OF EYE SYMPTOMS RELATE TO THEIR PERCEPTION OF THE APPEARANCE FROM THE WORK POSITIONS .....	20
2.5 REVIEW OF LITERATURE ON THE RELATION BETWEEN THE APPEARANCE FROM THE WORK POSITIONS AND THE OCCURRENCES OF EYE SYMPTOMS .....	22
2.6 LOGIC STRUCTURE ON CONNECTION OF LITERATURE .....	22
2.7 THE REVIEW OF LITERATURE .....	23
2.7.1 The Relation Of Light Pattern To The Occurrences Of Eye Symptoms .....	23
2.7.2 The Relation Of Light Pattern To Occupants Perception Of The Appearance From The Work Positions .....	23
2.7.3 The Relation Of Appearance And Visual Perception To The Individual's Psychological State .....	25
2.7.4 The Relationship Of Psychological State To The Occurrences Of Eye Symptoms .....	29
2.8 THE MECHANISM OF THE DEVELOPMENT OF SYMPTOMS AS A RESULT OF THE APPEARANCE FROM THE WORK POSITION .....	32

2.9 CONCLUSIONS .....	34
-----------------------	----

### **Chapter 3**

## **DIFFERENCE IN PERCEPTION OF APPEARANCE FOR WORK POSITIONS IN A UNIFORMLY LIT OFFICE**

3.0 INTRODUCTION .....	36
3.0.1 The Logic Structure .....	37
3.0.2 Organisation Of The Chapter .....	38
3.1 THE SEEING PROCESS AND THE SURFACE CRITICAL TO THE VISUAL PERCEPTION .....	38
3.2 FACTORS AFFECTING OCCUPANTS VISUAL PERCEPTION OF APPEARANCE FROM A WORK POSITION .....	39
3.2.1 The Effect Of Eye Adaptation On Perception Of Brightness .....	41
3.2.2 Limit Of Brightness Contrast .....	42
3.2.3 Factors Governing Brightness and Brightness Contrast .....	43
I. The Surface .....	43
II. The Light .....	44
3.3 DESCRIPTION OF THE VERTICAL WALL SURFACE (VWS) IN THE UNIFORMLY LIT OFFICE .....	45
3.3.1 The Surface Finishes .....	45
3.3.2 The Effect Of The Lighting On The VWS .....	46
I. The Effect Of The Artificial Lighting On The VWS .....	46
II. The Effect Of The Natural Light On The VWS .....	48
i. The Light Pattern On The VWS .....	48
ii. The Brightness Of The VWS .....	51
3.3.3 Summary .....	52
3.4 FACTORS AFFECTING OCCUPANT'S VIEW OF THE VWS .....	53
3.5 LIGHTING CHARACTERISTICS THAT GIVE POSITIVE VISUAL PERCEPTION OF APPEARANCE FROM A WORK POSITION .....	54
3.6 CONCLUSIONS .....	57
3.6.1 Hypotheses .....	58

### **Chapter 4**

## **THE RESEARCH METHODOLOGY**

4.0 INTRODUCTION .....	60
4.0.1 A Multidisciplinary Research Method .....	60
4.0.2 Research Opportunity In Association With The LINK Programme .....	61
4.0.3 Organisation Of The Chapter .....	62
4.1 RESEARCH MODEL .....	63
4.2 BUILDING SELECTION .....	63
4.2.1 The Building Selection In The LINK Programme .....	63
4.2.2 The Building Selection For The Ph.D Study .....	65
4.3 THE STUDY PERIOD .....	66
4.4 THE EXPERIMENTAL DESIGN .....	66
4.5 THE SAMPLING .....	67
4.5.1 Exclusion Criteria .....	67
4.5.2 Sample Size .....	67
4.6 COLLECTING THE DATA .....	68

4.6.1	Occupants Survey .....	68
	I. The Questionnaire .....	68
	II. The Survey Approach .....	71
4.6.2	Objective Measurements .....	72
	I. Variables For The Objective Measurements .....	73
	II. Instruments Used For The Measurements .....	75
	III. Time Of Measurements .....	77
	IV. Type And Frequency Of Measurements .....	78
	V. Condition For Measurements .....	78
	VI. Locations For Measurements .....	80
	VII. The Approach For The Physical Measurements .....	80
4.6.3	Eye Health Survey .....	83
	I. Formulation of The Eye Health Questionnaire .....	83
	II. Implementation of The Eye Health Questionnaire .....	84
4.7	STORING OF DATA .....	84
4.7.1	Coding .....	84
4.8	DATA RELIABILITY AND VALIDITY .....	85
4.8.1	Reliability And Validity Of The Subjective Data .....	85
4.8.2	Reliability And Validity Of The Objective Data .....	87
4.9	CHRONOLOGICAL ORDER OF THE METHODOLOGY .....	88

## **Chapter 5**

### **TESTING OF THE METHODOLOGY: The Pilot Study**

5.0	INTRODUCTION .....	89
5.1	A BRIEF DESCRIPTION OF THE BUILDING .....	89
5.1.1	Reasons For The Choice Of Building .....	90
5.2	THE DETAILED DESCRIPTION OF THE BUILDING .....	91
5.2.1	The Spatial Organisation .....	91
5.2.2	The Room Surfaces .....	92
5.2.3	The Electric Lighting Installation .....	92
5.2.4	The Window And Daylighting .....	93
5.2.5	The Light Pattern On The Surfaces .....	94
5.2.6	The Visual Environment In The Offices .....	95
5.3	COLLECTION OF THE DATA .....	96
5.3.1	Work Schedule .....	96
5.3.2	Floors Used In The Lighting Study .....	97
5.3.3	Problems And Mistakes Encountered In Obtaining The Data .....	97
5.4	THE NUMBER AND LOCATIONS OF THE OCCUPANTS SAMPLED .....	99
5.5	THE DATA .....	100
5.5.1	The Distribution Of The Occurrences Of Eye Symptoms In The Sample .....	100
5.5.2	The Measured Thermal And Pollutants Levels In The Building .....	100
5.5.3	The Occupants Assessments Of The Appearance From The Work Positions .....	101
5.5.4	The Measured Physical Light Attributes .....	101
5.6	THE LOGIC TREE FOR THE ANALYSIS .....	101
5.7	THE ANALYSIS PROCEDURE .....	102
5.7.1	Comparison Of The Mean Scores .....	103
5.7.2	Kruskal-Wallis Non-parametric Analysis .....	103
5.7.3	Significance Level .....	104
5.8	THE ANALYSIS .....	105
5.8.1	Analysis To Examine The Relationship Between The Appearance	

	From The Work Positions And The Occurrences Of Eye Symptoms .....	105
5.8.2	Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms .....	106
5.8.3	Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of The Appearance From The Work Positions .....	107
5.9	DISCUSSIONS .....	107
5.9.1	Discussions On Variables Measured .....	107
5.9.2	Instruments .....	109
5.9.3	Approach .....	110
5.9.4	Sample Size .....	110
5.9.5	Locations For The Measurements .....	111
5.10	CONCLUSIONS .....	111

## Chapter 6

### CASE STUDY 1: Welsh Development Authority (WDA), Pearl Assurance House, Cardiff

6.0	INTRODUCTION: A Brief Description Of The Building .....	113
6.0.1	Reasons For The Choice Of Building .....	113
6.1	THE DETAILED DESCRIPTION OF THE BUILDING .....	114
6.1.1	The Spatial Organisation .....	114
6.1.2	The Room Surfaces .....	114
6.1.3	The Electric Lighting Installation .....	115
6.1.4	The Window And Daylighting .....	116
6.1.5	The Light Pattern On The Surfaces .....	116
6.1.6	The Visual Environment In The Offices .....	117
6.2	COLLECTION OF THE DATA .....	119
6.2.1	Work Schedule .....	119
6.2.2	Floors Used In The Lighting Study .....	119
6.2.3	Problems And Mistakes Encountered In Obtaining The Data ..	119
6.3	THE NUMBER AND LOCATIONS OF THE OCCUPANTS SAMPLED ..	120
6.4	THE DATA .....	121
6.4.1	The Distribution Of The Occurrences Of Eye Symptoms In The Sample .....	121
6.4.2	The Measured Thermal And Pollutants Levels In The Building ..	121
6.4.3	The Occupants Assessments Of The Appearance From The Work Positions .....	121
6.4.4	The Measured Physical Light Attributes .....	122
6.5	THE LOGIC TREE FOR THE ANALYSIS .....	122
6.6	THE ANALYSIS .....	122
6.6.1	Analysis To Examine The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms .....	122
6.6.2	Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms .....	123
6.6.3	Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of The Appearance From The Work Positions .....	124
6.7	DISCUSSIONS .....	124
6.7.1	The Data .....	124



6.7.2	Discussions On The Relationship Between Thermal/Pollutants Levels And The Occurrences of Eye Symptoms .....	125
6.7.3	Discussions On The Relationship Between Uniform Lighting And The Occurrences Of Eye Symptoms .....	126
6.7.4	Discussions On The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms .....	127
6.7.5	Discussions On The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms .....	128
6.7.6	Discussions On The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of Appearance From The Work Positions .....	130
6.8	CONCLUSIONS .....	132

## Chapter 7

### CASE STUDY 2: Inland Revenue, Sapphire Plaza, Reading

7.0	INTRODUCTION: A Brief Description Of The Building .....	134
7.0.1	Reasons For The Choice Of Building .....	134
7.1	THE DETAILED DESCRIPTION OF THE BUILDING .....	134
7.1.1	The Spatial Organisation .....	134
7.1.2	The Room Surfaces .....	136
7.1.3	The Electric Lighting Installation .....	136
7.1.4	The Window And Daylighting .....	137
7.1.5	The Light Pattern On The Surfaces .....	138
7.1.6	The Visual Environment In The Offices .....	139
7.2	COLLECTION OF THE DATA .....	140
7.2.1	Work Schedule .....	140
7.2.2	Floors Used In The Lighting Study .....	140
7.2.3	Problems And Mistakes Encountered In Obtaining The Data ..	140
7.3	THE NUMBER AND LOCATIONS OF THE OCCUPANTS SAMPLED ..	141
7.4	THE DATA .....	142
7.4.1	The Distribution Of The Occurrences Of Eye Symptoms In The Sample .....	142
7.4.2	The Measured Thermal And Pollutants Levels In The Building ..	142
7.4.3	The Occupants Assessments Of The Appearance From The Work Positions .....	142
7.4.4	The Measured Physical Light Attributes .....	143
7.5	THE LOGIC TREE FOR THE ANALYSIS .....	143
7.6	THE ANALYSIS .....	143
7.6.1	Analysis To Examine The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms .....	143
7.6.2	Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms .....	144
7.6.3	Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of The Appearance From The Work Positions .....	145
7.7	DISCUSSIONS .....	145
7.7.1	The Data .....	145

7.7.2	Discussions On The Relationship Between Thermal/Pollutants Levels And The Occurrences of Eye Symptoms .....	146
7.7.3	Discussions On The Relationship Between Uniform Lighting And The Occurrences Of Eye Symptoms .....	147
7.7.4	Discussions On The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms .....	148
7.7.5	Discussions On The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms .....	149
7.7.6	Discussions On The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of Appearance From The Work Positions .....	151
7.8	CONCLUSIONS .....	153

## Chapter 8

### CASE STUDY 3: Oversea Development Agency (ODA), ODA Building, Victoria Street, London

8.0	INTRODUCTION: A Brief Description Of The Building .....	155
8.0.1	Reasons For The Choice Of Building .....	155
8.1	THE DETAILED DESCRIPTION OF THE BUILDING .....	155
8.1.1	The Spatial Organisation .....	156
8.1.2	The Room Surfaces .....	156
8.1.3	The Electric Lighting Installation .....	157
8.1.4	The Window And Daylighting .....	158
8.1.5	The Light Pattern On The Surfaces .....	158
8.1.6	The Visual Environment In the Offices .....	169
8.2	COLLECTION OF THE DATA .....	160
8.2.1	Work Schedule .....	160
8.2.2	Floors Used In The Lighting Study .....	160
8.2.3	Problems And Mistakes Encountered In Obtaining The Data .....	161
8.3	THE NUMBER AND LOCATIONS OF THE OCCUPANTS SAMPLED .....	161
8.4	THE DATA .....	162
8.4.1	The Distribution Of The Occurrences Of Eye Symptoms In The Sample .....	162
8.4.2	The Measured Thermal And Pollutants Levels In The Building .....	162
8.4.3	The Occupants Assessments Of The Appearance From The Work Positions .....	163
8.4.4	The Measured Physical Light Attributes .....	163
8.5	THE LOGIC TREE FOR THE ANALYSIS .....	163
8.6	THE ANALYSIS .....	163
8.6.1	Analysis To Examine The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms .....	163
8.6.2	Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms .....	164
8.6.3	Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of The Appearance From The Work Positions .....	165
8.7	DISCUSSIONS .....	165
8.7.1	The Data .....	165

8.7.2	Discussions On The Relationship Between Thermal/Pollutants Levels And The Occurrences of Eye Symptoms .....	166
8.7.3	Discussions On The Relationship Between Uniform Lighting And The Occurrences Of Eye Symptoms .....	168
8.7.4	Discussions On The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms .....	168
8.7.5	Discussions On The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms .....	169
8.7.6	Discussions On The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of Appearance From The Work Positions .....	171
8.8	CONCLUSIONS .....	172

## Chapter 9

### COMPARISON OF CASES STUDIED, CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

9.0	INTRODUCTION .....	174
9.1	COMPARISON OF THE THREE CASE STUDIES .....	174
9.1.1	Comparison On The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms .....	174
9.1.2	Comparison On The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms .....	175
9.1.3	Comparison On The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of Appearance From The Work Positions .....	176
9.2	GENERAL CONCLUSIONS .....	178
9.3	REVIEW OF THE STUDY .....	182
9.3.1	Review Of The Methodology .....	182
	I. Data Gathering .....	183
	II. Compatibility Of Objective And Subjective Data .....	184
9.3.2	Review Of The Analysis .....	185
9.4	RECOMMENDATIONS FOR FUTURE RESEARCH .....	186

<b>BIBLIOGRAPHY</b> .....	188
---------------------------	-----

<b>APPENDIX 1 : EFFECTS OF DAYLIGHT ON HEALTH</b> .....	205
---	-----

<b>APPENDIX 2a : The Sample Of The LINK Questionnaire</b> .....	212
---	-----

<b>2b : The Sample Of The Eye Health Questionnaire</b> .....	220
--	-----

<b>APPENDIX 3 : Factors Affecting Eye Health</b> .....	222
--	-----

<b>APPENDIX 4 : Testing Of The Semi-Cylindrical Cell</b> .....	227
--	-----

<b>APPENDIX 5 : Explanation For Figures In Volume 2</b> .....	233
---	-----

Figure 6.4.1a, 7.4.1a and 8.4.1a

Figure 6.4.1b, 7.4.1b and 8.4.1b

## Chapter 1

# INTRODUCTION

This study aims to investigate the relationship between the appearance of the built environment from a work position as perceived by the occupants, and the occurrence of eye symptoms. Appearance by itself is a vast subject of study, however, this research focused only on appearance caused by lighting conditions or the lit environment. Aspect of appearance affected by the lit environment used in the study are pleasant, likeable, peaceful, beautiful, interesting, sociable, friendly, relaxing, satisfying, inviting, uniformity, emotionally warm, unusual, homelike, spacious, private, airy, functional, light, cheerful, stimulating, visually warm, non-glaring, colourful, clean, uncluttered and natural. Henceforth, any of these aspects of appearance mentioned here will be in the context of lighting and its effect on appearance. Eye symptoms on the other hand are condition of the eye such as dry eyes, watering eyes, itching eyes, headache and problem with contact lenses.

At present the only aspect of appearance of the lit environment causing eye symptoms that has received some attention is the uniformity (Raw, 1992). Uniformity of appearance is typically caused by the use of fluorescent lights with uniform brightness (luminosity).

Raw has shown that uniformity is significantly correlated to the occurrence of eye symptoms. The association of uniformity to the occurrence of eye symptoms implicates that other aspects of appearance may be just as significant. This is because uniformity is only one aspect of appearance and as pointed out earlier appearance has many other aspects. At present, the relationship of the other aspect of appearance to that of the eye symptom occurrences have not been looked into. This study, therefore, examines whether other aspects of appearance have any significant correlation to the occurrence of eye symptoms.

This study was conducted in the context of office buildings in the UK. It is a part of a bigger research programme, the LINK project (The LINK project is sponsored by the Development, Trade and Industry (DTI) to study the Heat, Ventilation and Air

Conditioning System (HVAC) in office buildings) which is concerned generally with Sick Building Syndrome (SBS) in office building<sup>1</sup>.

Lighting is an important aspect of an architectural design. Lighting can be viewed from the aspect of economics and health. From an economic point of view, studies have shown that staff costs are by far the largest expenditure as compared to the operational (which includes lighting cost) and capital cost (Loe, 1993; Helm, 1980). Lighting, however, has a significant influence upon the staff. For a typical office building, lighting is often designed to minimise energy use. Due to this, lighting designs are often compromised. This would effect staff health and morale which in turn translate into medical cost. Therefore, good architectural practice should consider staff performance as a result of poor lighting.

From the health point of view, the negative perception of appearance of the lit environment can be considered as a health hazard. State of health implies more than freedom from disease and good health. It also implies the ability to attain the highest state of mental and bodily vigour and social well being of which any given individual is capable (as defined by WHO given in chapter 2). Thus to describe negative visual perception as a health hazard is valid. This is because negative visual perception might give rise to visual monotony which could lead to a reduced quality of life, boredom and lack of attention, which in themselves are symptoms of the "sick building syndrome." If visual perception has a major influence on the mental state and possibly health which relates to the occurrence of SBS, then this should not be left to chance. Although visual perception may not be a major cause of SBS, it could be a contributory factor. At present, there is a lack of awareness of this psychological effect of negative perception of appearance (of the lit environment) among designers. This can be observed from the use of uniform lighting strategy in offices although studies have shown (Loe, 1995) that office occupants express dislike of uniform lighting or more specifically the use of fluorescent light, yet designers keep resorting to this mode of lighting. If designers continue in the same direction they are likely to compound their errors. Consequently, there exists a clear need for research to establish the facts.

Lighting studies have mostly been carried out either by service engineers in the lighting discipline, psychologists or pathologists (those who study disease and illness). Research conducted by building scientists predominantly focused on the efficiency of installation and how lighting affects performance (Sundstorm, 1986; Boyce, 1981).

---

<sup>1</sup> By definition SBS occurs in buildings where occupants have little control on the environment. Office buildings are identified as one of such buildings.

This research was mostly performed under laboratory controlled conditions<sup>2</sup>. Researchers in the past dealing with lighting, often concentrated primarily on performance responses and speed of work. This type of research tended to dominate the literature (Boyce, 1981; Lynes, 1978, Pritchard, 1982). Thus, there is an enormous amount of research into lighting equipment but only a cursory or inadequate examination of the aesthetic. Even now, little research is being carried out into the quality of lighting for performance with even less investigating the effect on human health and well being (Sundstorm, 1986). Recently the lighting discipline has shown interest in the effect of the lighting quality (Hawkes et al, 1979). But the underlying factors influencing this interest are still performance and economics (Davis, 1987; Shepherd et al 1992). The concern of the researcher has usually been to establish how some variation in lighting appears to people, human preference to the lighting installation type or to validate some measure of light (this has mostly been attempted under laboratory conditions).

The study of lighting quality is primarily the study of light pattern. However, people do not see light but brightness as a function of surface reflectance. As a result the study of light quality in relation to people is the study of brightness pattern. Lighting quality in essence determines the perception of appearance of the space by the person. Space here refers to the "work position" or the location the person is occupying in relation to the whole building. This takes into consideration the location of the person on plan, on particular floor and orientation that position is facing (north, south, east or west).

The study of environmental brightness pattern is at present at an early stage of development (Hopkinson, 1963). All these studies have used correlation methods, basically relating some subjective judgement of lighting to a subjective physical descriptor of the lighting. They do not attempt to relate this lighting quality to health nor human well being. Meanwhile in the area of SBS, only a small area on the perception of the lit environment has been looked into. Here, the study identifies uniformity as a significant factor contributing to the occurrence of eye symptoms. This notion has only been conceived at a very simple level. These studies do not carry out physical measures to identify the physical attributes of the environment giving rise to this perception.

---

<sup>2</sup> Boyce (1981) cited a number of works to this effect. some of them are as follow. Stanzel and Sommers, and Benett et al had shown how illuminance affects task, Beutell showed how illumination varies with task, Weston carried Beutell's work further by using a Landolt ring chart and investigated how size and contrast effect task performance, Smith and Rae investigated how illuminance vary with age, Lyon et al showed the effect of fluorescent and incandescent light on a task.

Pathologists on the other hand are interested in the effect of light on health but have not looked at the quality of environment and visual perception created by light and how this in turn affects health or well being (refer to appendix 1). Meanwhile, the psychologists conducted studies on light quality (lighting affect on human thought and emotion) however are not interested in its health effects<sup>3</sup>.

Information gathered by engineers focused on product and process data bases are summarised in the form that can readily be used by designers. However it lacks association with fundamental psychological information. Meanwhile information gathered from research work by pathologists and psychologists were not summarised in the form that can readily be used by designers. These findings would require in-depth discussion to draw out their relevance. This demonstrates a gap in the feedback. For building design, to be successful, both ingredients are needed. Not until both are studied together will this research be of use to designers in improving their designs. It is the intention of this research to study both aspects together.

The literature review demonstrates that there have not been any specific studies carried out regarding the relationship between appearance from the work position and the occurrence of eye symptoms. No such study has been conducted, investigating health hazards in buildings using real situations.

As a result of research presented in this thesis designers may be able to recognise which aspects of appearance from the work position are critical. The research would also tell them how to manipulate the light attributes physically in order to promote these aspects.

This thesis is organised in 8 chapters. **Chapter 2** reviews the literature on the lit environment in the field of SBS, and specifically what is known about the effect of the lit environment on the occurrence of eye symptoms. In particular the aspects of appearance which may contribute to the occurrence of eye symptoms are reviewed.

**Chapter 3** discusses how occupants perception from work positions vary in a uniformly lit office which is the norm in speculative buildings which account for 95% of offices (Workplace Comfort Forum, 1995). This chapter starts with a review of the process of seeing, the surface that is critical to perception and the factors that affect perception. Next it describes this critical surface as seen in the office to determine how

---

<sup>3</sup> The increasing awareness of the need to design buildings for people has been behind the increased research in this area however much is still desired of the research.

the factors that affect perception vary. Next the chapter attempts to determine the situation that gives positive perception.

**Chapter 4** describes the research methodology. The chapter deliberates how the study will be carried out. It explains the need for a multidisciplinary study and how the research fits into the LINK programme. The chapter also discusses the constraints imposed as a result of the association to the LINK programme and the field conditions.

**Chapter 5** describes the testing of the methodology on a pilot study. It focuses on Kendal South Lakeland District Council. This chapter also explains the analysis procedure. The main aim of this chapter is to determine the shortcomings of the proposed methodology and to amend them accordingly for the actual case studies that follows.

**Chapter 6, 7 and 8** describe the 3 cases studied in detail. Each chapter is divided into seven sections which covers the following;

1. describes the building and explains the visual environment.
2. explains about the data collection.
3. explains about the sample and work positions in the building involved in the study.
4. explains about the data collected. This is divided into 3 parts.
  - i. explains about the eye symptom in the samples
  - ii. explains about aspects of appearance from the work positions
  - iii. explains about the physical light attributes.
5. explains about the results of the data analysis. It is divided into 3 parts.
  - i. analysis to examine the effect of occupants perception of appearance from the work position on the occurrence of the eye symptoms.
  - ii. analysis to examine the effect of measured physical light attributes on the occurrence of the eye symptoms.
  - iii. analysis to examine the effect of measured physical light attributes on occupants perception of appearance from the work position
6. discusses the analysis of results. It is divided into 3 parts presented in the same order as in the analysis.
7. the conclusions from each case study.

**Chapter 9** compares the findings in the three cases studied to see if the findings are consistent. From here the general conclusion is derived and the recommendations for future works are stipulated.



## Chapter 2

# **THE EFFECT OF THE LIT ENVIRONMENT ON SICK BUILDING SYNDROME (SBS) AND THE IDENTIFICATION OF A NEW STUDY AREA**

## **2.0 INTRODUCTION**

This chapter reviews the work carried out to date on the subject of SBS, and in particular the occurrence of eye symptoms due to the lit environment. The review of the literature begins with an introduction to Sick Building Syndrome (SBS) and the symptoms associated with it. This is then followed by a review of SBS studies that suggest that there is a relationship between the lit environment and SBS symptoms. Next the chapter explores this relationship further by considering the appearance of the lit environment.

## **2.1 SICK BUILDING SYNDROME (SBS)**

In recent years, 'Sick Building Syndrome' (SBS) has emerged as a significant problem in the built environment. A sick building is defined as a building in which complaints of ill health are more common than might reasonably be expected (Sykes, 1988). In another definition, a building is defined as sick when the occupants are exposed to health hazards due to poor design, poor management and maintenance, and use of hazardous materials (Tong and Tyler, 1991).

SBS is recognised as a disease by the United Nation (UN), the World Health Organisation (WHO), Health and Safety Executives (HSE) and the National Institute for Occupational Safety and Health (NIOSH - the American equivalent of the British HSE). However, SBS is not a form of infection (Wilson and Hedge, 1987). SBS causes acute discomfort which affects more than 20% of the total normal population, temporarily but consistently while in the building (Stolwijk, 1984). In SBS the occupants usually experience relief from symptoms immediately after leaving the building (Wood et al, 1987; Stolwijk, 1984).

Cronolly (1993) cited Burges (1992) as saying, while SBS affects an individual's state of health<sup>4</sup>, this effect is not serious. Although the individuals that suffer may not bother to seek medical advice, their work effectiveness is reduced (Casey, 1990). In the HSE report, SBS is said to adversely affect business productivity through high staff turnover, absenteeism and extended breaks. It also accounts for large increases in absenteeism. In a study conducted in 1994 it was shown that in sick buildings the absenteeism is up by 30% and productivity down by 40% (Pineger, 1994).

SBS is most often, but not exclusively, described only for office buildings (Raw et al, 1991). It was first reported 30 years ago when designers started to employ deep plans, restricted natural daylight, used more artificial light, sealed buildings, and restricted natural ventilation. In the 1980's the SBS phenomenon was compounded by the huge rise in the use of office equipment for example photocopiers that generate ozone, data processing computers that not only generate heat but also give rise to visual problems, and the increased use of synthetic materials in office furniture.

SBS is experienced predominantly by people working in air conditioned or hermetically sealed buildings that are free of known acute malfunction in the building services or diseases such as legionnaire's disease, humidifier fever, acute toxicosis or allergic reactions (WHO, 1987). It is limited to an environment where the individual has little control over their environment. Although buildings with natural ventilation also experience this, it is only at low levels.

The WHO estimates that 10-30% of new and renovated buildings are affected by SBS and have problems which may cause complaints and impair office workers performance. Currently SBS affects 80% of offices to some degree (Pineger, 1994). The Swedish Institute of Building estimated 30% of buildings risk becoming sick

---

<sup>4</sup> There is no consensus regarding the definition of health. WHO's definition, 'state of health' implies more than freedom from disease and good health. It may be defined as the attainment of the highest state of mental and bodily vigour and social well being of which any given individual is capable. Medical researchers like Herzlich (1972) and Hunt and MacLeaod (1987) define health as not only being physically fit and having the ability to discharge everyday routine, but also having reserve energy to feel good and enjoy life. The Oxford English dictionary defined health as the perfect condition of spiritual, moral and mental aspect of a person (Simpson and Weiner, 1989). The Black's medical dictionary also agreed with the concept that health is more than freedom from disease. The dictionary defined good health as the ability to achieve and maintain the highest state of mental and body strength (Havard, 1990). There exists a difference in perception of health between individual and cultural group (Helman, 1990). Health is considered as the ability of a person to function in a manner acceptable to himself as well as the group to which the person belongs (Rene Dubos, 1979).

In describing ill health, illness, sickness and disease have different meaning (Hunt, 1988: Allsop, 1984). Illness is the perception or experience of an individual that he is not healthy. This is further elaborated by Helman (1990). Sickness involves social behaviour that could be seen by others. A person whom is ill may be absent from work or even seek medical treatment. However more people experience ill-health than that observed or even confirmed to be unhealthy. Many more people are exposed to health hazards than those that seek medical treatment.

buildings, while 3-5% are sick (Pettersson, Swedish Newsletter, 1991). In buildings that are sick, 80% of staff may be affected.

## **2.2 THE SYMPTOMS ASSOCIATED WITH SBS**

SBS is a phenomena conceived by a group of researchers which involves a consistent pattern of several medical symptoms occurring together. The symptoms are the evidence of the worker suffering from building sickness and are also known as complaints. According to Pineger (1994), the principle symptoms of the SBS are:

- nervo toxin symptoms (mental fatigue, headache and nausea)
- sensoric irritation (eyes, nose, throat, itching and stinging)
- skin irritation (reddening, itching and dryness)
- hyper reaction (running nose, watering eyes, respiratory problems, odour and taste complaints)

This list of symptoms are also identified in Walker (1991) Melhuish (1978), Harvard (1990), Miller (1979), Wilson and Hedge (1987), Jablonski (1987) and Stolwijk (1984). Within each group there are a group of symptoms identified. The SBS concept states that if an individual has more than 4 symptoms of any combination, then SBS exists. The more symptoms reported the more ill the individual is. In the Building Use Studies (BUS) study, SBS is determined using the personal symptom index (PSI) (Vaughan, 1994; Wilson and Hedge, 1987). PSI is the index for individual workers, compared by aggregating ten different symptoms namely tightness of the chest, dryness of the eyes, itching eyes, runny nose, lethargy, dry throat, blocked nose, headache, flulike symptoms and difficulty to breath. Thus the index has a scale ranging between 0-10. Where occupants registered more than 10, they are listed as hypochondriacs and are eliminated from the study sample.

Research groups in Britain, however, have shown that there is no medical evidence to suggest that more symptoms are associated with the state of health of an individual. This has led to the suggestion that rather than focusing on the aggregates of the symptoms as a gauge for the state of health of an individual it is better to focus on the individual symptom itself as a check. These symptoms are of course present in the population at large, but they are distinguished by being more prevalent as a group, in some buildings in comparison with others.

## **2.3 THE EFFECT OF THE LIT ENVIRONMENT ON THE OCCURRENCES OF SBS SYMPTOMS**

Lighting condition is significantly correlated with reports of SBS (Wilson et al, 1987; Visher, 1989; Raws, 1992). If the work place is not suitably lit, visual disturbance can occur. Lit environments which fall outside the generally accepted design recommendations given by Code for Interior Lighting, CIBS (1984), are those most likely to lead to unsatisfactory conditions. Raw (1992) noted that visual privacy and satisfaction with lighting had some impact on the occurrence of symptoms. O'Sullivan (1993) stated that success or failure of a building appears to be related to the visual environment and air quality.

The main aspects of lit environment that have been recognised as significant to the occurrence of SBS symptoms are:

1. availability of daylight
2. presence of glare
3. presence of flickers
4. provision of an adequate illuminance level.
5. uniformity of lit environment

### **2.3.1 Availability Of Daylight**

Ruck (1989), Lechner (1991) and Cronolly (1993) have illustrated that a lack of daylight is hazardous to human health (refer to appendix 1). According to Stone (1993), the Medical discipline has noted that a quarter of an hour daily exposure of a person to daylight in the open air is the average requirement for good health. Therefore, when office workers are viewed in these terms, it could be said that they suffer from lack of exposure to sunlight and daylight. This is because research has shown that office workers, spend 90% of their time indoors exposed to low level illumination (Pearson, 1991; O'Sullivan, 1993). It is of common practise that they stay indoors from 9am-5pm punctuated by an hour lunch break at 1pm which probably is also spent indoors in restaurant or shopping malls. The matter is made worst by the fact that in northern nations, like Britain, nearly three quarter of the year is dark by 5pm. Thus, effectively these people do not see the sun except at their weekends and during their lunch break. Since human health is associated with daylight, this lack of exposure to daylight seems to be one of the major determinant of the cause of ill health of office occupants.

At present, researches have shown that deprivation of day light has given rise to not only skin sensitivity but also other complaints (Cronolly, 1993; Cawthorn, 1991). These sensitivities could not definitely be categorised as ill health. The sensitisations mentioned above, potentially take effect through the disruption of the circadian rhythm. The circadian cycle is potentially altered by relatively low illuminance and homogeneous lighting environments often found in office buildings (Cawthorne, 1991; Smith, 1986; Wotton, 1986). It is possible that the lighting produces a lighting regime that has a shifting effect that advances or retards the circadian cycle sufficiently. This alteration may not be large and could be incremental over time. As time goes by, the perception of the lapse of time will advance. The shift in the circadian cycle causes the timing of a number of human physiological processes to change in relation to the temporal time, such as sleep/wake cycles, body temperature, blood cortisol and hormonal processes. The de-synchronisation of circadian and temporal time disrupts the normal bio-rhythm pattern and potentially induces temporal disorientation, drowsiness, mood changes, sleep disturbance or mental fatigue. Consequently the well being of the occupant could be materially affected. Hypothetically, this de-synchronisation of circadian effect may contribute to the cause of SBS (Cawthorn, 1991). However, this has not been proven and is not within the scope of this study (this area is currently being investigated by Cawthorne in the Martin Centre, Cambridge). On the other hand, as reported by Cawthorne, Czeisler has shown that low light levels (500 lux) as found indoors once thought to be undetectable by the human circadian system has a similar effect to phototherapy when the exposure is timed. This demonstrates that an office lit environment dominated by artificial lighting does not upset the circadian rhythm, in fact it compensates for the daylight.

Leaving the circadian effect aside, provision of daylight is an aspect of lighting which has been considered as determinants of SBS (Raw, 1992). Research has shown that a lack of daylight is a factor that contributes to the occurrence of SBS symptoms. Markus (1967) noted that people seated nearer windows tend to have fewer complaints and symptoms. Raw (1992) observed that in buildings where high rates of SBS were found, the interior spaces had little daylight. Higher incidence of symptoms is also associated with the use of tinted windows. Robertson et al (1989) showed that air-conditioned buildings with smaller tinted windows where the amount of daylight was considerably reduced had a greater incidence of work-related headache<sup>5</sup>. Wilson and Hedge (1987) and Wilson et al (1987) found that the greatest number of symptoms occurs among occupants of air-conditioned, open-plan buildings that the decor was dull and glazing

---

<sup>5</sup> However this is not strong evidence as Robertson was comparing an air-conditioned building to a naturally ventilated building.

was tinted, which reduced the amount of daylight entering the room. Wilkins (1993) showed that the incidence of headache and eye strain decreases with increase in daylight level. He also showed that providing there is no glare or thermal discomfort, people prefer to work in daylight. In a Pilkington study, 69% of office occupants responded that electric lighting was not as good as daylight (Manning, 1965). This inferred that the provision of a large proportion of daylight is important to produce a subjectively satisfactory environment. The study showed that a large proportion of daylight in offices has the advantage of smoothing out any flicker effects and thus reducing eye symptoms related to flicker.

Raws (1992) noted that people in work positions with daylight were more satisfied with their lighting than those who did not have daylight. This may be because of the relatively steady nature of daylight, compared with the temporal modulations associated with the conventional fluorescent lighting or the variations in lighting produced by the changes in daylight. The changes in daylight is one of the major element of visual interest in an indoor space. Alternatively, the presence of a window together with its other associated properties such as contact with the external environment may be a crucial factor.

In a study of windowless offices, Ruys (1970) found that 87% of the occupants indicated that they would prefer to have a window in their office and that 47% of them thought that the lack of windows affected them physically and/or their work. The study of windowless buildings suggests that the significance of window provision is associated with sensory deprivation. It is well known that sensory deprivation induces a variety of undesirable symptoms (It is found in Building Byelaw that 1/3 of the wall areas should consist of windows). Coronolly (1993) noted that Mougan (1958) has shown that for the brain to be alert and active it was necessary for there to be a minimum amount of sensory input, an adequate variety and intensity of stimulation from the environment. Raw (1992) cited that this minimum sensory input was also substantiated by Schultz (1965) in his concept of 'sensoristasis'. He defined the concept of sensoristasis as "a drive of cortical arousal which impels the organism in a waking state to strive to maintain an optimal level of sensory variation". This balance may be upset by conditions of sensory restriction or sensory overload. If the sensoristasis balance is disturbed, disturbances in perception and cognition are likely. This may occur in spaces where the visual environment is highly uniform, as in some of the spaces found least satisfactory by Wilson et al (1987). The perception of adequate daylight corresponds with the reporting of a window view. Headaches tended to decrease with the height of the office above the ground and with increasing natural light. Although

natural light is usually said to be preferred, and people seated near a window tend to have fewer symptoms, the reasons for this have not been established.

### **2.3.2 Glare**

When glare occurs, the individual will suffer eye discomfort, headaches, eyestrain and watering eyes. Glare causes tiredness, dry and gritty eyes and headaches (London Hazard Centre, 1990). There is little evidence that glare increases eye symptoms (Raws, 1992). Raw cited that a cross-sectional study of 3 buildings by Wallace et al (1991) found glare to be one of the main environmental variables to be correlated with occurrence of headache and eye symptoms. Robertson and Burges (1986) considered glare in their investigations and rejected it but subsequent studies have found more positive evidence. A study by Robertson et al (1985) showed that there was a greater incidence of work-related headaches in the building where the workers expressed dissatisfaction with the lighting and more glare was perceived. Zackrisson (1983) noted that headaches and eye fatigue are directly caused by glare. Especially when the eyes is required to traverse from low levels of light to higher. This requires rapid eye adjustment thus causing eye fatigue by the continual contraction and expansion of the iris.

Glare is primarily caused by intensity of light. Glare can be experienced either by direct view of very bright sky, the sun, the electrical lighting installation or excessive contrast for example the presence of a source of light in the visual field which is much brighter than the surrounding objects or when light in the field of view illuminates the eye of the occupant more than the object itself (Weston, 1962) and veiling reflection.

Glare is rarely specified in a project brief or specification. Commonly, glare is associated with the lighting installation. However, the use of appropriate diffusers or louvered luminaires have been able to control potential glare from fluorescent lamps. Besides, the light sources are generally mounted well above the line of sight (Ruck, 1989). Thus, glare from electrical lighting should not in principle be a major problem in buildings for the majority of occupants (Stone, 1992). According to Raw (1992), glare as a result of veiling reflections (reflection of light from the surface that is directed into the individual's eyes) from paper on the work top is also unlikely in the present office environment as most of the surfaces are matt in nature. However, the increasing use of visual display units (VDUs) with less than ideal lighting solutions and reflections from the screen caused by extraneous light sources may be a contributing factor to

SBS. The other sources of glare are the external scenery and the sun as seen through the windows.

### **2.3.3 Flicker**

Flicker affects people differently. Flickering lighting in a working environment is at best a source of distraction and irritation and for some people can cause discomfort. 5-10% of building occupants are profoundly sensitive to it, which only represent a small percentage of the total population. 90% of building occupants are affected by it to some degree. Flicker can also have a profound effect on the human nervous system. At frequencies below 60Hz it can trigger epileptic seizures in those who are susceptible (Binnie et al, 1979).

Subliminal flickers from fluorescent tubes have been shown to contribute to headaches (Raws 1992). Veitch (1995) cited that Rey found in their study that flicker causes more visual fatigue. Pineger (1994) noted that where flicker does affect people, this is displayed as headache and eye strain. Flickers cause tiredness, dry and gritty eyes and headaches (London Hazard Centre, 1990). Wilkins et al (1984) proposed a link between headaches, eye strain and light modulation, based on neural inhibitory mechanisms. Wilkins et al (1989, 1993) studied the effect of fluorescent lighting on headaches and eye strain among a group of workers in an office building. Although the offices were not deep and had a reasonable amount of glazing they looked on to a narrow light-well and received relatively little daylight. The weekly incidence of headaches and eye strain reported by the occupants were compared under two illumination conditions: when the offices were lit by fluorescent tubes operated with conventional circuits (providing illumination that pulsed at 100Hz) and with electronic ballasts driving the tubes at about 32kHz and substantially reducing the 100Hz modulation. The average incidence of headache and eye strain was more than halved under the high frequency lighting. The mean incidence of headaches and eye strain changed with the change-over in lighting, showing a reduced incidence under the high frequency lighting, although the number of people who experienced both lighting conditions was small. A few subjects suffered headaches or eyestrain frequently and they did so mainly under the conventional lighting rather than the high frequency lighting. Wilkins (1989) cited that Golla and Winters (1959) and Smyth and Winters (1964) showed that people who look at flickering light have more incidences of headaches. Lindner et al (1993) also found that higher frequency fluorescent lighting decreases the incidence of eye strain and headaches.



Brundrett (1974), in a field measurement, showed that modulation below 60Hz is not likely to be found in practice. Well maintained modern lighting produces insufficient visible flickers to trouble the vast majority of people. However, even though it may appear steady, all discharge lighting operated directly from the standard 50Hz AC mains supply, including that provided by fluorescent tubes, produce some modulation in the light output at 100Hz<sup>6</sup>. This 100Hz modulation is above the critical fusion frequency for the human visual system and the light is not therefore perceived as flickering.

However, light which is pulsating, even if it is perceived as steady light, does not necessarily have the same effect as steady light. It is nevertheless registered by subcortical visual structure in humans (Wilkin, 1990). Studies of the electrical activities of the brain to simulations at 100Hz by Berman et al (1991) have shown that although the light modulation is not consciously perceived, certain areas of the brain are being stimulated. Wilkin et al (1989) cited that Eysel and Burandt (1984) have demonstrated that pulsating light from a fluorescent tube affects the firing of nerve cells in the visual pathways. These in turn are likely to influence cells in the area associated with the control of eye movements. This could potentially contribute to health effects of the eyes although there had not been any research work done to show this. Nevertheless, there is some evidence of this in a 1973 survey where 600 office workers in various parts of the UK responded to a set of questionnaires appraising sensitivity to flicker (Brundrett, 1974). 24% of those surveyed claimed to see light flickers when looking at the light source, 10% of the surveyed sample experienced after-image on looking back to their work. Sensitivity to flicker was greatest in young males, reaching a peak at the age of 20, then declining gradually. If this data is representative of current experience in the office, it highlights that a significant proportion of building occupants are conscious of light flicker (Stone, 1992).

#### **2.3.4 Illuminance Level**

Even though an engrossed office worker is visually stimulated by the task, it is long proven that the visual process is made much more difficult under bad lighting levels. In fact, it has long been known that poor lighting level contributes towards eye strain and headache. When light level is lowered below that recommended by CIBSE (which is 500lux) then there is a potential difficulty of carrying out tasks<sup>7</sup>. It creates extra stress

---

<sup>6</sup> Fluorescent lamps pulsate twice with each cycle of the alternating current (AC) electricity supply.

<sup>7</sup> Illuminance is specified in Lux at the working plane and varies depending on the task being carried out provided that the contrast is within 60-80% (Weston showed that it is not easy to obtain good

on the already overworked eye muscles. Tired eye muscles lead to a visual fatigue<sup>8</sup> which the layman calls eye strain. The eye strain can play havoc with the vision and can also cause headache and eye symptoms. Inadequate illumination causes tiredness, dry and gritty eyes and headaches (London Hazard Centre, 1990). Zackrisson (1983) noted that in most office environments, poor lighting quality and lower level of illumination causes eye strain, fatigue, headaches and seeing spot before the eyes.

In a post occupancy evaluation study of 912 work stations, Colin (1989) showed that visual health was poor in offices that were either too bright or too dim, and this was associated with lower scores on the lighting quality index developed from occupants reports of lighting satisfaction based on the amount of light needed for work and for reading. In another study, Robertson (1989) showed that workers with eye symptoms have darker work positions and the measured illuminance on the worktops were less than the 500lux recommended by CIBSE. Wilson and Hedge (1987) found the greatest number of symptoms among occupants of air-conditioned, open-plan buildings that are poorly illuminated; artificial lighting levels were low.

On the other hand, ophthalmological studies have show that there is no relation between illumination intensity and ocular health nor disability (Larson, 1964). Visual tiredness does not result from inadequate lighting intensity. Where task has high contrast, lower light level is sufficient. For the vast majority of people, a low level of illumination is adequate for visual activity such as reading high contrast print. Larson pointed out that this according to Blackwell is common in daily experience of most people. A person with healthy eyes could read for a life time by candle light with no ocular ill effect. According to Manning (1965), the Hawthorne investigation showed that people could perform remarkably well under low light levels and research has shown that unless an individual is dealing with a specific task which requires visual acuity, the variation in light level has little effect. The only form of lighting that might cause damage would be that of extreme brightness. Visual health is more likely to be affected by too much

---

performance measures on a small task with low contrast even if the illumination increases 1000 folds). Typically in an office the illumination level ranges from 100-1000lux and a standard service illuminance of 500lux is common, with tolerance limits either side of the specific level within the area considered. Individual preference comes into play but is overridden by the lighting requirement for type of task. Generally, higher illuminance is required where there is an increase difficulty in performing the task for example where prints on documents are smaller (Hopkinson & Kay,1969). Even so, there is a limit for doing so. There comes a point where it is better to magnify the task than increasing the illumination level. But when task is very large and contrast increase the illumination level becomes less significant to see clearly. Care needs to be taken in the terminology as minimum illuminance or average illuminance are apt to appear with less than clear definitions and both would depend on the aging of the light sources and the quality of the maintenance. Difficulty with lighting is that an acceptable lighting scheme in one situation is not in another depending on the task involved.

<sup>8</sup> Visual fatigue is the only factor that can directly cause any sensation of tiredness in the eye itself.

light than by too little. According to Yonemura (1978), for many common office tasks there is an optimum luminance level above which legibility decreases with further increase in luminance.

In real situations, lamps are used up to the point that they fail. Maintenance in buildings is generally so bad that there are always delays in replacing failed lamps. Lamp replacement is a slow process and staff have to wait for some time and meanwhile have to put up with no light from their immediate source and have to depend on nearby sources, with a reduced light level which is below that recommended by CIBSE. As the lamps fail at a different rate, the horizontal light level distribution pattern changes. Therefore, instead of the light being uniform at the worktop plane it varies quite drastically across the horizontal. However, individuals in their respective work positions do not notice this effect visually, but inevitably it does exist. In fact, research has shown that light level on the worktop does not correlate with symptom occurrence.

As cited by Sundstorm (1986), Langdon (1966) and Harris et al (1978) reported that office occupants always assessed lighting as adequate<sup>9</sup>. Inadequate illuminance level<sup>10</sup> is not a factor that often occurs in practise, as the light level is often pushed up to safeguard the designers. From the literature related above, the necessity of providing high illumination is questioned (Larson, 1964). Service engineers have been over zealous with providing more light. However, even service engineers reckon that more light does not mean better sight (Besides human eyes are more sensitive when there is less light).

### **2.3.5 Uniformity Of The Lit Environment**

Current lighting design focused on the provision of adequate illumination levels for the satisfactory performance of visual tasks. Yet, surveys of indoor environments have elicited complaints about such lighting conditions (Robertson et al, 1989; Schmits, 1995; Bean et al, 1992). The reason for such complaints concerning work positions

---

<sup>9</sup> The basic lighting calculations for office design use the surface reflectances of walls, ceiling and floor and the illuminance is therefore a function of the colour and finishes of the surfaces. The illuminance increases with higher reflectance. Lighting has to be designed for most office situations reasonably early in the overall process, in order to meet contractual and installation obligations. The value of the reflectances have to be agreed with the architect at this early stage, but his final decision on finishes frequently takes place much nearer the completion of the project and the reflectance may differ remarkably from those used in the lighting calculation, normally used to determine the illuminance.

<sup>10</sup> Current lighting design practise in working interiors such as offices, relies heavily on working plane illuminance but adequate illuminance will not guarantee that a space will be perceived favourably (Shepherd et al, 1992).

with CIBSE recommended lighting levels and glare control is that they do not give good seeing conditions and are uniform<sup>11</sup>. Even with adequate illumination, the lighting conditions are often judged as inadequately lit or underlit (Shepherd et al, 1989).

Hedge (1991) has since found evidence that lensed-indirect lighting is preferred to parabolic lighting and results in fewer eye symptoms. Conventional white fluorescent lighting in particular is likely to cause eye strain and headaches (Wilkins et al, 1987). Wilkins et al found that full spectrum fluorescent tubes seems less likely to cause eye symptoms. Robertson et al (1989) have shown that office occupants have a general dislike of fluorescent lighting. This dislike of fluorescent lighting was again demonstrated by Loe et al (1994). This dislike according to Stone (1992) is not due to the fluorescent lighting *per se*, but the uniform lighting environment that it sets up. Basically Stone was referring to the light pattern associated with the lighting. Weston (1962) also found that the more uniform the indoor brightness is made by artificial lighting, the more boring the environment becomes.

The quality of the artificial lighting is an aspect of lighting which has been considered as a determinant for SBS (Raws, 1992). In fact, homogeneity of the illumination in the occupant's field of view over a period of time has recently been gaining credence (Cawthorne, 1991). An homogeneous artificial lit environment is commonly reported as a significant feature in the occurrence of sick building syndrome. Wilson and Hedge (1987) has shown that where the appearance of the visual environment was assessed as highly uniform more symptoms were registered. Wilson and Hedge (1987) and Wilson et al (1987) found the greatest number of symptoms among occupants of air-conditioned open-plan buildings where the lighting was assessed as being highly uniform.

Where uniform lighting predominates, the occupant has a high level of even glare-free illumination on the work surface that is shadowless (Larson, 1964). The lighting has a blanketing effect somewhat akin to daylight under an overcast condition (Larson, 1964). Occupants can see all of the scene rather than just some; nothing is concealed by extreme brightness or darkness. The general illumination from the indirect lighting gives a soft effect. Everything appears hazy. Human perceived this almost as though objects were seen through a veil which softens their outline. Foreground, and background appears as one flat plane. There is no highlight to distinguish one object or plane from one another. The solid objects within this space lack three-dimensional

---

<sup>11</sup> The guidelines to achieve the 'quality lit environment' are the least read part of the lighting standard. This area is vague and uncalculable and are avoided by lighting engineers (Shepherds, 1989).

modelling definition (Durrant et al, 1977). According to Larson (1964) the diffused lighting is not so much quieting as disquieting because it minimises the form of objects but not their mass. By outcasting shadow, the modern lighting has lost its descriptive adequacy and evocative power. The space has lost its animated quality and becomes mechanised. Durrant et al (1977) this space is perceived as visually dull, uninteresting and depressing. Larson (1964) said that spaces that has high intensity and bright surroundings but is uninteresting offer no visual relief.

In a discussion with Loe the author established that the uniform environment emulates the lighting condition of overcast days. Weston (1962) noted that overcast days could have high enough illumination for acute vision, but have a depressing effect because the normally helpful shadows are much degraded. This is supported by Larson (1964). As a result of the shadow degradation the environment suffers an unsatisfactory modelling in terms of light and shadow, consequently it lacks visual depth. It throws an indistinct visual haze over the interior. There is no visual variety and all spaces look alike. Here it demonstrates that the elimination of shadows and dark area is a misconstrued concept, as it is not the darkness that makes a space depressing but rather the quality of light or lack of quality<sup>12</sup> (Larson, 1964). Depression is related more to a high degree of diffusion rather than its low light intensity (uniform lighting can exist under high or low light intensity).

Marr (1982) stated that uniform diffused lighting not only defies the way the visual system functions<sup>13</sup> but it also discourages ocular movement thus inducing ocular stress causing eye symptoms occurrences. The sameness in the surrounding is fatiguing to work in as it does not offer the eye a degree of diversion. Prolonged exposure to such an environment may have a debilitating effect.

Uniform lighting offers no contrast. A lack of contrast or unsuitable spot lighting can also cause tiredness, dry and gritty eyes and headaches (London Hazard Centre, 1990). Essentially the significance of a uniform environment is also associated with sensory deprivation as had been discussed under availability of daylight and window.

It is necessary to point out here that the initial provision of uniform lighting was based on the fact that harsh contrasting brightness levels leads to eye strain (Schmits, 1995).

---

<sup>12</sup> A single candle in an otherwise darkened space can be reassuring. A spattering of stars in a blue-black sky can be exhilarating.

<sup>13</sup> The visual system functions by responding to the detection of gradient in light intensity. Similarly this gradient in light intensity (variety of light from bright to dark, contrast and rest ) is important for the ocular well being (Larson, 1964).

Having to continually adjust to the different light levels means extra stress to the eye which could irritate the eye and lead to fatigue.

### **2.3.6 Summary**

From the review of the literature three factors are highlighted:

1. The review of literature on SBS studies as well as the effect of light on human health and well being suggests that there is a relationship between lit environment and occurrence of SBS symptoms. The literature has focused on four factors concerning the lit environment that are associated with occurrence of SBS symptoms namely inadequate daylight, glare, flickers, inadequate illuminance level and a uniform environment.
2. The review has highlighted that the lit environment significantly correlates with the occurrence of eye symptoms. When the eye symptoms are explored it is in effect a family of eye symptoms which consists of 5 different problems: dry eyes, itchy eyes, watering eyes, headache and a problem with contact lenses.
3. Spaces which conform to recommendations can still give rise to complaints about lighting. According to Raw (1992) these occur as a result of the lack of a complete understanding of the effects of the various aspects of the luminous environment on occupants comfort. Particular areas of concern are lighting quality. Much research has taken place over the years to try develop an index of lighting quality but the only quality index used concerns the avoidance of discomfort glare. Other aspects of quality are still not generally considered as part of most lighting designs although they have been shown to have strong influence on occupants' ratings of satisfaction with the lighting in a space.

This thesis intends to concentrate on the lack of research into the appearance of work positions and by considering other factors that may have been overlooked in previous studies.

## **2.4 REASONS THAT SUGGEST THAT OCCUPANTS OCCURRENCES OF EYE SYMPTOMS RELATE TO THEIR PERCEPTION OF THE APPEARANCE FROM THE WORK POSITIONS**

There are 4 main reasons that suggest appearance of work position as a factor that contributes to occurrences of eye symptoms.

The first reason is embedded in the following consideration. The review on the SBS studies has established that uniform environment is a contributory cause to the occurrence of SBS symptoms. The mention of uniformity in section 2.3.5 indicates the appearance of work position as the larger study area. Why is appearance considered the larger study area? This stems from what Stone discussed in section 2.3.5. Stone stated that the dislike of uniformity is attributed to the lighting pattern that it sets (lighting pattern refers to the highlight and shades, their size and shapes, and their juxtaposition). It has long been established in the lighting discipline that changes in light pattern in a space cause changes in an occupant's perception of the appearance of that space. Depending on the distribution of light pattern, the lit environment could produce a carnival like atmosphere or could produce an austere atmosphere for meditation. Lighting can alternatively produce a cold, impersonal public place or reinforce an impression of warmth, intimate, solace where a greater sense of privacy is felt. From here, it is obvious, that light pattern governs a host of perceptions regarding the appearance of a space. If light pattern governs the perception of uniformity and also the other different perceptions of appearance it is easy to conceive that uniformity is a subset of the larger group which is appearance. So, if uniformity is associated with occurrence of SBS symptoms it is not hard to perceive that other aspects of appearance could also be associated with it.

The second factor considers the availability of natural light. This argument stems from the statement that daylight makes people feel better, however the reasons for this have not been established. So far, medical research has identified that the only obvious benefit of daylight is its assistance in the production of vitamin D3 (Ruck, 1989; Holick et al 1982). But the wavelength that is essential for this does not pass through glass (Stone, 1993; Ruck, 1989; Wotton, 1986). Considering that most windows in modern offices are fixed, this benefit has been filtered out. Therefore, office occupants, far from or near to the windows are deprived of this particular wavelength of natural light alike. Yet, why do occupants sitting next to the windows have fewer occurrences of eye symptoms? In general, the window occupants have three advantages over those that sit further away from the window, namely the intensity of the natural light, the lighting

quality and the variability due to temporal modulation (as a result of the variations in lighting due to the changes in external daylight). However, intensity of natural light could be eliminated on the ground that high intensity of the natural light could be blinding. Besides, occupants could be satisfied with low light level as low as 350lux, this is especially so where computers are used (Pineger, 1994). Other factors that point out this effect have also been discussed under the effect of illumination on occurrence of SBS symptoms (refer back to section 2.3.4). This therefore suggests that the quality of the lit environment (how it appears to the occupants) and its variability are the ingredients that promote fewer symptom occurrences among the occupants. The closest evidence to support this was that conducted by the Pilkington research unit (Manning, 1965). Even so, the study has only shown that the office occupants dissatisfaction relating to the office interior are related to the variations in light intensity and the quality of the visual environment in the different parts of the working areas.

The third reason that suggests that the work position appearance has an effect on eye symptom occurrence is as follows. The review of literature on the effect of daylight suggests that occupants seated near a window would have fewer symptoms. However, upon comparing occupants in positions near the windows, it was found that some had more symptoms than others. In fact some occupants seated near the windows had more symptoms than occupants that are seated further into the building. Likewise, all work positions further into building ought to have a similar number of occurrence of eye symptoms as they have similar light patterns (they are equally removed from the effect of natural light). However, in both situations there is a difference in the occurrences of symptoms. The difference in symptom occurrence potentially relates to the difference in the perception of the appearance from the work position.

The fourth reason comes from the comparison of occupants satisfaction with availability of daylight between occupants that were seated near to and far from the windows. In section 2.3.1, SBS studies have shown that occupants that have more component of daylight are more satisfied with their work positions and have fewer SBS symptoms. But, if the satisfaction of the lighting environment is a factor that influences the occurrence of symptoms, the Pilkington research unit has shown that this is not influenced by the distance to the window (Manning, 1965). In fact, it noted that large windows and the reflected light on the vertical surfaces compensated for the lack of daylight, and gave the occupants the impression that they were not so deprived.



## 2.5 REVIEW OF LITERATURE ON THE RELATION BETWEEN THE APPEARANCE FROM THE WORK POSITIONS AND THE OCCURRENCES OF EYE SYMPTOMS

At present, there is no research to substantiate the effect of aspects of appearance on eye symptom occurrence. Consequently there is no literature that directly links occurrence of eye symptoms to aspects of appearance from the work position. However, there are works that suggest that the occurrence of eye symptoms is related to other factors that themselves can be related to aspects of appearance. There are two of these factors that are prominent, namely light pattern and psychological factor.

## 2.6 LOGIC STRUCTURE ON CONNECTION OF LITERATURE

1. Light pattern link:
  - i. Occurrence of eye symptoms are associated with light pattern.
  - ii. Light patterns govern occupants perception of the appearance of a space.
  - iii. Therefore, there is bound to be a connection between appearance of the environment and the occurrence of eye symptoms.
2. Visual perception and psychology link:
  - i. Occupants that are psychologically disturbed often manifest their problem as one or other form of eye symptom.
  - ii. Appearance of the environment has an effect on the human psychological state.
  - iii. Therefore, there is bound to be a connection between the appearance of the environment and the occurrence of eye symptoms.

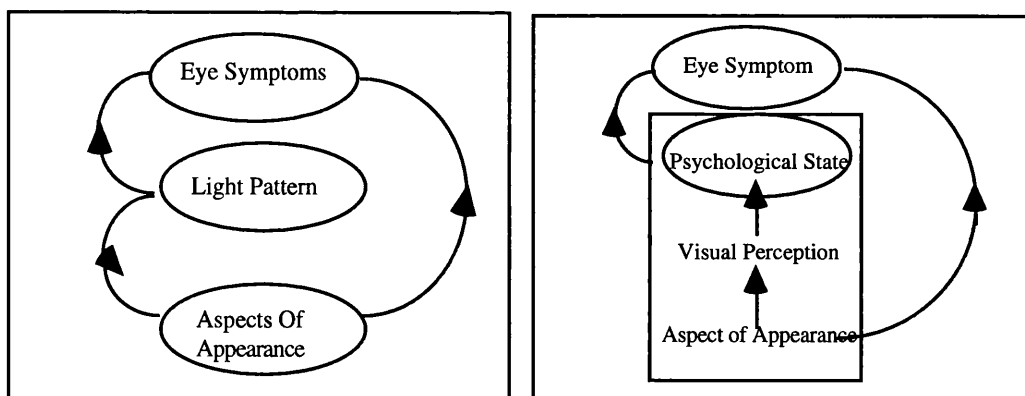


Figure 2.6: Effect of Appearance on Eye Symptoms

## **2.7 THE REVIEW OF LITERATURE**

There are 4 parts in the literature review:

- i. The relation of light pattern to the occurrence of eye symptoms.
- ii. The relation of light pattern to occupants perception of the appearance of their work position
- iii. The relation of appearance and visual perception to individual psychological state.
- iv. The relation of psychological state to the occurrence of eye symptoms.

By linking these studies together it is not difficult to perceive that the appearance of the environment could contribute to the occurrence of eye symptoms.

### **2.7.1 The Relation Of Light Pattern To The Occurrences Of Eye Symptoms**

This is mainly covered in section 2.3. The review of literature on the effect of daylight on health is related in appendix 1. Zackrisson (1983) pointed out that employees tend to feel that there is too much brightness at their work positions and the quality of the lighting is poor. These conditions produce eye fatigue which leads to headaches.

### **2.7.2 The Relation Of Light Pattern To Occupants Perception Of The Appearance From The Work Positions**

Davies (1987) stated that humans intuitively understand that light influences their impression of an environment. Human's perception of the character of a space, human emotional responses to the environment and their feeling of satisfaction and well being can be altered by a variation in lighting. Ruck (1989) stated that the quantity and quality of light the eyes received have a direct influence on how people see things. Lighting can contribute to people's impressions of an interior by giving character and atmosphere. When a room is lit differently it not only creates different perceptions but also evokes different feel. A room with wall lighting is different from those without, and human feelings regarding a room with non-uniform lighting is different from those of diffuse lighting (Davis, 1987).

Research has documented many of the effects of light on subjective impression or perception. The most familiar of these are the series of studies undertaken by Flynn (1962, 1973, 1974, 1975, 1976, 1977, 1979, 1988) indicating that lighting can influence individuals subjective impression or perception. Flynn (1979) and Flynn et al

(1988) related that as designers change the lighting modes (i.e the light patterns of light, shade and colour in the room) they change the composition and relative strength of visual signals and cues; and this in turn alters the impression of meaning. Work on these areas was conducted by Hesselgren (1969), Flynn (1972-73) Flynn et al (1973) and Sucov et al (1975). Hawkes et al (1979) and Rowland et al (1985) have conducted similar types of studies with consistent results.

Steffy (1986) pointed out that manipulation of individuals subjective impression is one of the more important functions of lighting. Grenald (1986) pointed out that the impact of lighting can be seen clearly in the design of theatres. He stated that light can be used to manipulate perception. It can be used to enhance space, form, texture and colour. By controlling light, scale can be altered and an element of emotion added. Lighting can manipulate individuals response by controlling perception. Siemen Aktiengesellschaft (1995) stated that perception and experience is made possible by light. Darkness gives rise to negative and depressive moods, whereas balanced light and shadow can evoke harmonious sensation. Schlaefle (1995) stated that light imbues architecture with characteristic forms of expression, and can accentuate, highlight and underline the character of a building. Perry et al (1987), Moon and Spencer (1944), Waldram (1958) and Campbell et al (1987) claimed that appearance and occupants impression of their space are linked to basic aspect of visual processing. Turner (1994) relates that different placing of the light changes the apparent shape and colour of the object, as well as affecting the perception of its depth. Svaboda (1985) noted that light is able to transform one space into another in an instant and to create an entirely different atmosphere. According to Watson (1990) light can unify space, reveal or conceal and control surfaces and heighten or diminish space. It can add variety, visibility, colour and comfort. Julian (1987) proposed that a room with uniformly lit spaces and dull surfaces, appears gloomy. Studies of visual perception of different lighting installations showed that a room where the upper part is not lit makes it appear gloomy; conversely, rooms where the ceiling is brightly lit claim total attention and make the room dull and inverted. A high proportion of direct light gives strong modelling while a low proportion of direct light gives low contrast with a softer and more restful character. Erhart (1994) related that good composition aids clarity, provides emphasis and adds to the feeling of pleasure. Light contributes to the manifold expression of the space. Erhart cited from IESNA Lighting handbook as saying "Light profoundly affects our feeling of well being, of awe and wonder, of mood, of comfort and motivation". The atmosphere of the space and the feeling of the viewer correlate. Change the atmosphere and the feeling will be altered. Provide an exciting atmosphere and the viewer's feelings will be heightened. Russell (1991) introduces the concept of light chords, which can stimulate emotions or evoke meaning.

According to Anderson et al (1994), lighting affects the human organism more pervasively than previously imagined. Bell (1987) proposed that the height and the shape of the shadow on the walls have a significant effect upon the expression of the interior. If the shadows are scallop shaped, the expression will be ponderous and when it meets low down the wall surface, the interior may appear depressing. Where a lecture hall is lit from a luminous ceiling, it draws the eye upwards to the position it occupies in sleep and has a resultant auto-hypnotic effect. Shepherd (1992) also argued that occupants perception of appearance of a space is linked to the light technical parameters. Here, she also reviewed works done by other researchers. Shepherd accounted that large changes in appearance occurred when the lighting distribution was changed. Flynn et al (1988) instituted that light structures enhance impression of spaciousness, reinforce impression of cheerfulness and stimulate sensation of spatial intimacy or warmth.

### **2.7.3 The Relation Of Appearance And Visual Perception To The Individual's Psychological State**

Perception in terms of function involves overlap between the various five senses (refer to figure 2.7.3). These five senses function in complex interaction. But, visual senses have been stressed to have the most important and strongest influence on perception (Goldstein, 1989; Grenald, 1986; Pearson, 1991). As visual senses give rise to visual perception this suggests that visual perception holds the key to perception on the whole and is in effect playing out the role of perception. The works of psychologists have illustrated the extensive influence of visual environment on perception (Bruce and Green, 1993; Ittelson,1960).

The significant of perception is the multi-faceted psychological effect embedded in it. Experimental psychologists - starting from Wurzburg, then Gestalt and today on many fronts have shown the complexity of perception<sup>14</sup> and relate this to many psychological processes which include the conscious and unconscious process (Bruce and Green, 1993). In fact, perception has been reasoned to hold the important key to this multi-faceted psychological process. As such, perception is a crucial process not only because it is intimately involved in the effective functioning of the individual but also because it occupies a central, unifying position within the total functioning of the individual.

---

<sup>14</sup> The visual pathways do not copy the retinal light pattern directly into a pattern of neural activity.

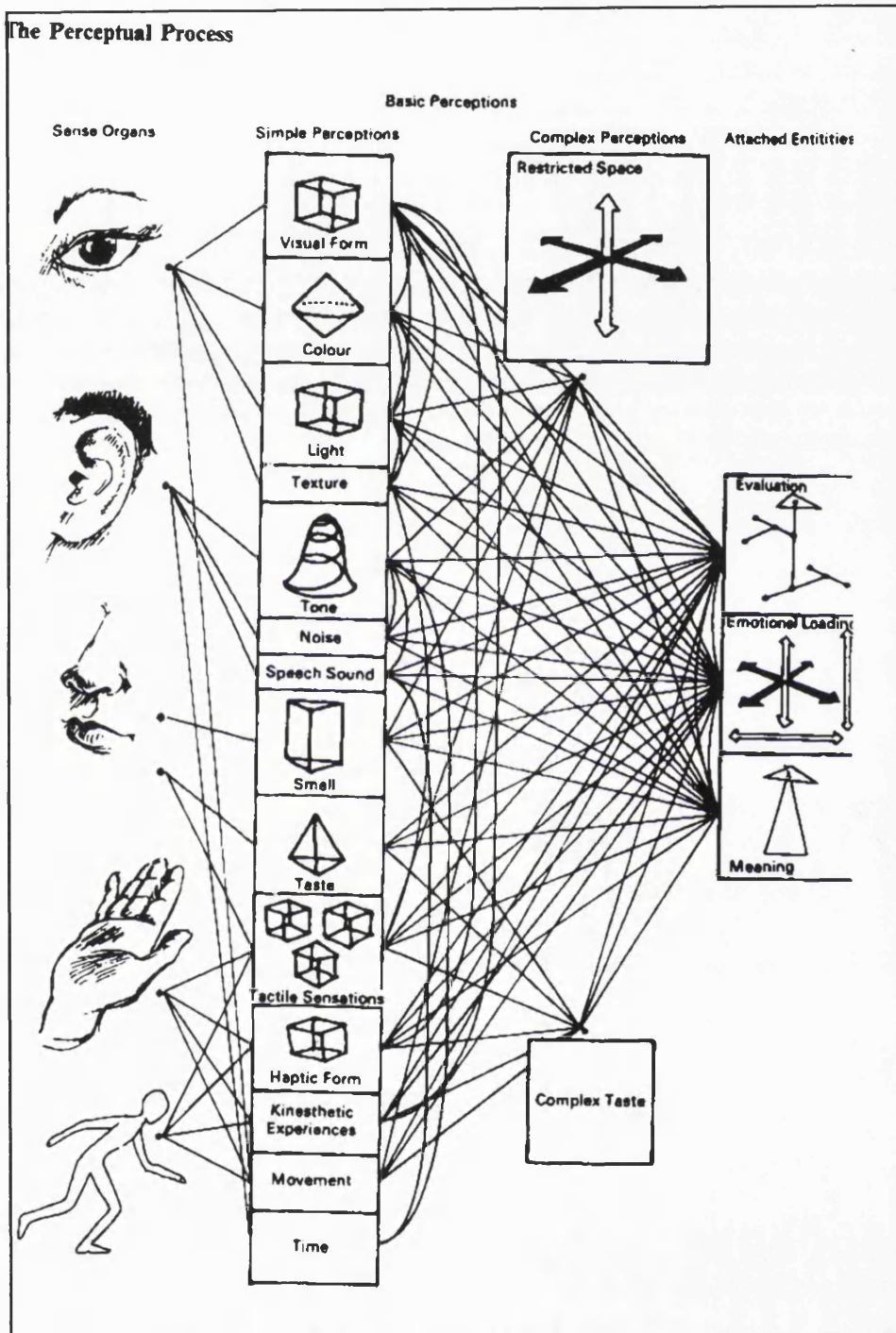


Figure 2.7.3: The Perceptual Process (source: Hesselgren, 1975)

Visual perception is always perceived in collaboration with the mind (Bruce and Green, 1993). There has been a long development of speculation, a vast body of accumulated wisdom and observation which indicate that visual perception is interwoven with human thought. This is illustrated when the perception of the world is considered in terms of the image produced in the eyes. The image produced by the eyes is flat, static, meaningless and lacks many of the qualities that a human perceives of the world, yet visual perception reveals a solid, mobile and meaningful world. The world only becomes meaningful when information related by the eyes is interpreted by the intellectual faculty in the human brain. Perceptual experience is the result of certain dynamic forces in the brain (Hopkinson & Kay, 1969, Bruce and Green, 1993). This shows that visual perception involves processes that go beyond the information present in the image.

There are two significant effects that result from this collaboration. Firstly, when perception interacts with the mind it gives the man qualitative capabilities such as abstract thought and emotions (Hesselgren, 1975). As a result of this linkage, visual perception is accompanied by sensation, experience and impression (Bruce and Green, 1993). Watson (1990) related that man has been influenced emotionally and artistically from the beginning of time - terrified by lightning and angry storms, calmed by a peaceful sky covered with white fleecy clouds, depressed by gloomy overcast days and entranced by the sheer beauty of sunrise and sunset. Mostepanenko (1984) stated that light has a spontaneous influence over the feeling and mood of the audience. These qualitative capabilities are in fact complex psychological activities. Ruck (1989) cited Hughes (1983) relating that the information the brain received from the illuminated environment is an essential element in shaping our mood, reactions and psychological well being.

The second effect comes about because of the first effect of the collaboration. The second effect is that in perceiving, the human creates his own psychological environment (Stone, 1993). This conception is also shared by Flynn et al (1988). Flynn believes that the information obtain from light patterns are used to cue the internal psychological environment. Psychologists have shown that a negative environment is accompanied by physiological and psychological disturbances. Boyce (1981) stated that the psychological effect influences people's mood and outlook. Boyce believes that the appearance of the lit environment can almost certainly affect arousal and motivation. Ben Bova (1988) added further that where the lighting gives a good visual perception it has an alleviating effect that gives an uplifting feeling. An environment that looks pleasant gives a feeling of pleasure and evokes satisfying sensations. According to Wurtman et al (1985) light is a psycho-biological

phenomenon that affects humans mood, energy and physiological functioning. Heerwagen and Heerwagen (1986), Smith (1986), O'Mahony (1985) and Wotton (1986) also argued similarly. O'Mahony remarked that light has a physical and an emotional reaction. If an individual feels good it helps the individual feel better and if the individual is "under the weather" it can boost the spirit. The effect of light on the psychological state is well presented in the study of Seasonal Affective Disorder (SAD) (Rosental et al 1984; Rosental et al 1985; Lewy et al 1982, Lewy et al 1983). This study was also carried through by Lieberman, Kripke, Rutger, Davies, Holick, Neer, Felten, Lucey, McDonagh, Sutherland and Edelson (refer to Smith, 1986). Another aspect that illustrates the psychological effect of seeing is the study of windows and windowless environments. Wotton (1986) cited Beck stating that, "the window today is viewed as a psychological connection between the institutional environment and the outside world". Cronolly (1993) cited that in a study comparing intensive care units with and without windows, Wilson (1972) found that there was an increased incidence of post-surgical depression in patients in a windowless ward.

Where the lit environment projects a positive perception people will feel better. Consequently these people would possibly have a healthier existence. This is well demonstrated in the effect of sunny days. It is also observed that most bedridden people simply lose the will to live when the weather turns dark for days on end. In a survey cited by Ben Bova (1988), in cold northern nations, where there are greater numbers of cloudy days per year, the number of suicides and alcoholism is higher as compared to nations in the sunny Mediterranean climates. According to Weston (1953), the negative perception would create a visual affront. It will dishearten the individuals of their work and thus they will not operate well. If the individuals persist to work under this condition they will be subjected to stress which induces psychological infliction and consequently lead to ill health.

From the above it could be said that a lit environment that projects a positive perception acts as a psychological resource. Its alleviating effect acts as a coping strategy to counteract antagonistic environments: where other environmental conditions are unfavourable it helps to make it more tolerable. For example, a researcher is prepared to put up with adverse working conditions such as cramp and tight space for the sake of medical advancement to contribute to the better of mankind. However, he could never last cooped up in a claustrophobic and dingy place continuously for long. This meant that his health could deteriorate steadily as a result of the work place condition. Here, better lighting quality; the impression and the character of the space created, would become a compensation and will make the space be that much more tolerable. As aptly put forward by Larson (1964), individuals psychological health and well being is

dependent to some degree on the individual perception and visual comfort. Other research also supports this statement. Cawthorne (1991) noted that the homogeneity of the illumination in an occupant's field of view over a period of time has a significant influence on the occupant's psychological well-being. Shepherd (1989) stated that uniform lighting often gives rise to the "gloom" phenomena. Weston (1962) remarked that although uniform lighting gives good visual acuity it is said to be unpleasant and psychologically the environment is dreary, lifeless and has a depressing effect.

#### **2.7.4 The Relationship Of Psychological State To The Occurrences Of Eye Symptoms**

There is no literature on SBS studies that directly link psychological effect to occurrence of eye symptoms. However, ophthalmologists have often observed that many visual problems (visual fatigue and eye strain) are psychosomatic (psychologically induced): rooted in emotion or lack of emotional health. Sarafino (1990) cited Andrasik et al (1986), Feuertein et al (1982), Bakal (1979) Gannon et al (1987), and Kohler and Haimerl (1990) and many more for the above. Larson (1964) stated that Weston said that eye strain more often occur due to a psychoneurotic disposition. In other words, emotional problems often evidence themselves in eye related symptoms. Stone (1980) cited a case-history related by Wong (1949) as relating the above condition. Wong relates the story of a man who was subjected to frontal headaches that prevented him from working for a long period of time. He saw several specialist that could not find any physiological problem. It was learned subsequently that he was insecure at his job and it appeared that his headaches were an escape which he was able to use whenever responsibilities were too great.

LaBar (1992) showed that 50% of cases of reported building sickness are manifestations of psycho-social factors. The significance of psychology on an individual's health was formalised by Freud in the 20th century. Freud noted that some patients have symptoms of physical illness without organic disorder. Freud believed that these symptoms were converted from unconscious emotional conflict (This is now an established branch of medicine called the psycho-somatic medicine).

The relationship between psycho-social factor and symptom occurrence is well studied and documented in psychomedical journals and texts. Health psychologists have clearly demonstrated that psychological events influence bodily functions. Much of this can be read in Kosky et al (1991), Mandler (1984), Shorter (1994), Goldstein (1989), Sarafino (1990), Gatchel et al (1989), and Fletcher (1992). A few of them cited



by Fletcher (1992) are: Warr's (1987) vitamin model proposed that a person's health is affected by environmental psychological factors; Kagan and Levi (1974) showed that psychological stress reaction may lead to clinical manifestation of diseases and Selye (1936, 1946, 1976 and 1983) proposed that when individuals have psychological stress this may show up as symptoms. According to Fletcher, Selye (1983) noted that psychological stressors play some role in the development of every disease. Sarafino (1990) stated that psychological factors play a role in an individual's state of health. In fact according to Sarafino and many other psychologists, these psychological factors are the reason why some people are more susceptible to illness and recover slower. In fact, Fletcher (1992) stated that psychological factors have primacy as the causal core of bodily responses. According to Fletcher, psychomedical research has revealed greater specificity of diseases' outcome for the effects of psychological factors. Studies revealed that the link between the mind and body is more direct and pervasive than was previously thought.

Symptoms or illnesses that are caused or aggravated by psychological factors are referred to as psychosomatic or psychophysiological disorders. Health problems that are thought to be psychosomatic are ulcers, high blood pressure, asthma, migraine headaches and rheumatoid arthritis. As can be seen from this list some of the symptoms overlap with SBS symptoms listed earlier on in this chapter.

The psycho-social factors that relate to the occurrences of symptoms are themselves related to stress. Sarafino (1990) cited Lipowski (1986) stating that stress itself is the biological change brought about by intense emotion. Emotion is a subjective feeling that affects and is affected by human thoughts, behaviour and physiology. Emotion relates to health and illness in many ways (Fletcher, 1992). People whose emotions are relatively positive are less disease prone and recover quickly from illness than are people whose emotions are relatively negative.

Stress is the result of human reaction to outside events and not due to the events themselves (Carter, 1995). Humans require some level of stress to keep life on the move. But when stress becomes overwhelming and lasts for a prolonged period of time it becomes bad. The common stress-inducing emotions are frustration, anger, fear, anxiety and self-doubt.

Things that can trigger stress are called stressors. Stressors need not be nasty. Over-excitement could also be a cause of stress. Stressors vary with individuals. One person's stressor could be another's relaxation. It is not what the individual does that causes stress but how the individual feels about doing it. If an individual views a task as a

challenge, this will generate a frisson of stimulating stress that helps him to carry out the task and give the relaxing glow of achievement afterwards. However, if the individual regards it as a threat it will trigger stress.

When an individual is stimulated by some stressors - nice or nasty - the body will respond with the flight-or-fight reaction. Adrenaline and glucose flow into the blood, the breathing becomes shallow and fast to give extra oxygen, the muscles contract (ready for action) and the heart rate goes up. The early stages of stress could be exhilarating as the adrenaline gives a sense of excitement while the oxygen and sugar supply gives the added energy which makes the individual alert. The stress chemical can only be broken down by a physical workout. However, in modern life, individuals are not involved in much physical work, thus the chances are that a new stressor will start the whole process up again before their bodies have a chance to return to normal. When this stress situation occurs continuously the individuals will be in a permanent excited state. The excitement turns to worry and irritability and the individuals begin to get panic attacks. The individuals begin to demand more sleep rather than less, but is unable to sleep as anxiety wakes them up at dawn. Individuals caught up in this vicious cycle, where challenges are often read as threats, begin to doubt their own ability and problems appear insurmountable. Eventually this leads to depression where the individuals give up.

The stress effect described above also has physical effects. Consistently high levels of adrenaline make the blood viscous. This increase the individual's risk of heart attack or stroke. The individual's immune system also becomes exhausted and the individuals become more susceptible to infectious diseases. The acid secreted in the stomach during stress causes ulcer and the hormonal system is also disturbed. This is evident in female students sitting for exams whereby they experience disruption in their menstrual cycle. Research has also shown that fertility is lowered when people are stressed. In extreme cases, it is said that stress could also causes some cancers.

According to Wood et al (1987) psychosocial stress (social<sup>15</sup> and occupational factors - limitations and expectations) imposed on individuals cause depression and boredom. Research has shown that people who do not like their jobs are more sensitive to the environment than somebody who is highly motivated.

The psychosocial factor drawn up by psychologists as the most likely factors to cause stress are: death of spouse, divorce, separation, going to prison, serious injury or illness,

---

<sup>15</sup> Social factors refer to etiquette imposed by society or peer pressure.

getting married, having a baby, sex problems, a large mortgage, trouble with the boss, retirement and trouble with relatives. The degree of stress is reflected by the ability to sleep properly, indigestion and changes in appetite.

In the light of the above literature, any environmental factor that acts as a stressor is therefore a cause for any ensuing disease and is likely to have ramifications for an individual's physical well-being.

## **2.8 THE MECHANISM OF THE DEVELOPMENT OF SYMPTOMS AS A RESULT OF THE APPEARANCE FROM THE WORK POSITION**

The mechanism of symptom development as the result of the effect of stress can be explained by psychoneuroimmunology (Psychoneuroimmunology is the relationship between psychology and the activities of the nervous, endocrine and immune system). Fletcher (1992) and Sarafino (1990) have discussed indepth and cited research works demonstrating that people with emotional problems have lower immune functions.

Based on the mechanism of symptom occurrence as a result of stress, theoretically (based on crude speculation which is not substantiated experimentally) there are two ways the perception of appearance from the work position can cause symptom development. It is believed that both ways take effect through the complex interrelation between the perception cortex, the pineal and the reticular formation<sup>16</sup> (Stone, 1993; Sarafino, 1990; Fletcher, 1992; Kosky et al, 1991). This model is derived from the fact that the visual system involves two pathways which are intertwined. The first path is from the eye through to the brain which gives perceptual information and link to the outside world. The other, goes through to the glandular system which regulates the hormonal and chemical secretion. Weston (1962) also argued similarly. Weston stated that the effects of visual strain are diverse since the activity of seeing is associated with the eye, the brain as well as the nervous system. Similar arguments are also put forward by Smith (1986), Lewy at al (1982 and 1983) and Rosenthal et al (1984).

In the first way, the perception of the appearance from the work position following the first pathway sets the internal environment. This internal environment is then communicated by the brain to the second pathway (the glandular system) which enables

---

<sup>16</sup> The 'reticular formation' alerts the brain in general sense.If it shuts down as in an accident it causes death or permanent coma (Stone, 1993).

the internal environment and state of mind to influence hormonal production<sup>17</sup>. These hormonal changes affect and influence the chemical reactions that go on in the body which in turn effect the nervous system (Smith, 1986; Sarafino, 1990; Fletcher, 1992). As these chemical reactions spread, they trigger a chain of other reactions. The hormone production and associated chemical reactions lower the individuals immunity in other word create "immune suppression". As a person's immunity to the invasion of viruses is now lowered, the person is more sensitive and more susceptible to any ailment. Eventually, the individual's state of health is affected. In fact for precisely this reason the lit environment has a far reaching effect. This is demonstrated in a simple headache which is a systemic symptom. A person who experiences a headache also experiences distress, depression and irritability of temper. In other word, the lit environment which gives negative visual perception such as a uniform environment can create a negative internal environment.

In the second way, the perception of the appearance from the work position affects the alertness of the brain. This is demonstrated by Hopskinson (1963) in a study comparing old and new schools, those with bright and airy interiors the feeling of freshness and alertness is more pronounced. The alertness of the brain is affected by reducing or restricting the sensory input to the brain. The sensory restriction comes about due to the lack of visual variety (pattern of light level distribution). The sensory restriction is believed to lead to perceptual monotony (Raw et al, 1992). This sensory restriction induces sleep and numbs the sub-conscious system, all the body defence systems which are co-ordinated by the brain are down, as a result the resistance and body immunity are lowered and this makes the occupant more susceptible to experiencing more symptoms.

In processing the visual information the eye and the brain effect each other. The eyes pass the information for visual perception to the brain to be processed, then the brain passed back the processed information to the eye for further action. The eyes have more sensors per mm square than any other part of the body (O'Sullivan, 1993; McMullan, 1992). Each of these nerve sensors occupy a larger part of the brain than any other nerve sensor from any other part of the body. As the eyes have the greatest area of nerve sensors and cover a greater area of the brain, that makes them more sensitive and prone to experience symptoms themselves. Negative visual perception could cause eye symptoms due to the perceptual strain involved in interpreting the

---

<sup>17</sup> It has been shown that melatonin, which is influenced by light can sometimes inhibit and sometimes stimulate the activity of the pituitary, thyroid and adrenal gland as well as the gonads. This indicates that cortisol and ACHT (adreno cortico thyrotropic hormone ) gave an interdepent relationship with melatonin (Stones, 1992; Lewy et al, 1978; Rosenthal et al, 1985; Lewy et al, 1987).

visual sensations "processed" by the brain. This is because the perceptual strain could give rise to visual fatigue. The effect of appearance on eye symptom is also explain by Stone (1980).

## 2.9 CONCLUSIONS

The review in section 2.3 and concluded in 2.3.6 suggests that the studies that were conducted have focused on the effect of daylight, glare, flickers, illumination level and uniform environment. Other aspects of lighting, especially lighting quality (the appearance of the lit environment as perceived by individuals) have not been investigated.

There is no literature at present that directly supports the hypothesis that the appearance from the work position as perceived by the occupants is related to the occurrence of SBS symptoms, more specifically the eye symptoms. However, logic suggests that eye symptoms are related to two other factors that themselves can be related to aspects of appearance<sup>18</sup>. These two factors are namely light pattern and psychological factor.

1. light pattern has been shown to affect eye symptoms and light pattern also affects an individual's perception of the appearance of a space, then the perception of the space must have some influence on the occurrence of eye symptoms.
2. individuals that are psychologically disturbed often manifest their disturbance as a form of eye symptoms and as the appearance of the environment has an effect on human psychological state, there is potentially to be a connection between appearance of the environment and the occurrence of eye symptoms. From the discussion in this chapter, the psychological effect of visual perception can easily represent a form of stress or it can aggravate a psychological stress that an individual is already experiencing. It is believed that visual perception is not a stress on its own. But occupants that are stressed are more conscious of the faults in the environment such as visual appearance. As a result an occupant with other psychological stresses that have a negative visual perception of the appearance from the work position tend to experience more occurrence of eye symptoms by compounding the psychological effect. This is also argued by Larson (1964). Even if the psychological factors of the appearance of the lit environment are

---

<sup>18</sup> It is important to point out here that eye symptoms constitute only part of the symptoms associated with SBS, so in term of SBS the study will look at only a part of the total study. Therefore, this study does not attempt to show whether SBS exists or not. This is because SBS is not judged based on occurrence of eye symptom alone.

subtle, it is fallacious to conclude that this factor is less important or less influential to an individual's state of health.

From the review of the literature it is inferred that there is a possible connection between the perception of appearance from the work position and the occurrence of SBS symptoms and this seems to be an issue that merits further investigation.

## Chapter 3

# DIFFERENCE IN PERCEPTION OF APPEARANCE FOR WORK POSITIONS IN A UNIFORMLY LIT OFFICE

### 3.0 INTRODUCTION

The affect of the appearance of an office on the occurrence of eye symptoms is best studied by changing the appearance of an office and monitoring the level of eye symptoms<sup>19</sup>.

Essentially this study compares offices with different lighting installation. The best way to conduct this study is by undertaking an intervention study whereby the lighting system is altered in a particular office. The draw back of this method is that it is costly, and requires substantial financial backing. The alternative is to compare different offices with different lighting systems. However, the effects of variables (different organisational climate and environmental determinants) other than lighting, on the occurrence of eye symptoms, cannot be isolated. Furthermore, it is difficult to obtain suitable offices with different lighting system to participate in the study. This is because 95% of offices are speculatively built and designed with uniform lighting<sup>20</sup> using

---

<sup>19</sup> Appearance of an office can vary according to the finishes and fittings or the lighting installation. As most offices have standard finishes, it is the lighting installation that makes the difference in the general appearance between these offices (This is before considering that 90% of offices are speculatively built and uses the uniform lighting and have the same lighting installation as explained in the following paragraph). Next, How to determine the situation? There are basically three alternatives: real existing rooms planned mock-ups and random mock-ups. The advantage of using existing room is that they are by definition real, and therefore any conclusions drawn from their appraisal is applicable to other similar real rooms. However against that it must be admitted that differences in lighting could well be swamped by differences in other characteristics like furnishings or orientation or view. In mock ups, wrong decisions can mean a considerable deviation from real or normal rooms. The gains is that the lighting can be held constant (for further discussion refer to Hawkes et al, 1979).

<sup>20</sup> General lighting of the whole building is at present the usual practise by electrical engineers (Phillips lighting, 1994). As a result offices have been given uniform illuminance of the required lighting level on the horizontal plane, with single control for all work positions as opposed to non-uniform and individual control lighting. Designers employ the uniform lighting concept for the following reasons:

1. Although human eyes function over a wide range of lighting conditions it could only cope with a small range at any one time (Flynn et al, 1988). By adopting uniform lighting, the eyes do not have to fight in an adaptation problem not knowing which part of the range to focus on .
2. Uniform lighting is also thought to create a restful ambience.
3. 95% of office buildings are speculatively built. When consultants are requested to design for the lighting installation, insufficient informations are available: often it is found that designers design for this with no knowledge of the occupants and how the building is to be used. Without sensible information it is impossible to design, especially now that it is common for an establishment to occupy a whole building (Previously, it is rare that a building block is occupied by one organisation. Businesses where of small organisation by nature, occupied two or three

fluorescent lights (Workplace Comfort Forum, 1995; Hawkes et al, 1979; Stone, 1992; de Boer and Fisher, 1978). This leaves the study with a third option using only uniformly lit offices. But if the office is uniformly lit how could the appearance differ? This is the problem that needs to be considered here.

This chapter discusses how individual's perception of appearance can vary in an office that has only fluorescent lighting installation. Once this is shown, the study using uniformly lit office is considered justified.

### 3.0.1 THE LOGIC STRUCTURE

In order to understand how individuals perceptions could be different in a uniformly lit office, it is necessary to review;

1. how people see, and the surfaces that are important to visual perception of appearance of a work position,
2. the factors that affect human visual perception of appearance of a work position,
3. how the factors that affect human visual perception of appearance vary on the Vertical Wall Surface (VWS) in an office employing a uniform lighting strategy.
4. After determining that perception varies, it is then necessary to determine how it varies. This requires a review on lighting characteristic that gives positive visual perception of appearance of a work position.

---

compartments at the most. When these spaces change tenants it was easy to accommodate the change in lighting installation that is needed (different establishment needs or preferred different lighting arrangements). This changes also cost less and also it has only a small scope of needs, probably additional one or two fittings with additional one or two staffs). Hence, uniform lighting is naturally the first choice for the lighting concept as it gives everyone equal visual chances (Electricity Council, n.d).

4. Increase in rate of change of tenancy. As tenants change different partitioning is required. Here, uniform lighting becomes significant as it enables partitions to be installed as required.

In theory, this uniformity is designed for the whole room (Manning, 1965). Furthermore, to reduce design complications, the lighting strategy is to make all the floors the same. As such the light fittings and the lamps are kept the same throughout the building. The office is designed as one functional space irrespective of the task involved, for example staffs higher up the management ladder whom are involve in thinking and talking do not require high illuminance level.

The uniform lighting concept stipulates a recommended level of illuminance of 500 lux (Economically, uniform lighting is not sensible as it provides light where it is not needed. It is also unsound economically, as the present practice to safe guard designers tends push up light levels, hence, provides light more than necessary). The reason for this recommended level is due to the efficiency of performing task. Uniform one level illumination engineering design is aimed only to simplify lighting design but is not sympathetic to the human eye nor correspond to the nature of the human eye.



### **3.0.2 Organisation Of The Chapter**

This chapter uses field observation obtained from simple experiments, and the reviews the literature to determine the methodology that needs to be developed for the study.

This chapter is divided into 5 parts:

1. The seeing process and the surface critical to visual perception.
2. The factors that affect human visual perception of appearance of a work position.
3. Description of the VWS in the uniformly lit office.
4. Factors affecting occupant's view of the VWS.
5. The lighting characteristic that gives positive visual perception of appearance of a work position.

(1), (2) and (5) are entirely a review of literature on lighting studies, while (3) and (4) are a combination of review of literature and field observation.

### **3.1 THE SEEING PROCESS AND THE SURFACE CRITICAL TO THE VISUAL PERCEPTION**

The most prominent surface in any line of sight are vertical surfaces. Even when seated, individuals look straight ahead and around in the direction in which they are facing in order to appraise the appearance from the work position (Manning, 1965)<sup>21</sup>. Flynn (1988) noted that the wall areas (vertical surface) in the normal visual field serve a significant function and represents a dominant influence in the visual interpretation of space. He also showed that people tend to prefer a lit environment that appeared bright. This assessment correlated with wall lighting. This was substantiated by Hawkes et al (1979). Steffy (1986) noted that lighted walls establish the visual cues necessary to define a space. According to Schmits (1995) it is the luminance level of the walls and the ceiling that determines the overall brightness in the space.

Perceptual processes are determined predominantly by vertical surfaces. The Chartered Institute of British Service Engineers (CIBSE) guide for interior lighting (1994) also pointed out that the spatial distribution of light particularly on the vertical surfaces determines the subjective response to a space and adaptation. In fact, Loe et al (1994) has shown that the 40° band in the individuals solid angle of view has a strong

---

<sup>21</sup> For a seated person the centre of vision is about below 15° below the horizontal when the head and eye are at rest. Focus and awareness in the field of view decrease with distance from the central 2° cone of vision. Awareness is still quite high in the foveal surround, which is within 30° cone around the centre of the vision (Lechner, 1990)

correlation to the visual perception of the space. Loe showed that this 40° band constitutes largely of the vertical surfaces. Having said that, from field observation it is noted when the field of view gets bigger the more the ceiling<sup>22</sup> and floor areas become significant. In general, however, the office is divided such that the floor and ceiling are not big enough to become significant. As the horizontal planes (floor and ceiling) and the lighting installation in each work position are alike, this implies that the critical difference of the work position refers to the vertical wall plane. From here it is possible to infer that it is the difference on these vertical wall surfaces (VWS)<sup>23</sup> that accounts for the difference in occupants perception of the appearance from their work positions.

This section concludes that the methodology to be developed shall focus on the vertical wall surfaces in the occupants field of view.

### **3.2 FACTORS AFFECTING OCCUPANTS VISUAL PERCEPTION OF APPEARANCE FROM A WORK POSITION**

Canter and Lee (1974) identified the stimulus that gives rise to binocular depth in the field of view as one of the factors that affect perception. This variable includes the size of objects, overlay (interposition or superposition), and aerial and linear perspective effect (whether the object is in recession in the visual field). These factors are also identified by Mansfield (1994). However, Mansfield identified three other factors. According to Mansfield, first there is a perspective effect, which consists of aerial perspective (whether the object is in recession in the visual field), and the geographical perspective (determined by the boundary of the space which gives rise to binocular depth in the field of view). Secondly, overlaid on the above is the sequence of the illuminance from the source being reflected by the surface back into the eye giving rise to a range of luminances (a photometric brightness that depends on adaptation). Thirdly, overlaid on this brightness is the colour; the apparent colour of the object and the colour rendering of the light source.

Of all the factors listed above the most significant factor that affects occupants visual perception is brightness. This is because humans see by virtue of brightness (Bruce and

---

<sup>22</sup> Where huge area of the ceiling and a large number of light sources comes into the field of view, these become potential glare sources particularly when they are near the normal line of sight.

<sup>23</sup> What constitutes the vertical wall surface? Open plan has been the traditional office set up since second world war (Grewjewski, 1992). A huge area of the office does not have walls and clusters are created lined with shelves and filing cabinets.

Green, 1993). Flynn et al (1988) similarly stated that occupants perceived light as surface brightness and colour. The reason lies in the physiological make up of the eye. Physiologically, it has been shown that the eye is not sensitive to illuminance level but sensitive to brightness difference. This is substantiated by Canter and Lee (1974) and Hopkinson (1972). Canter showed that visual stimulus acts as cues which helps to differentiate, identify and locate<sup>24</sup>. Of these three functions differentiating is highest in the order of importance. The visual cue that is important to help an individual to differentiate is brightness. The importance of brightness in perception could also be seen in the following quote from Erharth (1992):

*".....light is invisible in an empty space. Objects without light are also invisible. Objects and light interact. Each makes the other visible to the eye. The eyes see illuminated objects. More accurately it receives a luminous image, which with the help of the brain it conceive as a known or unknown object. Brightness and colour originate in light sources. It maybe altered by objects, but objects kind of create them. Brightness and colour can be sensed and perceived only in the mind. Light does not alter objects but it can alter the construct derived from the mind's image."*

However, it is not just the brightness level that is responsible for an occupant's perception. Flynn et al (1988) stated that a viewer perceives the appearance from the work position largely through brightness relationship or brightness pattern and organisation. Brightness pattern refers to the composition, organisation or distribution which are essentially the manipulation of brightness gradation and contrasts (the interaction of light and dark). This is also supported by Durrant (1977), Flynn et al (1988) and Waldram (1923-1989). Flynn noted that brightness and brightness contrast are basic in visual communication. Waldram stated that the level of luminosity and the luminous pattern are the crucial factors in human's ability to see and the principal means of achieving the 'mood' of the interior. Brightness contrast gives rise to variety, stimulation and interest. Depending on its distribution, brightness pattern communicates meaningful spatial information. Collin et al (1990) speculated that the distribution of illuminances within a space was responsible for difference in rated satisfaction and brightness for several different lighting systems studied in a post-occupancy evaluation project.

Brightness pattern structures, the sense of space, spatial limits, enclosure and depth. This structuring assists the occupant's spatial comprehension by revealing or accentuating a space, a volume or a surface which in turn assists in visual clarity and this spatial comprehension enables the space to be appreciated better. This spatial comprehension

---

<sup>24</sup> Identification is cued by light and shadow, stereopsis, shape, size and perspective. Whereas the important cues involve in locating are size, overlay, position, stereopsis, perspective and parallax.

also contribute to the character of the space (Flynn et al, 1988). When brightness pattern is properly organised and the space is imaginatively lit, it creates a pleasant, perhaps a stimulating and attractive environment. Through communicating all these values the brightness pattern sets quality (Durrant, 1977) which encourages perception (Larson, 1964).

A change in brightness pattern means a change in visual signal, consequently forms and cues will also change, hence altering the visual perception. Depending on the distribution of brightness pattern, the lit environment could produce a carnival like atmosphere or to produce an austere atmosphere for meditation. Brightness and its contrast can alternatively produce a cold, impersonal public place or reinforce an impression of warmth, intimate, solace where greater sense of privacy would be felt.

Having pointed out the importance of brightness on human perception, there are two important points to be discussed here, namely:

- The effect of eye adaptation on perception of brightness
- The limit of brightness contrast

### **3.2.1 The Effect Of Eye Adaptation On Perception Of Brightness**

Human perception of surface brightness is influenced by eye adaptation. The eye adaptation not only affects the appreciation of apparent brightness but it also changes the appraisal of the magnitude of things (Weston, 1962). The latter is maintained through altering the sensation, determining the brightness tolerance and creating the glare discomfort.

Adaptation is a relative phenomenon that works based on a reference level<sup>25</sup>. The reference level refers to the adaptation state of the eye at the time of seeing. The eye adaptation is dependent on the prevailing general level of brightness and amount of light arriving at the eye of the observer. The prevailing general level of brightness refers to the impression of lightness of the interior perceived as a whole (Waldram, 1954, 1958) or the average luminance of the visual field (Hopkinson and Kay,1972). Higher average luminance gives higher adaptation state.

---

<sup>25</sup> Everything human sees is referred to some reference level whether of light, darkness, or colour, and visual interpretation is made in terms of this adapting reference level.

The eyes have a tendency to focus on bright surfaces (Erhart, 1994; Shepherd et al, 1992; Waldram, 1954 & 1958; Larson, 1964; Hopkins, 1969). When the eyes focus on a bright surface this results in increase in eye adaptation level. Areas below the adaptation reference level will look dark, even if the actual physical quantity of light is not low or may in fact be above the recommended statutory minimum. This makes the immediate surroundings appear gloomy (Manning, 1965)<sup>26</sup>. This could be demonstrated by varying the blind/shading on the window. By pulling down the blinds the adaptation level is lowered thus the interior does not appear as gloomy as otherwise. On the other hand when the eye adaptation is adjusted to the surrounding, the eye adaptation level is lowered. Consequently, area above the adaptation reference level will look glaring, especially when these bright surfaces are on or near to the line of sight. The surface that has a different brightness to that which the eyes focus on will be perceived to be out of the adaptation state.

### 3.2.2 Limit Of Brightness Contrast

The eyes have the ability to assume the degree of sensitivity best suited to the amount of light which falls upon it (Hopkinson, 1963). Because of this, the eyes can perform under a wide range of brightness conditions, and can tolerate high contrasting brightness. However, there exists a limit to this contrast. Although the eyes can adapt to large variations in brightness, it cannot adapt to two very different brightness level simultaneously (Lechner, 1990; Durrant, 1977; Hopkins, 1969). A sharp contrast of brightness levels occurs when these brightness levels are seen together in the visual field: 0-40° vertically, and 45° horizontally (left and right) to the normal line of sight. Flynn et al (1988) states that excessive contrast can not only disrupt the ability of the eye to perceive detail but also cripple vision. Hopkins (1963) pointed out that when the brightness contrast exceeds the limit, the contrast causes strain and discomfort, and the ability to see clearly diminishes.

Excessive contrast occurs because of unfavourable adaptation when the eye adaptation is lowered. Unfavourable adaptation means that the adaptation required to see a particular surface is out of the adaptation state. Hopkins (1963) has shown that the degree of discomfort likely caused by a glaring source depends on the brightness of the environment in which it is seen. For example in a room, the sky may be seen glaring if the wall seen simultaneously with the sky is dark, but the sky will appear less glaring if that wall is brighter in colour. To avoid glare discomfort the brightness of the

---

<sup>26</sup> A gloomy appearance is due to unfavourable adaptation rather than lack of light.

surrounding needs to be increased proportionately to the source brightness. By means of the adaptation mechanism, the eye is able to see in a range of brightness of 1000:1, and partially see in a range of over 100,000,000:1 (Lechner, 1990). Flynn et al (1988) noted that the eyes have the best acuity when the brightness range is 100:1. Generally where excessive contrast exists, the smaller the area of the object that is causing the excessive contrast and the further it is out of the occupant's line of sight, the higher is the occupant's tolerance towards the contrast (Ruck, 1989).

### **3.2.3 Factors Governing Brightness And Brightness Contrast**

Leaving the effect of human visual system aside, brightness can be manipulated by the characteristic of;

1. the room surfaces, and
2. the light.

Brightness contrast is a function of the reflection factor of surfaces (colour and finishes: matt or specular), and illumination level (Flynn, 1988). This is also supported by Hopkinson and Kay (1972), Lechner (1990), and Canter (1974). Canter stated that assuming the eyes are healthy and the accommodation, convergence, stereoscopic vision of the eyes are functioning normally, differences in brightness can be achieved by manipulating surface colour and illumination level, light, and shadow. Both colour and illumination level can be used to draw attention in the same way. Bruce and Green (1993) stated that visual perception is mediated by light reflected of surfaces. Therefore the characteristic of the light and the surface influence the perception.

#### **3.2.3-I The Surface**

The way bright surfaces are placed in the field of view would effect the perception of the space. The character of the surface that governs brightness is reflectance, which in turn is governed by the surface colour and finishes (Bruce and Green, 1993). Reflectance of office furnitures is closely tied to the choice of materials. By placing different reflectance<sup>27</sup> (matt against specular) against each other, the designer can obtain brightness contrast. Similarly by locating this varying shade of contrast in the field of view will create varying brightness pattern, as such it affects the light pattern and

---

<sup>27</sup> If reflectance is kept constant, by varying the light level to 3:1 could create good accentuating effect. If reflectance has big difference, the illuminance will not be able to compensate and object appear black and white; see in contrast.

lighting quality. Reflectance also has a marked effect on the light distribution, that is the proportion of indirect and interreflected light in the room. A room with high average reflectance has a high proportion of indirect light which gives soft contrasts and gentle modelling. On the other hand, a room with dark surfaces and a high proportion of direct light has harsh, dramatic character with strong contrasts of light and shade (Hopkinson & Kay,1972).

However, as mentioned earlier, in the office environment (in line with the uniform lighting design strategy), the surfaces are normally of matt finishes to avoid reflected glare, and they are generally grey in colour.

### 3.2.3-II The Light

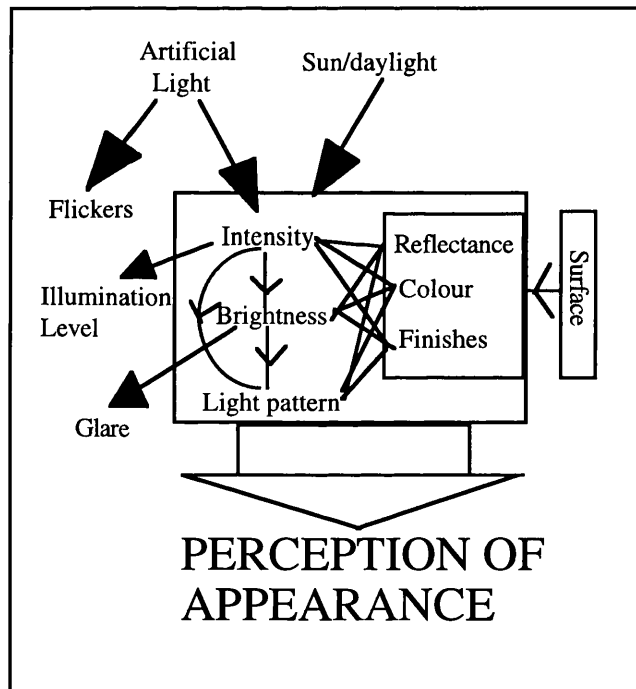


Figure 3.2.3: The chain reaction effect of light and surface on the perception of appearance

In an environment where surface factors remain constant (same colour, reflectance and finishes), the brightness and its contrast could be manipulated through the light variable<sup>28</sup>. Effect of light on brightness is influenced by its colour and intensity

<sup>28</sup> The importance of light intensity on perception is toned down where surface colour intervened (Campbell, 1994). Light intensity or illumination level enhance appearance in the sense that it may appear lighter and more colourful. Illumination level has little effect on hue (colour) but influence apparent lightness (value) and colourfulness (Chroma) directly. Colour in shadow will lose its colour attributes.

(Hopkinson and Kay, 1972; Tiller and Veitch, 1995; Bodmann, 1967; Cuttle and Boyce, 1988; Davis and Geithner, 1990; Kanaya et al, 1979). The colour spectrum of the light depends on the type of lamp used. As pointed out earlier, only offices with fluorescent lighting will be considered in this study. When light colour is eliminated, then its intensity becomes the major factor. Campbell (1994) showed that when the colour spectrum of the light is the same, brightness contrast can be achieved through difference in light intensity. This is supported by Flynn (1988). Flynn stated that light brightness and its contrast are basic in visual communication. When different light intensities are placed against each other, it will create visual composition of light and darkness (Hopkinson and Kay, 1972). The brightness composition can be varied by the shape and the position of the light pool in the field of view. In artificial lighting, the intensity is determined by the type, size, wattage, and number of light source used in the lighting installation.

This section therefore concludes that the methodology to be developed in this study should focus on the brightness and brightness pattern in the occupants field of view.

### **3.3 DESCRIPTION OF THE VERTICAL WALL SURFACE (VWS) IN THE UNIFORMLY LIT OFFICE**

From consideration of the factors that affect perception, the VWS in the offices will be described from two aspects, namely;

- i. surface finishes,
- ii. lighting.

#### **3.3.1 The Surface Finishes**

As part of the uniform lighting concept, neutral, inoffensive, dull, and often serviceable grey type colour surfaces are employed. This strategy is adopted to enhance the uniformity. Surfaces with light finishes facilitate high interreflection. In most offices the reflectivity of the wall is estimated to be within the range 43-63% (Manning, 1965)<sup>29</sup>.

As, the surface finishes of the VWS has been normalised, the difference in lighting on the vertical surface is the factor that contributes to the difference in the perception.

---

<sup>29</sup> The reflectivity of the ceiling is estimated to be within the range 64-75% and the desk tops have matt finishes, with reflectivities of 15-48%



### **3.3.2 The Effect Of The Lighting On The VWS**

The light pattern on the vertical surface depends on the light sources in the office setting. Although the offices employ uniform lighting strategy (Comfort in Workplaces, 1995; Hawkes et al; 1979; Stone, 1992; de Boer and Fisher, 1978), the light in an office setting are derived from two sources;

- i. the artificial lighting installation, and
- ii. the natural daylight from the window.

In an office, the artificial lighting is used in conjunction with daylight resulting in an integrated lighting scheme (Electricity Council, n.d). The artificial lighting is used because the lighting level that is needed for office work is very rarely achieved with daylight, and also daylight is inconsistent due to constant variation in sunlight, cloud-cover, and seasons. The Pilkington research unit observed that there is a tendency in many of the offices for the electric lights to be switched on as soon as the staff arrived in the morning, and to be left on for the rest of the day (Manning, 1965). According to the research, this pattern of usage is typical during winter and summer. This pattern of usage is also noted by the electricity council. The electricity council observed that although modern office buildings often have large windows, electric light is still used throughout the day.

In conclusion, the effect of lighting on the VWS it is divided into two parts:

- i. The effect of the artificial lighting installation on the VWS.
- ii. The effect of the natural daylight on the VWS.

#### **3.3.2-I The Effect Of The Artificial Lighting On The VWS**

Before it is possible to describe the effect of the artificial lighting on the VWS, it is necessary to relate the mode of artificial lighting that is associated with the offices that employ uniform lighting strategy. The artificial lighting installation commonly used to execute the uniform lighting employs the fluorescent lamp with RA 80. The fluorescent scheme is often done with linear luminaries, and is normally installed across the ceiling in a regular array, either surface mounted or recessed<sup>30</sup> (Weston, 1962,

---

<sup>30</sup> Prior to 1960, most lighting installation was regular arrays of surface mounted fitting, with diffuser or prismatic wrap around control in which light was distributed fairly evenly. It was found that these fittings were bright and caused visual discomfort. This was particularly due to some being merely bare lamps. This scattered light in all directions but the source itself was very bright. In 1960, a series of studies were set up to try exert a control on the the light pattern in term of visual comfort. More specifically it looked at the effect of the luminaire luminance within the field of view. As a result of this studies a series of glare system was launched. This had the effect of making installation glare free. These also had the effect of making the installation more comfortable and manufacturers started to produce luminaires that were less bright within the field of view (Manning, 1965). Therefore,

Slater, 1989; Durrant, 1977). The installation followed the guidelines set out by CIBSE, with half spacing towards the sides of the rooms.

The luminaire used in association with the fluorescent lamp is designed to give a light pattern that is predominantly downward with a wide band (Weston, 1962). As a result the office is evenly lit with the artificial lighting. Durrant (1977) noted that the diffuse lighting installation employed in the uniform lighting strategy results in a room consisting of large uninterrupted areas of nearly uniform brightness<sup>31</sup>. Therefore, in a field of view, the luminances are not far apart, and are limited to the range that the human eyes can tolerate. This is in accordance with CIBSE (1994) requirement whereby the worktop luminance ratio,  $E_{min}/E_{max}$ , does not go below 0.8.

As a result of the above design strategy, all the VWS are therefore lit with diffuse reflected light from the horizontal worktops. The VWS are not designed for any specific lighting<sup>32</sup>. In typical offices, there are no wall washers or other type of remedial lighting installed. Thus the walls have low luminance ratio, and the composition of light pattern in the field of view lacks variety (Larson, 1964). At the most, with the fluorescent system there is a cut-off-point for the light projected towards the wall due to the distance of the fluorescent lamp to the wall. This commonly occurs at 2/3 of the height of the wall from the floor. The cut-off-point is not clear. There will be a bright patch of light pattern only where the luminaire gets close enough to the wall. However, this is normally avoided at the design stage.

In conclusion, as fluorescent lamps with RA 80 are commonly used in speculative office buildings, the colour of the light becomes insignificant. As a result of the design approach and calculation, the artificial light component on the vertical surface is constant throughout the office. Thus, the artificial light component on the vertical surface could not contribute to the difference in the occupants perception. This leaves the daylight as the potential cause of the difference in light pattern on the VWS, which account for the difference in perception of appearance from the work positions.

---

suddenly, there was a change from installations that were generally bright in the horizontal plane luminance, to an interior scene that was darker and not related to the horizontal plane. By this time, designers became aware that light pattern was an important feature (Bedwell, 1972).

<sup>31</sup> The ceiling is normally not illuminated. With the downward lighting pattern from the ceiling mounted fluorescent lamps the ceiling is expected to be dark. Following on to this a harsh contrast between the luminaries and the surrounding dull ceiling is anticipated. However, the high interreflection from the room surface finishes has made the ceiling brighter and reduces the contrast between the ceiling and the luminaire.

<sup>32</sup> In areas designed for prolonged work, research and experience have indicated the need for lighting the walls to avoid uncomfortable or fatiguing working conditions produced by excessive lighting.

### **3.3.2-II The Effect Of Natural Light On The VWS**

Before discussing the effect of natural light on VWS, it is necessary to establish two facts:

- i. The source of natural light in the office is the windows.
- ii. A space is bounded by four walls (considering a small cubicle room).

When the walls are categorised according to its juxtaposition to the window, it could effectively be spilt up into three groups; the external walls where the windows are integrated, the wall parallel but opposite to the external wall, and the flanking walls (perpendicular to the external wall). From observations in offices, it is noted that the effect of natural light on the external wall is mainly due to light that is seen through the windows, while the other two walls are due to light that comes in through the windows.

So how does natural light illuminates these four walls? The first way is by considering the nature of natural light. A well-known fact regarding natural light is that its colour and intensity vary through out the day. This is well described by Kalff (1970) as in the following quote:

*" .....In the morning, the sun... is up and full of colours which is light and cool. As the sun rises higher, the light becomes more profused and warm in colour. During the second half of the day, ..... the gradual decline of the sun assuming a warmer glow and the consequent reduction of light. "*

From the above, it is initially thought that the external wall has the advantage of this variability as it is link visually to the outside via the window. However, due to the space continuum, change in the daylight will effect all the vertical wall in similar manner. This eliminates variability in day light as a cause to the difference in perception.

However, the VWS's differ on two aspects:

- i. The light pattern (juxtaposition of brightness and shades).
- ii. The brightness level.

#### **3.3.2-II(i) The Light Pattern On The VWS**

Taking an office space, the light pattern on the VWS could be conceived as follows. The difference in the light pattern on the four walls is due to the presence of the window. The light pattern on the wall varies according to the position of the wall in relation to the window. The first wall is the external wall. On the external wall, where windows are integrated, the light pattern will vary depending on the number of windows. On this wall there exists a contrast between the bright window area and the wall area

which offers more variety in light level. The contrast gives this wall a high luminance ratio. The second wall is the wall opposite to the external wall, and it has a low luminance ratio. The daylight that falls on it either directly or by interreflection is superimposed on the light caused by the artificial lighting. The two flanking walls have low luminance ratio vertically but higher horizontally. The end near the windows is always brighter than the end further away. This pattern in lighting is associated with the drop in light level attributed to daylight. The difference in light level is gradual but falls off steeply once it exceeds 6m into the building.

### Factors Governing Light Pattern On VWS

On the **external wall** where the window is integrated, the light pattern (proportion of bright to dark) on the wall varies with the ratio<sup>33</sup> of window area to that of the wall area, and the shape and arrangement of the windows: one large window or many small intermittent windows that runs the whole length of the external wall or just a small window.

The appreciation of the window dimension is a function of the distance of the occupant from the window, that is the window area projected to the occupant's eyes. An occupant seated closer to the window would see a larger window area. In fact, an occupant who sat next to and facing the window would see a huge window area in their field of view. This is a function of the solid angle subtended by the window which in turn is related to the window size relative to the distance away from the window.

The light pattern in the window itself is governed by the proportion of bright to dark in the window itself. This in turn is affected by the sky area, blind area, obstruction from adjacent buildings, and the position of the window in the building (polarity). The greater the sky area the more is the bright area. During daylight hours, where unobstructed sky is seen through this window, it presents very high luminance.

Where the window is blinded, much of the sky is screened off. This therefore introduces a darker area. As a result, the window will adopt the brightness of the wall and effectively the area of window which appears bright is reduced.

---

<sup>33</sup> Where ratio is dealt with there is the drawback of categorising in one class when the effect from which the ratio is derived from is totally different. For example a work position with a small isoarea and a small window could have the same ratio as that for a work position that has a big window and a large isoarea.

The position of the window in the building (polarity) determines whether the sun is seen through the window. For offices in northern latitudes, work positions that face a VWS with the window facing south, no matter if the occupants are near or far from the window, the sun would probably shine right into the occupants eyes. On sunny days, this effect will be experienced throughout the day. The presence of the sun in the field of view introduces a bright light source. This tends to increase the brightness ratio further. In work positions that face a VWS with the window facing east or west, the sun will be seen obliquely. But the effect is the same as that of the work position facing south. In work positions that face a VWS with the window facing north, where the occupants are seated right beside the window, the occupants have the advantage of looking onto a sunlit area, provided the work positions are on elevated levels which are sufficiently high and above the shadow cast by the building. This, like seeing the sun, increase the brightness ratio. But, should the occupants be removed from the windows, no sun lit areas will be seen and the brightness ratio is lowered. However, this factor becomes irrelevant on overcast days. As 84% of the year in Britain is overcast, the condition discussed above rarely applies.

On the **internal walls** (the opposite wall and the flanking wall), the only factor that governs the light pattern is the position of the window in the building (polarity) which determines the light coming in due to sunlight penetration. The sunlight will project sun patches on the walls<sup>34</sup>. This is applicable for work positions that face a VWS with the window facing south, east and west. When the sun is up, work positions in the east only view the sun in the morning, and do not see the sun in the evening while work positions in the west experience the opposite. Work positions in the south, however, experience the sunlight penetration as long as the sun is up. In the northern latitude, for work positions that face a VWS with the window facing north, there would be no sunlight penetration into the office space. The work positions adjacent to VWS with this orientation in the building would always get diffuse daylight. The VWS will never be subjected to sunlight and there will be no sun patches on it. However, as 84% of the year is overcast, these work positions have the same light pattern as described above for work positions that faces a VWS with the window facing north for 84% of the year.

---

<sup>34</sup> The sunlight would fall onto occupants task and possibly cause disability glare.

### 3.3.2-II(ii) The Brightness Of The VWS

The brightness of the three walls varies from one another. Assuming the external wall has a window that is not blocked by an adjacent building, it is the brightest. Next brightest would be the two flanking walls. Its brightness reduces gradually starting from the window end. The wall opposite to the external wall would be the darkest. However its brightness depends on its distance to the window walls, the nearer the brighter it is.

The above is a simplistic view of the wall brightness. In fact the wall brightness could vary in;

- actual brightness, and
- apparent brightness.

The difference in actual wall brightness refers to the difference in brightness that can be physically measured. This difference in brightness of the wall is caused by the difference in the amount of light that falls on these walls<sup>35</sup>. Meanwhile, apparent wall brightness is the result of the eye adaptation as explained earlier in section 3.2.

#### Factors Governing Actual Brightness Of The VWS

On the **external wall**, the actual brightness is affected by similar factors that govern the light pattern on it. The wall is brighter when it has a bigger window and more sky area.

On the **opposite wall** and the **flanking wall**, the actual brightness is affected by the light that falls directly on it (coming in from outside through the window) and the inter-reflected light. This component of light is called the daylight component<sup>36</sup>. The more the daylight that comes through, the higher will the brightness level (average luminance) of these walls be. Both these factors are governed by the windows on the external wall. So, the factors that govern light seen through the window on the external wall (as discussed in section 3.4.2-II(i)) would effect light coming in through to effect the light seen on the other two walls in a similar manner.

---

<sup>35</sup> Should the comparison be made on a sunny day it is possible to find that an internal wall in the south quarter of a building due to the patches of sunlight on it could have the same brightness as an external wall on the north quarter.

<sup>36</sup> Daylight component is made up of the sky component, external reflected light and internal inter-reflection.

In conjunction with the discussion in section 3.4.2-II(i), it is important to point out 2 issues here.

1. As different windows have different composition of dark to light this would mean that they have different composition of light coming through the window. The more the light area means the greater the sky area. The greater the sky area the greater the sky component and consequently the greater the daylight component that comes through.
2. Lower floors in a building become darker as much of the light gets blocked out by adjacent buildings. The effectiveness of the adjacent buildings in blocking out daylight depends on the distance and height of the adjacent buildings to the building facade of the space considered. The further away and the lower the height of the adjacent buildings the less they pose a problem .

### Factors Governing Apparent Brightness Of The VWS

Apparent brightness is a relative phenomena and is a comparative concept. Where the comparative or reference level is absent the whole concept ceases to exist. A typical situation is as follows, because of eye adaptation the wall with the window is perceived darker than wall without window although the brightness of the wall with the window itself could be higher or at the very least the same.

#### **3.3.3 Summary**

Section 3.3, highlights that the brightness and brightness pattern on the VWS vary depending on the light source, here referring to the windows. This suggests that the methodology should measure the following variables;

1. average luminance (brightness of the wall),
2. luminance ratio (maximum luminance: minimum luminance),
3. window width,
4. window area,
5. isoperimeter,
6. isoperimeter area,
7. percentage of daylight,
8. daylight factor.

### **3.4 FACTORS AFFECTING OCCUPANT'S VIEW OF THE VWS**

From the above discussion the VWS and the difference of the brightness and brightness pattern influences occupants perception. The crucial factor here is really the occupants seeing the different walls. Only then will the perception of the individual differ (even if the VWS are different but the occupants only see one kind of wall i.e internal wall, they will have similar perceptions).

As stated earlier, a room consists of four walls. In most circumstances an occupant would sit facing one, two or at the most three walls. At least one wall will always be behind the occupant. As to which wall is seen by the occupant depends on occupant's work position orientation with respect to the wall. This in turn, dictates the light pattern that is projected into the occupant's eyes. Occupants can be seated facing the windows, with their back to the windows or with the windows to their side. When occupant is sitting facing the window he is in actual fact facing the external wall, while with the back to the window would mean the occupant is facing an internal wall and with the windows to their side means the occupant is facing the flanking walls. The light pattern projected to the occupant will be as those described for that particular wall in section 3.3.2-II(i).

Meanwhile the extent of the wall seen depends on the occupants' field of view and dimension of the wall itself (refer to fig 3.4). The extent of "field of view" is indicated by the isoarea. The wider the field of view the more the stimulus exposure, that is more visual variety integrated in the vertical surface in the form of lines, shape and texture. Bigger field of view also implies more chance in variance of light pattern as more VWS is included. Therefore, areas that are more open would give different subjective impressions to those that are more confined.

Section 3.4, highlights that the brightness and brightness pattern on the VWS in occupants field of view vary depending on the orientation of the occupants with respect to the windows. This suggests that the methodology should have 3 groups of occupants; facing towards the windows, with the window to their side, and their backs towards the window.



This section also suggests that the methodology should measure the following variables:

1. Isovist area.
2. Amount of light arriving at the occupants eyes.

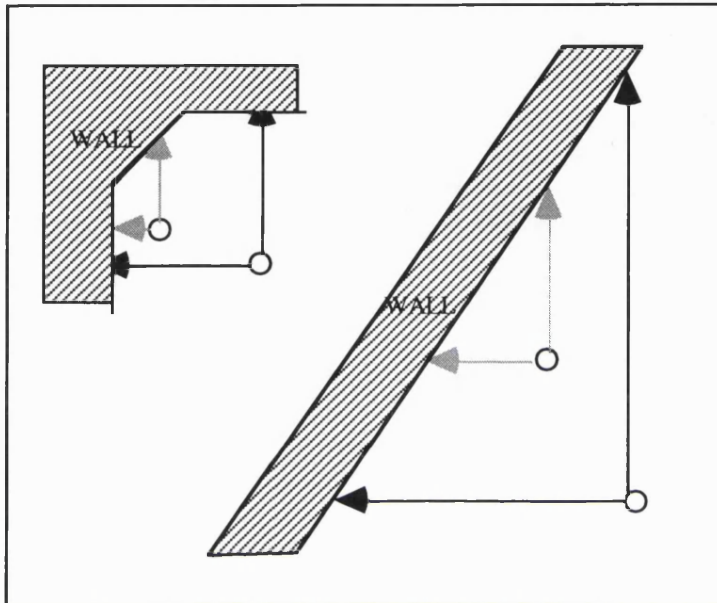


Figure 3.4: Occupant's Field of view

### 3.5 LIGHTING CHARACTERISTICS THAT GIVE POSITIVE VISUAL PERCEPTION OF APPEARANCE FROM A WORK POSITION

The question here is whether the presence of the window in the field of view gives a positive or negative perception? To answer this it is necessary to first identify the lighting characteristics that give a positive visual perception.

The first criterion to project a positive perception for the work environment is brightness. Julian (1987) proposed that gloom occurs in uniformly lit spaces, where the light sources are not visible and where the room surfaces do not appear to be bright. The apparent brightness of the objects in the field of view is important in judging whether the room is adequately lit. Bell (1987) proposes that the height and the shape of shadows on the walls have a significant effect upon the 'expression' of the interior. If the shadows are scallop shaped, the expression will be ponderous and if the scallops meet quite low down the wall surface, the interior may appear depressing. Reinterpreting Bell, it is possible to infer that vertical surfaces which are darker are more prone to give rise to depressing interiors. Bright walls washed with light are well favoured for office.

Flynn et al (1988) showed that high general brightness tends to contribute to an impression of increased activity and efficiency. Lighting studies have shown that visual comfort increases with increase in luminance of the surrounding area. Marsden (1969) in his extensive review of psychophysical studies concluded that the perceived brightness of simple visual field was a function of luminance. Steven (1976) also found that perceived brightness is related to luminance. Rowland, Loe, McIntosh and Mansfield (1985), in a study of light adequacy in office interiors, found that the "subjective lightness" of the space in the field of view is crucial to the interpretation of visual perception by individuals. The study has also shown that the subjective lightness or brightness has a significant correlation with average luminance in the field of view and not necessarily the amount, as in engineering terms. Tiller and Veitch (1995) stated that ambient lighting can effect perceived brightness (and gloom).

However, brightness alone is not sufficient to create a positive perception. Waldram (1923-1989) pointed out that if the ambience light level is high but the range of luminosity is small, the effect though bright is still dull and uninteresting. The scene lacks an attraction or a focus and appears dull and gloomy for there is little emphasis on modelling. Rowland, Loe, McIntosh and Mansfield (1985) have also shown similar findings. The study showed that situations where the lighting is bright and uninteresting, and those that are interesting but have low brightness are not liked by building occupants. The study also showed that people like bright non-uniform light patterns with a combination of installations.

So what is the other ingredient to promote positive perception? Larson (1964) pointed out that part of the requirement to create proper ambience and to project positive perception is to have visual interest. What constitutes visual interest? According to Larson, it is the brightness difference within the visual field that gives the visual interest. Flynn et al (1988) agrees with Larson, and argued that good visual perception requires variability in lighting. In 1969, in a London Research Council commission, Stone found that an individual that has a varying lighting condition tends to assess the environment favourably (Stone, 1993). Weston (1962) said that the artificial lit environment could be more satisfying if the distribution of brightness within a room could produce a rate of change without being distracting. According to Weston, where the visual field does not contain variation boredom sets in. Loe (1993) had shown in a study on museums that in addition to bright walls, some dark and bright regions are necessary for an attractive appearance and impression of pleasantness. The study also show that by keeping the luminance ratio of 5:1 good visual quality could be achieved. Rowland, Loe, McIntosh and Mansfield (1985) have shown that visual interest has a significant correlation with the luminance ratio. According to Larson (1964) visual

interest is a matter of light and shadow, of multiple contrasts within the central visual field, and of highlights and lowlights. CIBSE guide to interior lighting (1994), points out that lighting for effect depends on large contrast in the field of view. Boyce (1978) argues to the same effect by pointing out that even at low illuminance the effects can be interesting provided the gradient of luminance is sharp. The lack of brightness contrast makes a dull environment. This condition can occur under any illumination level, high or low. It is not the amount but the way it is distributed that accounts for the contrast.

Early on in the paragraph above, it is mentioned that to promote positive perception variability in lighting is needed. However, Stone argued that there is no need for a dynamic change in the lighting. This is because the visual system functions by responding to the detection of gradient in light intensity in the image. When the eyes scan the scene, they introduce a change of light entering the eyes provided there is a difference in light pattern in the field of view as opposed to a uniform lit environment.

Perception is a function of seeing, and all factors that determine the ability to see better are also essential to good perception. This means that if a person can see better, they will perceive the surrounding more favourably. Flynn et al (1988) pointed out that the ability to see detail and gather information within a scene is assisted by contrast in luminous intensity. Weston (1962) stated that provided that shadows are not too dense and not in the wrong places, they prove helpful and are often essential for visual discrimination and pleasant modelling effect. Lythgoe (1932) showed that visual acuity is best when brightness of work is slightly brighter but in the same order to that of the general environment.

Having said the above, an individual's perception of the appearance from the work position is also a function of visual comfort. When factors affecting visual comfort were probed, it was found that they are profoundly influenced by the brightness of the surroundings (in the general environment). The contrast grading becomes more important, the higher the general level of brightness. For visual comfort it is usually preferable for the work to be a little brighter than the surroundings (Loe, 1993). Maximum comfort appears to arise if the brightness in general surroundings is between  $1/3$  and  $1/10$  of the brightness of the task. Background brightness should not be less than  $(\text{task brightness})/10$  nor more than  $(\text{task brightness}) \times 10$ . Spatial brightness exceeding  $10x$  task brightness should be kept well outside of the  $40^\circ$  visual cone (Flynn et al, 1988). Experimental studies have shown that the best compromise between visual comfort and efficiency and excessively bright lighting is achieved if the illumination on the work is not greater than that which would render the work of an average brightness 'luminance' of 1000asb. This figure for the maximum comfortable brightness in a

working interior has been arrived at independently by different investigators and seems to be the figure at which about 20% of people with normal vision complain of too much light, and the remaining 80% being satisfied (Hopkinson,1969). BRS had established that excessive local lighting to the exclusion of its surrounding can lead to visual discomfort.

Where the vertical wall has no emphasis (window absent) the downlight becomes dominant, the system therefore produces a horizontal illumination. The central areas appear intensively illuminated and the lighting in the lower field becomes the dominant brightness feature, consequently the work position appears as neutral and gives increased awareness of nearby details. On the other hand, when visual emphasis is focused on the vertical wall (window present), through the brightness relationship, the lower horizontal surface brightness is reduced. Foreground detail is lost as objects and people in the central area go into silhouette. This demonstrates that the brightness (luminance) ratio between foreground horizontal surfaces and background vertical surfaces affects impression (Flynn et al, 1988).

The review on factors that give positive visual perception leads to the conclusion that good visual perception is achieved when the central field of view not only is subjectively bright which means a high average luminance, but also has variation in brightness pattern which means a high luminance ratio to give rise to the interest in light quality. When this information is compared to the four walls mentioned in section 3.4.2 it is observed that the external wall has both higher average luminance and luminance ratio as compared to the other internal walls. From here it is possible to deduce that occupants that sat facing an external wall would have more favourable assessment of appearance of their work position.

### **3.6 CONCLUSIONS**

Perception of appearance of a work position has been shown to correlate significantly with vertical wall surfaces. Perception is shown to be governed by brightness and brightness pattern. Merging these two principles together implies that perception would vary if the vertical wall surface have differences in brightness and brightness pattern.

With this combined principle, it is possible to infer that the individuals in a uniformly lit office would have different perception of the office space. This is because although the office employed uniform lighting, the walls have different brightness and brightness pattern. There are effectively three different kinds of walls; the external wall, the

opposite wall, and the flanking walls. The reason for this is that the offices employing uniform lighting are effectively lit with integrated lighting (using of both artificial and daylight). The window as a source of natural light disrupts the uniformity of these VWS as preplanned for the artificial lighting. Depending on the occupants seat orientation, the occupants will have view of different wall. Because of the difference in the light pattern on the wall, a different light pattern will be projected to the occupants.

The comparison of the observed situation in the office to the combined principle only demonstrates that perceptions do vary but does not explain how it varies. This is achieved by comparing the lighting characteristic that gives positive visual perception. From here it is determined that high brightness/average luminance and luminance ratio is required for good visual perception. By comparing this condition to the 3 different VWS, it is inferred that when an occupant sat facing the external wall (where the window is integrated), the occupant has a better light pattern projected in their field of view. This is because the presence of the window offers the possibility of high average luminance (average luminance takes into consideration the brightness distribution in the room) and high luminance ratio which are the two criteria for good visual perception. It is thus inferred that work positions facing the windows in a uniform lit environment project positive visual perception, it is bright and interesting. As argued earlier on in chapter 2, positive perception promotes health. Thus it is hypothesised that work positions facing windows promote health. Promoting health would mean reducing the occurrence of eye symptoms as compared to those facing away from the windows.

### **3.6.1 Hypotheses**

Combining chapter 2 and chapter 3 results with two main hypothesis to this thesis.

1. The eye symptoms that office occupants displayed are related to the appearance from the work position the occupants perceived. When the occupants have better perception of appearance from the work position they will display fewer occurrences of eye symptoms.
2. Occupants in work positions facing windows have fewer eye symptom because they perceive the appearance of their work positions as being better. The secondary hypothesis is as follow:
  - i. the number of eye symptoms an occupant experiences vary with the occupants orientation with respect to the window. Occupants that were seated facing the window will have fewer symptom occurrences.

- ii. the perception of appearance from the work position varies with the occupants orientation with respect to the window. Occupants that were seated facing the window will have a better perception.
- iii. light pattern in the occupants field of view varies with the occupants orientation with respect to the window. Work positions facing the windows project good light pattern in the occupants field of view.

## Chapter 4

# THE RESEARCH METHODOLOGY

### 4.0 INTRODUCTION

To test the hypotheses as prescribed in the previous chapter, an experimental methodology is required. The experimental model used by the SERC/LINK research programme for the study of HVAC in SBS was adopted.

The introduction to the methodology consist of two parts. It will explain about;

- i. the necessity for a multidisciplinary approach to the research, and
- ii. the way the research was conducted as part of LINK programme, and the opportunity offered by the association with the LINK programme. This section clarifies how the Ph.D was run as a part of LINK.

#### 4.0.1 A Multidisciplinary Research Method

Review of the literature on SBS studies has indicated that the occurrence of eye symptoms involves complex interaction between environmental,<sup>37</sup> and organisational factors of the building with the occupants personal factors. All three factors cannot be isolated, replicated and controlled as in laboratory experiments. Therefore, a methodology that enables researchers to understand health, needs to be responsive to all these factors simultaneously rather than focusing on a particular issue to the exclusion of others. Any attempt for a comprehensive inquiry is best tackled by a multidisciplinary research as opposed to a single discipline. A multifactoral experimental study avoids the danger of diluting significant effects that are caused by focusing on single aspect of the environment (so, although the Ph.D study looks only at the lighting aspect, it is necessary to also isolate and verify the effect of other environmental factors). Thus multifactoral study has greater weight in assessing the evidence and is able to arrive at a coherent understanding of symptom occurrence. This

---

<sup>37</sup> A variety of building designs as found in the real world. In its true sense, if environmental and psychosocial conditions are considered, every building is unique. It is impossible to find buildings of the same characteristic. Impossible to find future buildings of same characteristic so that general guidelines established could be applied. Even if building could have same physical characteristic by prototyping design, the applicability is limited by the management and the organizational climate issues.

method allows cross examination of a large number of variables. It also enable complex proposition, and a variety of explanatory models involving several variables in simultaneous interaction to be constructed and tested.

#### **4.0.2 Research Opportunity In Association With The LINK Programme**

The research conducted by the LINK group<sup>38</sup> to look at the effect of environment on SBS involved a multidiscipline team. As such, the LINK group consists of various specialists assessing different aspect of the environment. As the situation stands, the Ph.D research represents an additional area of investigation. The multidisciplinary approach adopted by LINK offered the Ph.D study an opportunity to look at the interaction with other environments which otherwise could not be conducted by an individual with no support from other disciplines and expert advice. If not for this link, the research would be too vast an area for a Ph.D. work.

The Ph.D study commenced on January 1993, a year later than the LINK<sup>39</sup> programme. At this stage, the programme had completed its research on 2 buildings, one in Peterborough and another in Trowbridge, and was already on its third building study. As the LINK research programme was moving on fast, to take up the advantages offered by the LINK programme, a method to study the lighting environment had to be formulated quickly.

The Ph.D study aims to measure the subjective assessments and symptom scores by questionnaire and physical measurements in the work positions<sup>40</sup>. The LINK methodology also involved these different measures. The Ph.D study adopted the LINK methodology<sup>41</sup> since it is comparable (The appropriateness of the methodology

---

<sup>38</sup> The SERC/LINK Study regarding health hazards in offices constitutes of the Science and Engineering Research Council (SERC), the Department of Trade and Industry (DTI), The Bartlett School, The Welsh School of Architecture, British Gas, Gilberts (Blackpool) Ltd, Building Use Studies (BUS) and Rooley Consultants .

<sup>39</sup> Link commenced on January of 1992 and aimed at completion by September 1994. It aimed to study 8 office buildings in that duration.

<sup>40</sup> Essentially both Link and the Ph.D study aim to study the effect of symptom occurrence in building although there is a difference in the focus area . LINK aims to study the effect of HVAC on SBS symptoms while the Ph.D aims to look on the effect of appearance of work positions on eye symptoms. The symptom scores that are of specific to the Ph.D was the eye symptom scores. This in fact is a subset of the symptom score considered by the LINK programme.

<sup>41</sup> LINK initially did not have a set method. The method was constantly upgraded as the sophistication of procedures was refined and the review of literature progressed. However, it was the aim of the LINK programme to have a core path which was kept constant and has an "upward compatibility". Nevertheless, the method had to be freeze earlier on in the study considering that it had only a small



was assessed by liaising with the working committee of the SERC/LINK project). The LINK questionnaire was made more compatible to the Ph.D research by adding questions on subjective assessments of appearance based on the factors identified earlier.

As such, the Ph.D study was carried out as a part of the existing work of the LINK project. It is not another method overlapping with that of LINK. As a result the schedule of the Ph.D research programme adhered to that of LINK's. The schedule of the research programme depended on the permission obtained from the occupier or owner. This was handled by the LINK project manager.

### **4.0.3 Organisation Of The Chapter**

This chapter consists of 8 sections:

1. Explains the research model.
2. Explains the process used to select a building.
3. Explains how the study period was selected.
4. Explains the sample selection.
5. Explains the process of data gathering. It is laid out in three sub-subsections.
  - i. explains the occupants survey, how the questionnaire was formulated, the rules used to construct it and the survey approach.
  - ii. explains the objective measurements, listing variables that are to be measured in the study and other variables that were left out, though it seems logical to have been included initially. This is followed by the instruments that are used for the measurements, time of measurements, type and frequency of the measurements, condition for measurements, location of measurements and the approach for each measurement.
  - iii. explains the eye health survey, how the eye health questionnaire was formulated and the implementation of the questionnaire.
6. Explains the storing of the data, the computer package that is used and the coding system that is employed.
7. Discusses the data reliability and validity. This is divided into two parts. The first part discusses the subjective data, while the second part discusses the objective data.
8. The chapter concludes with the chronology of the research methodology.

---

number of building to study so as to enable some reasonable comparison. The Ph.D proper commenced when the method was finalized.

In the sections where the interface with LINK occurred, the first paragraph of the section described the LINK programme, and the second paragraph relates the work that was carried out for the Ph.D.

## **4.1 RESEARCH MODEL**

The Ph.D methodology has adopted the case study approach<sup>42</sup>. Each building selected is treated as a separate case study. The data is not compared across building as the finishes and the thermal environment of each building varies one from another. As such, they are not loaded into one data file. Besides, treating each building as a case study, the organisational climate could also be kept constant as each building is occupied by the same organisation. This approach is also recommended by Raw as it avoids compounding errors when comparing between buildings.

## **4.2 BUILDING SELECTION**

The building selection will be discussed in two parts.

1. It will describe how the building was selected in the LINK programme.
2. It will describe how the building was selected for the Ph.D Study.

### **4.2.1 The Building Selection In The LINK Programme**

Gaining access to occupied buildings is difficult when carrying out the research. Many buildings that meet the research criteria cannot be investigated unless permission is obtained from the owner/establishment.

Whilst office buildings throughout the UK may be fairly homogenous in terms of their design and operation, the organisational structure and occupants practise vary considerably. Such variation may have important consequences for the apparent

---

<sup>42</sup> The case study is preferred in examining contemporary events where relevant behaviour cannot be manipulated. Case studies are generalizable to theoretical proposition. It is adopted to deliberately cover the contextual conditions which are highly pertinent to the phenomenon of the study.

The case study investigation used by the Ph.D study stems from the method adopted by Link in its initial stages when reporting to the building owner/management. LINK later dealt with one large data file. However, should the researcher be interested to combine this case studies into a single file they have to be conducted simultaneously or the comparability between seasons depend on the external illuminance have to be taken into consideration. As advised by Loe, where the external illuminances were comparable to one another the data was comparable otherwise this is non applicable.

performance of the building and the health of the occupants. Therefore, a wide dispersion of geographical location is desired.

The buildings selected by LINK were chosen from a variety of cases with different types of air-condition system, layout, organisation, task and with different health ratings.

The selection of buildings for the SERC/LINK project was based on initial questionnaires sent to the building owners followed by a preliminary visits. Approach by a building organisation, the first criteria used by LINK to determine the use of the building in the study, is the building occupants rate of response to the questionnaire. LINK aimed for 50% response rate before considering the building for the research purposes. This is because a higher response is statistically more representative of the occupants reaction to its environment. It also provides more information and clearer understanding of the situation in the building.

Thereafter, the LINK research team carry out a preliminary visit to investigate and ascertain the state of maintenance (the HVAC system was also assessed to ensure that it is functioning properly) of the building. This visit helps to determine the feasibility of the building to be used as a case study. The purpose of this check is mainly to ensure that the building is typical of its type, and that there are no unusual factors or design faults that would lead to an obvious cause relating to its occupants feeling unwell (so that the result of the finding is not invalidated). Buildings with faulty design and poor maintenance (those with environments which experience acute malfunction in building systems such as Legionnaires disease, humidifier fever, acute toxicosis or allergic reactions) were eliminated from the study. The main group also gather as much information as possible concerning the building, its management, layout, and mechanical and electrical service system.

The buildings selected by LINK includes healthy and unhealthy buildings (The BSS (Building Sickness Score) varies from 0-10. 3.0 is the threshold between healthy and unhealthy buildings. Lower scores refer to healthier buildings. The scores for the buildings in the Ph.D study are Kendal-2.9, Cardiff-3.2, Reading-3.1, and London 2.5). Healthy buildings by definition comply with that of WHO requirement. In a healthy building, majority of the work force will exhibit characteristics of high morale, low absenteeism, productivity level approximating the peak level attainable, and near absence of SBS symptoms.

From the time the Ph.D study commenced until the end of the LINK research work in late 1995, there were 7 buildings examined by the LINK group. The 7 buildings were;

Kendal (South Lakeland), Pearl (Welsh Development Authority), Glasgow (British Airways, ticketing office), Reading (Inland Revenue), London (Euston), London (ODA), and Plymouth (Western Morning News).

#### **4.2.2 The Building Selection For The Ph.D Study**

The Ph.D study examined the same buildings that were selected by LINK. This helps justify buildings that are appropriate for SBS studies from all other environmental aspects. However, the study does not use all 7 buildings. Only 4 buildings were selected from these. The 4 buildings were decided based on the lit environment, to ensure that they are comparable. The factors affecting the lit environment was determined in the previous chapter.

To normalise the effects of artificial lighting, it is necessary that the following conditions are satisfied:

1. It has to employ an almost similar fluorescent lighting installation. In this case the lighting installation should consist of a linear array of fluorescent lighting either recessed in or fixed on to the ceiling employing uniform lighting strategy.
2. The artificial lighting has to have similar luminaire form that is of the downward lighting system category<sup>43</sup> (this category represents the majority of office lighting). This is because where lighting installation and the luminaire differ it would affect the light pattern distribution on all planes and give rise to a different lit environment.

Based on the above criteria, the buildings in Glasgow, Plymouth, and London (Euston) were eliminated from this study. In Glasgow, the lighting system used downlight using a dichroic light source. This made the ambience lighting very low. The building in Glasgow was also omitted on the account that it did not permit identifying work positions to questionnaires which is essential in the methodology adopted. Meanwhile, the Western Morning Star in Plymouth was omitted as the architecture and the lighting system were significantly different. The lighting installation used a direct-indirect discharge light source suspended from the ceiling. The ceiling was much brighter than the other cases studied in this study. This could potentially give rise to a different perception of appearance from the work position due to the difference in the plane lit. The London (Euston) was omitted on the account that there were insufficient response.

---

<sup>43</sup> Lighting system could be categorised into three groups; downward, diffuse or combination of both (M.Sc Lecture Notes, UCL, 1994).

To conclude this section, 4 buildings have been chosen for the study. The four buildings are:

- South Lakeland Authority, Kendal.
- Welsh Development Authority, Pearl House, Cardiff.
- Inland Revenue, Sapphire Building, Reading.
- Overseas Development Authority, London.

### **4.3 THE STUDY PERIOD**

The study period for each building takes place in different month of the year, starting from January 1993 to December 1994. However, the duration of each study is approximately two months. The first month is dedicated to the questionnaire (distributed and collected over one month), and the second is allocated to physical measurement. Although one month is set aside for the physical measurements activity, the actual time taken to gather the data is only one week. When problems arise in obtaining good measurements, this activity will take the entire month whereby the researcher will make several visits to the building to gather all necessary physical measurements.

### **4.4 THE EXPERIMENTAL DESIGN**

An experiment was designed to compare the occupants perception with different orientation on the occurrence of eye symptoms. As argued in chapter 3, the brightness pattern on the VWS influences occupants perception, and this in turn is influenced by occupants orientation towards the wall. As such, occupants with different orientation were selected. They were asked to report on their perception of the appearance of their work position, and the number of eye symptoms experienced. The lighting attributes were measured to see if it influenced the occupants perception.

## **4.5 THE SAMPLING**

The work positions selected for the physical light measurements will be determined by the project coordinator based on the information gathered from the questionnaire. The process is described under section 4.6.2-VI.

The sampling needs to satisfy two conditions:

1. It is necessary to assure all types of different individuals are taken into account, including the atypical samples to avoid bias due to human element.
2. It is necessary to ensure that each individual in the population is listed only once. This is because replication could weaken or strengthen finding (Sarantakos, 1994).

The study used the floor plan as the sampling frame to allow for the two conditions stated above.

The occupants are selected from three groups; facing the windows, with their back to the windows, and with their side to the windows.

### **4.5.1 Exclusion Criteria**

1. The effect of the appearance of the lit environment on health has a time factor.
  - i. Therefore the evaluation study only applies to those that use a particular location constantly, and thus excludes visitors and occasional users.
  - ii. It is necessary to eliminate occupants that do not get better away from the building.
  - iii. to eliminate occupants that have just occupied a particular work position. This is because lack of relationship may be caused by occupant being new and would introduce bias to the sample giving misleading result.
2. To eliminate occupants with eye health problems.

### **4.5.2 Sample Size**

Qualitative research has no strict agreed-on rules on sample size. This depends on division of sample as required by the analysis procedure (Blalock, 1979). It also is dependent on the nature of the population (Sarantakos, 1994). If the population is homogeneous a small sample will suffice, where it is heterogeneous (composite/mixed samples) a larger sample may be required. The more the samples are subdivided the

bigger the original sample is required. Generally, the bigger the sample size the more reliable the finding is. With large samples, the probability with sampling error is less. Therefore the relationship observed is less likely due to sample error. However, the non-parametric analysis used in this study requires only 5 sample per group. As there are only three groups only a minimum of 15 samples are required.

## **4.6 COLLECTING THE DATA**

The Ph.D data gathering will be carried out in three phases.

1. Occupants survey/subjective measurements.
2. Physical measurements/objective measurements.
3. Eye health questionnaire.

Phase one is devised, carried out, and logged entirely by the LINK group, and all the data will be made available to the Ph.D study. Phase two and three are formulated and conducted by the researcher. The eye health questionnaire resulted from the lack of questions appraising eye health (as the eye health also determines eye symptom occurrence) in the LINK's questionnaire. Otherwise only two phases would be required; occupants and physical measurements.

### **4.6.1 Occupants Survey**

The occupant survey is of key importance to the conduct of the study (the research is derived from the questionnaire). This survey forms the basis of establishing the multiple factors that influence occurrence of eye symptoms. This methodology uses people as a measure, since people are competent to gauge and relate whether they experience occurrences of eye symptoms, and they are also reliable to identify the problem.

#### **4.6.1-I The Questionnaire**

With regard to this study, the primary aim of the questionnaire is to establish whether occupants experienced eye symptoms. The secondary aim is to establish occupants assessment of the appearance of their work positions. The questionnaire developed by the LINK team is judged appropriate for the Ph.D as it also includes questions assessing the eye symptoms, the assessment regarding the appearance from the work positions and assessments of the lit environment.

However, as the questionnaire was designed primarily for the LINK study, it has more variables than necessary for the Ph.D work. It assessed all the symptoms related to SBS, and the causes that exist in the environment that potentially relate to the occurrences of the eye symptoms. An example of the questionnaire is given in Appendix 2a.

### The Scale For The Eye Symptom Assessment

The symptom occurrences are measured on a continuous scale 0-220<sup>44</sup>. This is the other reason that makes the LINK approach suitable for the study. In presenting building occupants' symptoms, the largest study to date carried out by BUS (Wilson and Hedge, 1987) employed a binary scale to ask occupants to recall whether or not they had experienced more than two episodes of a symptom over the preceding 12 months (LINK interim report). Whilst such a scale was satisfactory to produce Personal Symptom Index (PSI) and Building Sickness Score (BSS), it yields only limited information about the frequency of individual symptoms and restricts the analysis that can be performed. In constructing the symptoms question for the LINK study, whilst wishing to use a procedure and time scale that was compatible with the previous work by BUS, there was a desire to use a measure that allowed a better estimate of symptom frequency.

Initially, the original binary scale was extended into a seven points (0-6) numerical scale by which an occupant notified the number of times they had experienced the symptoms. This scale was chosen instead of the daily, weekly or monthly scales as it was thought that the latter would not be sufficiently responsive to seasonal variations in symptom occurrence. Subsequently, this seven point scale was changed to the 0-220 scale so that occupants could record the number they have actually experienced. The need to modify the questionnaire in such a way was highlighted by the diary appraisal techniques used by LINK. It allows a better estimate of a specific symptom occurrence. It is important to stress that this figure is an estimate since occupants do not remember exactly the number of occasions they experienced a symptom.

---

<sup>44</sup> LINK explicitly changed the way the symptom is measured compared to BUS. BUS look at this in a binary fashion, either an individual has or does not have a symptom. In LINK earlier studies the scale was 0-6. From Kendal onward LINK has set symptom measure 0-220. The samples can not be mixed, because the latter had larger scale it introduces bias and portrays the latter buildings as unhealthy.



## Formulation of the Lit Environment Assessment Questions

The contents of the LINK questionnaire had been extended for the purpose of the Ph.D. study. Initially, lighting questions were not included in the LINK study. The questionnaire was derived from the EPA study where the test-retest method (test-retest merely refers to giving a person a test and retesting them after a lapse of time) was carried out. The necessity of the test-retest method is explained under section 4.8.1. The lighting questions include a mixture of qualitative and quantitative aspects of lighting appraisals.

The lighting questions were formulated based on earlier studies carried out by the EPA research group. This earlier study itself used questions developed for various other work that was done in the Welsh School of Architecture, 5 years before. The main criterion that is of importance which made the researcher consider this questionnaire relevant and can be adopted here is its capacity to identify the more dominant lit environmental factors that cause eye symptoms, such as glare, flicker, and inadequate worktop illuminance level. Failure to identify these factors would mask the main study area. As appearance of the lit environment is the main study area, naturally the questionnaire ought to contain questions on this aspect. The researcher's guide to what constitute appropriate questions are those used in Loe's and Crome's lighting studies which evaluate appearance of the lit environment. In assessing the suitability of the questions adopted for the lit environment, references were made to the work done in the IES journal, Lighting Design and Applications (LD&A), and papers drawn for the CIBSE National Lighting Conferences, CIBSE code of Interior Lighting (1994), UCL M.Sc Light and Lighting Course - lecture notes, with special regards to work done by Flynn, Loe and Waldram.

## Rules On Constructing The Questionnaire

Words that could introduce bias should be avoided (de Vaus, 1994). Questions that are leading could introduce bias. To avoid ambiguity the questions are worded clearly. The questions are kept short, precise and as simple as possible, and jargon and technical terms are avoided. The questions are given a frame of reference to make it sufficiently clear e.g within a particular time frame or over the last 12 months, and uses vignettes (short introduction for context standardisation).

The questions are grouped into sections. Where positive and negative items are used to form a scale, the scale are flipped now and again to avoid an acquiescent response set. The questionnaire uses a variety of question formats to maintain respondents interest.

The recommended maximum word length for a question is 20 words (ITM research workshop, 1991). Long complicated questions could be misinterpreted. Choice of wording is important in question construction as it sets the issue in both the mind of the researcher as well as the respondent. With this intention in mind, de Vaus (1994) cited Payne (1968) as suggesting the following;

1. never use double negatives,
2. check all meanings of words,
3. avoid use of concept words,
4. stick to familiar words,
5. do not abbreviate words,
6. underscore words to be emphasised to avoid misplaced emphasis, and
7. use minimum punctuation.

#### Assumptions In Implementing Questionnaire

1. The study assumes that there has been no mutual influence amongst participants with respect to the scores.
2. All occupants have similar standard of office finishes, fixtures and fittings.
3. Occupants awareness towards the effect of lighting on perception of work position appearance are of the same level.
4. Assumes all occupants work 90% of their working hours in the offices.

#### **4.6.1-II The Survey Approach**

At the start of the study the main questionnaires were distributed to all the building occupants. LINK sets out that the survey was done only once, distributed and collected prior to monitoring to avoid bias in assessments. This strategy is set for the following reasons:

1. Research has shown that people become sensitised to the environment that they assess repeatedly.
2. When the occupants are aware of the factors being studied their judgement is influenced. Whereby a factor previously unnoticed became a major irritant and the deficiencies of the environment becomes focused.

3. Experience has also shown that sometimes occupants associate monitoring with the possibility of an underlying problem.

Each occupant is given a questionnaire with a reference number that relates to occupant's position on the floor plan (The complete and up-to-date plans describing both the fixed parts of the building and precise detail of furniture, fixture and fittings were drawn up by LINK at the inception). The identification of the occupant to the work position was absolutely necessary to enable the mapping of physical data to subjective assessment and occurrence of eye symptoms. This is because the lighting physical measurement is specific to each work position. The lit environment changes with respect to the layout.

#### **4.6.2 Objective Measurements**

Physical measurements will be conducted to;

1. relate if occupants perception of appearance from the work position is associated to the physical lighting attributes of their work position, and
2. determined whether significant differences occurred between areas in terms of the environment.

The lighting measurements are separate from the subjective measurements gathered by LINK. The LINK group had no use for it. The lighting measurements will be conducted solely by the researcher and will be carried out simultaneously along side LINK (enabling direct data comparison) to enable the verification of the environmental factors present that affect the eye symptom occurrence.

The LINK team consists of various specialists from the research staffs of the Welsh School of Architecture (WSA) and the Bartlett School of Architecture. These various specialists assess different aspects of the environment. These aspects are: space use observation, assessment of HVAC system, thermal environment data logging and measurement of pollutants. These data will be made available for the Ph.D study and will be used in the analysis. The physical measurement takes place a month after all the questionnaires have been gathered.

The following sections will relate:

- i. Variables for objective measurements.
- ii. Instruments used for the measurements.
- iii. Time of measurements.
- iv. Type and frequency of measurements.
- v. Condition for measurements.
- vi. Location for measurements.
- vii. Approach for measurements.

#### **4.6.2-I Variables For The Objective Measurements**

The study will only focus on the luminous variability due to spatial effect (as explained below). From the review of literature in chapter 3, the following variables were identified:

- Average Luminance (Ave. Lum)
- Eye Illuminance (Eye E)
- Worktop Illuminance (WT E)
- Percentage of Daylight (% DL)
- Daylight Factor (DF)
- Maximum luminance
- Minimum luminance
- Isoarea (IA)
- Isoperimeter area (IPA)
- Window area (WA)
- Distance of work position from window
- Orientation of work position

The luminous variability or the way the light pattern/composition would change could be divided into two categories:

- a) temporal effects
  - change in luminous environment within a space
  - sequential exposure of different spaces
- b) spatial effect
  - luminosity
  - geometry of space
  - colours

The need to study the change in luminous environment within the space is eliminated due to the overcast condition set for the study (refer to previous section under climatic

constraint), whilst the sequential exposure is eliminated due to the sedentary state of the occupants. The argument for the second part is as follows. An occupant may move from one location to another in the course of a day. But of the time spent in the office, a high proportion of it, the occupants tend to be sedentary at their assigned work position with little body movement. Thus, most of their perception of their work positions would be contributed by their work position as compared to the time spent moving around the entire building. Sequential exposure was also excluded because of the approach it dictates, which practically requires mounting a device on the occupants such as a sensitive cell on individual foreheads as done by Cawthorne (1993). Apart from being expensive, it is cumbersome and would deter participation from the occupants. It gets in the way and proves to be too intervening and would probably bring out hostility from the office management. As a result the study could only focus on the spatial effect.

The variables are selected based on their affect on brightness (luminosity) and light pattern/composition as related in chapter 3. Illuminance on worktop has no relation to the perception of the work position and the vertical surfaces. However, it is necessary to demonstrate that eye symptom was not due to the inadequacy in the quantity of light for the job to be undertaken at various locations in the room and identify if any falls below 500 lux, the levels recommended by Illuminating Engineering Society (IES).

### Variables Not Measured

The literature review had also pointed out other variables that are important and should be considered. They are:

1. Psychological effect of view out of the windows.
2. Superposition, size and perspective, aerial perspective, filled and empty distance, parallax of movement, reversible perspective and height and location of objects in the view.
3. Colour in field of view.
4. Choice of materials.

These variables are not measured for the following reasons:

1. The psychological effect of view out of the window which included content of view height from street level, is not taken into consideration as it does not effect luminosity in the field of view which this study is investigating. Similar reasoning applies for superposition, size and perspective, aerial perspective, filled and empty

distance, parallax of movement, reversible perspective and height and location of object in the view.

2. The lighting installation will not be measured because the lighting installation is normalised (refer under building selection). The office fluorescent lamp has 60-80 Colour Rendering Index (CRI). Therefore, it is anticipated that not much subjective impression difference will occur due to colour rendering of the light. Hence, the categorisation of the light source; luminaire ceiling map, identification source of light, numbers of light sources in field of view, type of fitting, brightness of fittings, size and position of lamps in visual field could be ignored. Research has also shown that light control has no correlation to subjective impression and thus will not be measured.
3. The study acknowledges that colour affects the perception of brightness. As such surfaces that have light colour are perceived brighter than the darker surfaces. But, the office surfaces are typically of serviceable grey (however, there are localised variations in colour due to partition and personalisation of the work position). Since there is an insignificant difference in this aspect, differences in subjective impressions could not be caused by it.
4. Flynn has shown that the type of furnishing is not as important as expected, subject to the limitation that furnishing is typical of the building function. In an office, the furnishes, fixtures and fittings approximate to one another. Under normal circumstances, design guidelines ascertain that the main surfaces of a room; walls, floor and ceiling, should have a matt finish (Hopkinson & Kay, 1969). As a result, office occupants do not experience reflected images of bright light fittings in smooth, shiny surfaces especially dark ones. Since the offices have comparable reflectances, this variable is also normalised (Office Lighting, T7). The luminance of the light fittings is not a relevant factor, rather the light that fall on the planes is (Rowland, Loe, McIntosh and Mansfield, 1985).

#### **4.6.2-II Instruments Used For The Measurements**

The objective measurements will be carried out on site using instruments that give direct readings (this is described in detail in each appropriate section). The instruments that will be used in the study depend upon their availability.

Appropriate instruments are those that give readings close to those of human assessment. It is noted that the difference between using human and sensor to monitor is that human moves between spaces and is receptive to many modalities and ranges of sensitivities. Human as a monitoring media integrates the input. Humans also

communicate with each other which has the effect of adjusting sensitivity. A sensor on the other hand is fixed in space. It has fixed modality, sensitivity and does not take into account the composite effect of the environment.

In selecting the instrument the following factors were considered :

1. In light measurements, the instrument needs to have the same sensitivity as the human eye (the average eyes, at least)<sup>45</sup>. Thus the instrument that will be used to measure light needs to be sensitive to the V-lambda light adapted visual response curve, therefore it needs to be selenium or silicon<sup>46</sup> based instrument. However, selenium fatigues easily so silicon based is preferred. In modern instruments, the effect of impedance and resistance of the measuring circuit on the linearity of the measurements is not of great concern<sup>47</sup>.
2. Most light measuring devices are applicable between 0-30°C. Hence, where extreme temperature is involved care is necessary but this is not be a concern in an office environment.
3. Measurements will be made using an instrument that is regularly used<sup>48</sup>, as this gives more accurate and reliable readings (Note of caution: Depends on type of sensor. Some deteriorate with age while others deteriorate with use).
4. Use an instrument that gives the smallest error in readings. Thus the reason for selecting luminance meter was that it has a surrounding field error of 1% and all other errors such as focus, range change and temperature coefficient of 0.2%.
5. The battery will be constantly checked to determine that it is operating properly and above the battery check line. Readings will be taken on the scale that reads higher on the analog meter as this gives more accurate readings.

The following lists the instruments that will be used for the specific physical measurement:-

<u>Measurement for</u>	<u>Instrument Used</u>
1. luminance	- Minolta luminance meter (refer plate 4.6.2-IIa)
2. illuminance <sup>49</sup>	- Hagner ECI-S lux meter (refer plate 4.6.2-IIb)

---

<sup>45</sup> If device did not have same sensitivity as the eye than the device is only measuring electricity with respect to light.

<sup>46</sup> Do not follow the V-lambda curve closely but has a reasonable response over that range.

<sup>47</sup> Overcome with the use of operational amplifier. It amplifies the current flow and has zero impedance.

<sup>48</sup> An instrument that is seldom used are less sensitive.

<sup>49</sup> The illuminance measurements could be obtained using Hagner ECI-S or the Universal Photometer. If universal photometer was to be used researcher should be constantly having to fine tune it (refer to universal photo meter handbook) This precaution is eliminated when using ECI-S.

### Daylight Factor (DF)

The daylight factors will be obtained by building a scaled model at 1:10 which represent the actual building as reasonably as possible (ideally a larger scale model is preferred but it will be difficult to build the external building obstruction and to be as close to the actual site due to experimental limitations). Particular care will be given to reflectance of surfaces, obstruction from external buildings and major internal partitions. The daylight factor obtained will then be corrected for light transmission through glass and obstruction due to window panes.

### Isometric Measurements

From scaled floor plan on the computer, the following isovist measurements<sup>50</sup> will be obtained:

1. Isoarea.
2. Isoperimeter area.
3. Ratio of window area to isoperimeter area.
4. Distance of work position to nearest window.

These variables will be measured to characterise the visual field from occupant's work position.

### **4.6.2-III Time Of Measurements**

The time for measurements varies with the time of year. In winter it would be a shorter period, and extend to be longer in summer. The physical measurements will be conducted during office hours merely due to the fact that this is the effective time that office workers are in the offices. The measurements will be conducted between 9am-3pm to avoid drastic change in external daylight especially when the study is conducted in winter.

---

<sup>50</sup> Isovist measures are described in detail in Benedict, Environmental Planning B,1978.



#### 4.6.2-IV Type And Frequency Of Measurements

The measurements consist of spot measurements (grab and snap sampling). The measurements will be taken at regular interval in time (this is explained in section 4.6.2-VII). This method is employed due to the lack of equipment and manpower. The spot measurements go hand in hand with the limited access allowed.

Although continuous monitoring of each of the variables at each work position is logically the best option, it is not the choice of the study because it is not economical, viable nor practical and is beyond the capacity of research conducted by a single person. Besides, continuous monitoring is intrusive (requires the occupants to be wired up as conducted by Cawthorne) and would deter the participants.

#### 4.6.2-V Condition For Measurements

The measurements will be conducted under overcast conditions. The overcast condition is selected for the following reason. Occupants visual evaluation will change with conditions of view - interior brightness and appearance as perceived by the occupants are affected by the lighting condition (Hunter and Harold, 1909). The lighting condition as a result of the natural lighting varies with level of exterior daylight which, in turn, varies with the time of day, time of year, sun and variance in cloud cover (refer to figure 4.6.2-V(i)).

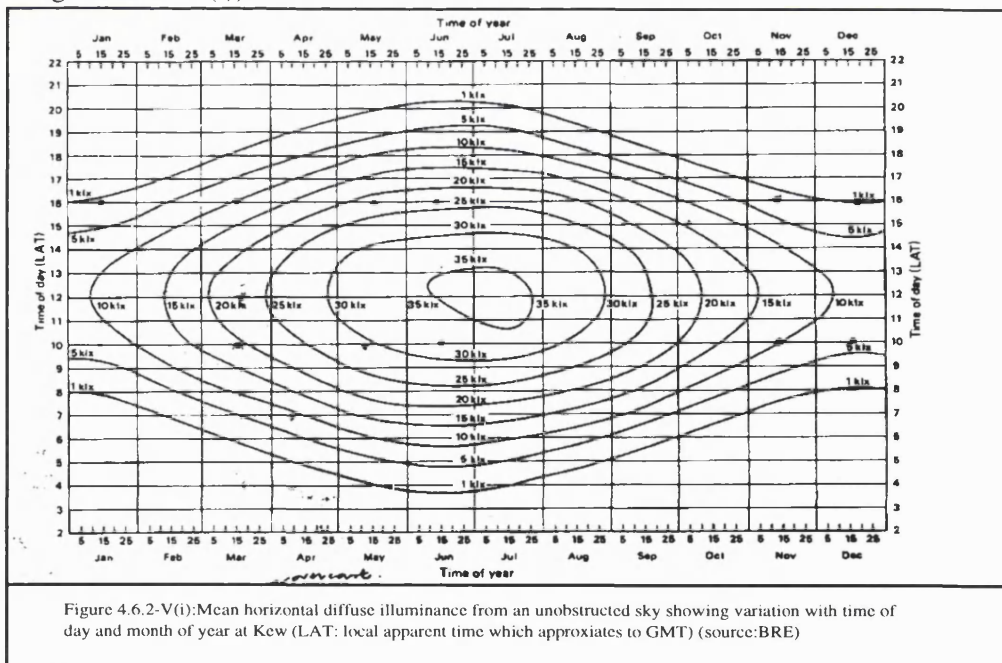


Figure 4.6.2-V(i): Mean horizontal diffuse illuminance from an unobstructed sky showing variation with time of day and month of year at Kew (LAT: local apparent time which approximates to GMT) (source: BRE)

Considering the above, a "one off" snapshot site measurement, would and could not describe a typical condition experience throughout the day nor the conditions experienced throughout a year. To facilitate the study, the variance in the external conditions needs to be reduced if not standardised so that the physical arrangements would be the same for all evaluations and the physical data comparable. The variance in external conditions is reduced by comparing days of almost similar weather condition. There would still be some variation in daylight but this does not result in a large change in the occupant's perception of appearance from the work position because the eye adapts to it (Hopkinson and Kay,1972). According to CIBSE, 68% of the year in United Kingdom the illuminance level was likely to be over 10,000lux and 84% of the year over 5,000lux (This was based on the last 20 years meteorological data. It is important to note that this information was collected based on the minimum unobstructed diffuse illuminance (lux) likely to occurs between 9am-5pm). This statistic indicates that overcast days are predominant in the United Kingdom (refer to figure 4.6.2-V(ii)). It is also important to point out that the overcast condition is selected because the range of luminance in interiors will remain relatively constant despite changes in the external illumination and as a result external illuminance measurements using a solarimeter is not required (CIBSE, Code of Interior Lighting, 1994). From day break to dusk the light is very much the same on an overcast day (Larson, 1964). CIBSE stated that the interior apparent brightness does not vary significantly under overcast conditions. The overcast condition constraint also eliminates the need to monitor continuously using data loggers as temporal changes and rapid changes in lighting conditions no longer apply. The overcast condition is also selected for two other reasons. Firstly, most design guidelines here are developed based on this situation. Secondly, seasonal affective disorder (SAD) studies have indicated that it is during this time that people feel most depressed.



Figure 4.6.2-V(ii): artist's impression of the British Weather

#### **4.6.2-VI Locations For Measurements**

The light measurements will be carried out in specific cluster areas. The cluster areas<sup>51</sup> will be the same as those that will be identified by the LINK group due to the need of mapping the physical light measurement to that of the environmental monitoring. The cluster study is also adopted to set measuring to a manageable proportion that could be conducted by one person. Thus, the physical measurements will be carried out for all the individuals that respond to the main questionnaire within these clusters. However, where clusters consist of only a small number of occupants, the measurement will be extended beyond these areas.

The clusters to be measured will be identified by the project manager before going on site. The cluster will be identified using factor analysis on the symptoms obtained from the occupant survey instead of using Personal Symptom Index (PSI)<sup>52</sup>. The factor analysis will give a factor score<sup>53</sup>. This factor score will help to identify the problem (symptomatic) and non-problematic (asymptomatic) areas according to the prevalence of symptoms. This will give a fair sample of both clusters for comparison purposes. This symptom distribution was not communicated to the researcher to avoid bias. The extent of a cluster area will then be defined by an expert member of the LINK group. All work positions in these clusters are measured for the Ph.D study.

#### **4.6.2-VII The Approach For The Physical Measurements**

To make the study least intrusive, the work position will only be measured when the space is not occupied. The work positions will be measured "as used". This describes the every day situation the occupants have decided to mould and adapt their visual environmental conditions. The work position has been opted to be measured as used because it gives a true impression of the resultant visual environment lived in.

---

<sup>51</sup> A cluster is identified as the space which could well be a part of a space defined or enclosed by cabinets and partitions to mark a section or a work group with imaginary boundary shared by more than two occupants.

<sup>52</sup> From the questionnaire a personal symptom index (PSI) was derived. This method was developed by Building Use Studies (BUS), (Wilson and Hisk). However, through discussions with the medical discipline, O'Sullivan has indicated that PSI was not reliable in indicating building symptoms. This was further supported when a factorial analysis was carried out by Vaughan.

<sup>53</sup> The factor analysis gave each person a value which was the factor score. High score means the occupant has more ill-health symptoms. Factor score was closer to some factors than to others. Therefore, these groups would vary with building studied. However, it was believed at this stage that these identified groups stand true for all buildings to be studied.

Studies in lighting have identified that light pattern within 40° band affects subjective perception (as compared to 20° and 50° band). Hence, all measurements will be confined within this band in the field of view. The field of view is identified as the angle that subtends from 45° to the right and left of the normal path of view. This field of view describes what the occupant sees sitted at his work position with head but no body movements. This is opted for as opposed to binocular view as it indicates what a person sees more realistically. The reason for this is that the human eye at an instant samples the peripheral field with low acuity and a much smaller central field with high acuity. Smooth and saccadic eye movements shift this high acuity segment rapidly, so that acute vision over a wide angle is achieved (Bruce and Green, 1985).

In the following section each variable of the light physical measurements is considered, and the approach for each particular measurement is described (see section 4.6.2-I).

### General Approach

The measurements will start with the largest and visually extensive cluster to establish the time interval. After completing a cluster, the researcher will then move to the next cluster, and then return to the first cluster for the following reading.

2 clusters will be measured in one day<sup>54</sup>. Measurement of all the variables for a cluster with 3 occupants will be carried out over 1 hour. After completing a cluster, the researcher will then move on to the second cluster. When the second cluster is completed the researcher will return to the first cluster to repeat all measurements. Thus there will be 4 repeat measurements of all the variables taken on a 2 hour interval during office hours, 9am-5pm. Where only one individual can be measured in a cluster, another cluster with 2 persons will be measured simultaneously.

When measuring, it will be necessary for the researcher to be out of the light path so as not to effect the measurement. However, it is acceptable for the researcher to be in the occupants normal position when taking measurement.

---

<sup>54</sup> From consultation with Loe it was established that overcast readings done on the same day or immediately thereof, were comparable to each other.

### Average Luminance

An imaginary grid lines of 1m on the work position will be used and the luminance will be measured at the centre of each grid. These readings will then be averaged out for each work position<sup>55</sup>. The number of measurements that will be taken on the vertical plane will vary with the pattern of light distribution on these surfaces. The more non-uniform the lighting pattern, the more readings will be required.

### Eye Illuminance

This measurement will be taken at sitting position, 1200cm from floor level for West, North-West, North, North-East and East orientation. The measurement will be taken by placing the light sensitive cell vertically outward from the occupant's sitting eye position. This measurement will be carried out simultaneously with the surface illuminance.

The measurement of the eye illuminance takes into account the amount of light arriving at the eyes which comprises of the light that comes from the different directions relative to the position of the occupants in the space be it an open plan office or a personal office and also in relation to light source; artificial or natural.

### Worktop Illuminance

Two points will be measured on the work top, middle right and middle left point of the table. The reason for this is that the work area is not just a spot, thus at least two values representing the light level on the worktop must be taken.

---

<sup>55</sup> Although the researcher has focused on the vertical surfaces as it composed of the highest percentage of the field of view, in actual measurement all planes were considered. The field of view could constitute of 5 sections (ref Fig):

- ceiling plane
- floor plane i.e including worktops and floor
- left wall plane
- right wall plane
- front wall plane

According to Mansfield, inserting additional plane alters the perception and luminance of the workplace drastically. The measured luminance conditions resulted with an abundance of data. This was then condensed into a figure for average and ratio of luminance to describe each surface in the workstation.

### Percentage Of Daylight On The Worktop

This will be determined by repeating worktop illuminance measurements when the sun is down. These night measurements will then be subtracted from the day measurements to give the percentage of daylight on the worktop of a specific work position. Night measurements will be carried out in winter times as the building has restrictions in accessibility later in the evenings for security reasons.

### Percentage Of Daylight In The Field Of View

The process is similar to calculating the percentage of daylight on the worktop but by repeating average luminance measurements.

After completing all the above measurements, each work position will be photographed to show the light distribution in the work positions (to describe what it looks like). This is necessary for record and reference.

## **4.6.3 Eye Health Survey**

Symptoms could be due to eye health factors. This is because, when people cannot see well, they become more sensitive and get irritated easily, and this could manifest as any one of the eye symptoms. Therefore, it is important to isolate them. The intention of the health survey is to verify that occupants eyes are healthy or where there are defects they are corrected appropriately. This process excludes eye health as a contributing factor to the occurrences of eye symptoms. In this manner, the researcher was able to identify that the environment is the factor that generates higher level of eye symptoms. Therefore, the questionnaire includes questions that could identify as to whether the eye is healthy or otherwise. An example of the questionnaire on eye health is contained in appendix 2b (Discussions on factors that effect eye health is presented in appendix 3).

### **4.6.3-I Formulation Of The Eye Health Questionnaire**

The length of the questionnaire was limited to one page as an extensive questionnaire deters response and the risk of people ticking answers at random. Where more detail is necessary, a matrix type questionnaire is recommended as it helps compact the presentation. The format of the questionnaire is also important. An appealing

questionnaire encourages response (clear format, no ambiguous question and avoid excessively long sentence construction).

#### **4.6.3-II Implementation Of The Eye Health Questionnaire**

The questionnaires will be distributed while conducting physical measurements. This survey adopts a strategy opposite to that of the LINK group. LINK surveyed all occupants but will measure only specific clusters, whereas the lighting study will measure lighting variables for as many work positions that responded to LINK survey as possible, but the eye survey will only be carried out on all 15 positions identified in the lighting study. As such this part of the research is only representative in the sample examined.

### **4.7 STORING OF DATA**

The subjective data will be logged in by the LINK group into a commercial statistical package called "Stats View". The LINK data holds information on observed used, questionnaire and other measured environmental variables. The objective data from the physical site measurement will then be entered and stored into the same file based on individual scores. "StatsView" will be used basically to stay consistent with the main group. This is also to reduce error due to data transfer from one programme to another. As the two parts are carried out separately, they originally have a different reference number, although referring to the same location. Therefore, when the objective data is linked to the questionnaire survey data from the LINK research team, it requires to be mapped out.

#### **4.7.1 Coding**

The scaling used in the questionnaire creates forced-choice questions. The responses are already in numerical form. The scale itself represents the code fed into the computer. Occupants whom provided no response and those whom responded as zero are to be distinctively separated. This will be indicated with a bullet rather than 999 as normally fed into the computer by social researchers. The intention is basically to avoid confusion between a missing code and a valid code.

Where a particular question contains a lot of different information and is in effect tapping a number of different variables, each question is conceptualised and allocated a code. Each possible response becomes a variable. The variables will be coded in a consistent manner so that the scores obtained are interpretable. To create an interpretable score, all items will be coded in the same manner.

## **4.8 DATA RELIABILITY AND VALIDITY**

The data are of two kinds, the subjective data obtained from the questionnaires and the objective data from the physical site measurement. Here, the reliability and validity of the data will be discussed in two sections. The first will discuss the subjective data and the second will discuss the objective data.

### **4.8.1 Reliability And Validity Of The Subjective Data**

The reliability of the subjective data that will be gathered in this research is preassessed using the test-retest method in the EPA (Energy Passive Architecture) study. The reliability is gauged by repeating the test on the same person using the same method. In the EPA study the questionnaire was distributed thrice; once at the start of the study, then 12 months later, and then again at 24 months. The intention of carrying this out was to check if the way the questions were phrased gave rise to different answers as occupants maybe "infatuated" by the newness of the building and if occupants appreciation of the building changes. The EPA study test-retest using the same measure showed that generally the score on the scale moved half a point up or down and statistically there were little difference in the distribution. This movement is related to the occupants settling in the building rather than the accuracy of the judgement. From this, it was found that occupants appraisal after 12 and 24 months was close. Therefore one of the criteria of the implementation of the questionnaire was that occupants must have occupied the building more than 12 months. The correlation coefficient from the test-retest method gives measure of stability because they relate to consistency over time (The new questions added on did not have the test-retest method).

To further enhance the reliability of the subjective data, the alternate form method is employed in the questionnaire. This is achieved by using other questions that address similar aspects but are differently phrased in the same questionnaire. The test carried out on the same questionnaire automatically ensures that the measurements are repeated



under the same conditions<sup>56</sup>. Testing on the same questionnaire also takes care of different events<sup>57</sup> occurring between the two tests which may influence their views.

The subjective data is also validated by flipping the assessments in the questions to ascertain that the respondents are aware and had thought carefully whilst answering the questionnaire and not ticking the questionnaire at random.

To ascertain that the scale is valid, it is necessary to ensure that it is measuring what it is designed to measure so that difference between individuals' scores can be taken as representing true differences in the characteristic under study. The subjective data obtained from the methodology is valid for the following reasons:

1. It has cumulative validity - The success of the questionnaire measuring what it sets out to measure is supported by other studies already using similar methods such as BUS. Besides the semantic scale used in it is proven to have substantial validity as a general measure of perception.
2. It has ecological validity as the study is carried out in a natural environment
3. It's representativeness of the office occupants due to the big sample size.
4. Researcher effect on the normal condition is minimised by using an unobtrusive method.
5. It has theoretical (face) validity<sup>58</sup> as the questions refer to both symptom occurrence and occupants appraisal of the appearance from the work position.

---

<sup>56</sup> The practical difficulty of the this test-retest method is however self-evident; if a person was submitted to repeat questioning, a comparison of the two sets of results would hardly serve as an exact test of reliability, since they could not be regarded as independent. As occupants may remember their first answer and give a consistent retest answer, an action which would make the test appear more reliable than is truly the case. The tactic for overcoming this was to make the questionnaire extensive enough.

<sup>57</sup> Where different events do occur to influence assessment the scores are not comparable, so the difference between the two is a mixture of reliability and change in the characteristic itself; the effect of this is that an underestimate of reliability is obtained.

<sup>58</sup> The measure is said to have theoretical validity when the finding complies with the theoretical finding of the discipline i.e they do not contradict already existing rules. Theoretical validation are of 3 types:

1. Face validity - seems to measure what it is expected to measure. Findings comply with the theoretical finding of the discipline i.e they do not contradict already existing rules.
2. Content validity - when it covers all aspects of research topic. Elements that are considered to be important aspects associated with appearance appraisal.
3. Construct validity - when a theoretical construct is valid, whereby the researcher assumes to be true the type and degree of association between the scale and other variables based on the theoretical consideration and then examines these associations to see whether they confirm to the expectation (the essence of construct validity is its dependence on theory and the examination of the observed association is as much a test of the theory as of the scale of validity). The weakness of this check is the relation between subjective assessment and personal preference. A positive result would give increased confidence in the scale. The existence of good correlation acts as supporting evidence. Where correlation is low, conformity of these correlations to expectations provides the necessary test (Moser and Kalton, 1971). Better appearance of work position propogates fewer symptom occurrences is the research topic. Comparing the group with good appearance and bad appearance (two groups known to have different attitudes to the research issue) satisfies the construct validity and thus the theoretical validity.

6. It has communicative validity - by administering additional questioning to building occupants. LINK required the occupants that are willing to further participate in the study to keep a diary.
7. The sensibility of the subjective assessments are also established in the factor analysis whereby the assessments do not contradict one another. Thus, a work position that was appraised as pleasant would also constantly be assessed with positive remarks.

#### **4.8.2 Reliability And Validity Of The Objective Data**

The objective data from the physical site measurement is divided into two parts. The first part is that of the geometric type that describes space and object dimensions, and the second part describes the light parameters. The reliability of both sets of measurements are closely associated with the instruments that will be used (refer to section 4.3.2-II(ii)). The instruments themselves are calibrated in laboratories. By satisfying the criteria set for the instrument selection, the data is automatically made valid and reliable. From here on the geometric data of the visual environment are straight forward. However, the light parameters are rather complicated and vary dynamically. The appropriateness of the instrument alone is insufficient to verify these data. These data need to be further verified (giving the right reading) by repeating the measurements, at least twice. The measurement is said to be reliable as the repeat measurements made under the same conditions gives the same reading.

The light parameter data are obtained under overcast conditions and valid only for this condition. Stating this, a spot reading is representative of the daily variation. This daily representation of the data is also verified by the 2hrs interval measurements that is carried out throughout the working day. Readings showed that they are relatively constant throughout the day. Thus, the physical light measurements represented the daily variation but not the yearly variation as sunny days and sunlight penetration was not taken into account. However, as overcast days represent 84% of the year, and we could say that the light parameters that are measured represent the condition for 84% of the year, that is when the external illuminance is less or equal to 10,000 lux.

## 4.9 CHRONOLOGICAL ORDER OF THE METHODOLOGY

1. Select building
2. Primary LINK assessment
3. Distribute questionnaire
4. Collect questionnaire
5. Log in survey questionnaire data
6. Conduct factor analysis to Identify Cluster
7. Go into building to do objective physical measurements (simultaneously with the LINK team)
8. Distribute Eye health questionnaire
9. Log in objective physical measurements data and Eye health questionnaire data

Where organisations are unwilling to allow this, the investigation becomes impossible and will be abandoned as there is no way to link the physical data to that of subjective assessment nor the occurrence of eye symptoms<sup>59</sup>.

This methodology will be tested in a pilot study which will be discussed in the next chapter.

---

<sup>59</sup> Although the inability to correlate physical measurements to the questionnaire renders much of the study obsolete, in these cases part of the study could still be carried out, that is the relation of occupants perception to the occurrence of eye symptoms. This is because when correlating occupants perception to the occurrence of the symptoms no work on position identification is required as data are retrieved from one questionnaire. However, the analysis is only half done as it could not relate to the physical attribute of the environment.

## Chapter 5

# TESTING OF THE METHODOLOGY: The Pilot Study

## 5.0 INTRODUCTION

This chapter describes the testing of the methodology that has been developed. It focuses on South Lakeland District Council in Kendal as a pilot study to test out the methodology.

The chapter consists of 8 sections:

1. Will give a brief description of the building, explain the choice of building.
2. Will describe the building in detail. The description of the building includes;
  - i. the spatial organisation,
  - ii. the room surfaces,
  - iii. the electric lighting installation,
  - iv. the window and daylighting,
  - v the light pattern On the VWS,
  - vi the visual environment in the office.
3. Relates the collection of the data. This includes;
  - i. the schedule when the pilot study was conducted,
  - ii. the floors used in the study,
  - iii. the problems that were encountered on site were discussed.
4. Relates the data.
5. Relates the logic structure for the analysis.
6. Relates the analysis procedure.
6. Relates the results of the analysis.
7. Discusses the problem with the methodology adopted and the amendments made.

## 5.1 A BRIEF DESCRIPTION OF THE BUILDING

South Lakeland House, a complex of interlinked buildings, is located in the centre of Kendal, behind the Victorian town hall and adjacent to the High Street (refer figure 5.1-1, 5.1-2 and plates 5.1(1-3)). The complex provided accommodation for the South Lakeland District Council (SLDC), responsible for the south Cumbrian area.

The South Lakeland District Council (SLDC) offices is in the centre of Kendal. It consists of three distinct buildings of varying age; two existing buildings of different dates refurbished just over a year ago, together with a newly built wing and a new entrance with a light well atrium. South Lakeland House is a complex of three buildings whose overall form resembles an inverted "T," and whose plans are reproduced in figures 5.4. The complex is surrounded by the backs of existing buildings on the north and west sides. On the east side, it overlooks the top deck of a largely below-ground car park. On the south side it faces Lowther Street, which is a narrow road leading to the High Street, with buildings directly opposite.

The most recent part of the complex, dating from the middle of 1991 (zone 1), with three floors on the north part of the site. The next most recent building also with three floors dated from 1981 (zone 2), is located in the south western part of the site. The oldest part of the complex (zone 3), with two floors dated from the eighteenth century and is located in the south east corner of the site. The two older buildings were extensively refurbished during 1991, with the interior spaces and layout dating from this time.

### **5.1.1 Reasons For The Choice Of Building**

The building has been selected from those listed for LINK SBS study, so the building is appropriate from all other environmental aspects.

This building is selected because it is speculatively built, and is designed to have uniform lighting in all occupied areas. The uniform lighting system is achieved by:

- i) A linear array of fluorescent tubes<sup>60</sup> fixed on the ceiling.
- ii) Downward lighting luminaires<sup>61</sup>.

---

<sup>60</sup> In the literature review the study has identified that perception varies with light pattern on VWS. As the offices have integrated lighting the light pattern on the VWS is affected by the artificial and natural lighting sources. Where both factors vary it is difficult to determine which changes that cause the variance in perception. Therefore, one of the factors has to be normalised. As most offices are speculatively built and the artificial lighting employs uniform lighting concepts and uses fluorescent lamps, it is easier to make this factor (the artificial lighting) constant rather than the source of the natural lighting therein the window opening.

<sup>61</sup> Specifying this luminaire category is important to ensure same light pattern distribution (a different luminaire would give a different light pattern distribution on all the planes), because a different light pattern distribution would give rise to a different environment and consequently the occupants perception of appearance of the work position.

## 5.2 THE DETAILED DESCRIPTION OF THE BUILDING

This section is divided into 6 parts:

- i) The spatial organisation.
- ii) The room surfaces.
- iii) The electric lighting installation.
- iv) The window and daylighting.
- v) The light pattern on the surfaces.
- vi) The visual environment in the offices.

### 5.2.1 The Spatial Organisation

The building has a layout in which all the office zones are similar in design and placement of furniture. The design resembles Burölandschaft practice<sup>62</sup>. Spaces are well broken down into small interlocking sections with good space progression i.e good access and circulation, ease of communication, good visual links within, and between departments on the same floor. The floor height varies between the zones. The new wing, zone 1, has the floor to ceiling height of 2.1-2.3m. The old building built in the 18 century has a much taller floor to ceiling height of 2.8-3.0m.

Generally, the layout of all parts of the complex is based on open plan. A single contemporary furniture system is consistently used in the layout. Occasionally, some fully enclosed offices for senior staff. Zone 1 had air conditioning installed as an integral part of the design. Air conditioning was added to levels 1 and 2 (but not level 3) of the older buildings at the time of reconstruction.

Level one consisted of the treasurer's department in zone 1, leisure service in zone 2, housing in zone 3 with the public lobby and reception, located at the apex of the three buildings (centre of plan) separating the three office components on this floor (refer figure 5.4a). Level two consisted of the treasurer's department in zone 1, clerk and executive in zone 2, and environmental health in zone 3 (refer figure 5.4b). The office elements were interlinked by means of short corridors and stairs at the apex of the three buildings. Level three consisted of the planning department in zone 1, and clerk and executive departments in zone 2 (refer figure 5.4c). Most of the zones had central circulation elements, with work positions on either side, and comparatively little enclosure, except between sub-groups of departments.

---

<sup>62</sup> landscaped Open plan office layout for further information refer to Grajewski, 1992.

### **5.2.2 The Room Surfaces**

Using the reflectance card, the interior reflectances are as follow:

Wall	:white
Ceiling	: 58/58
Carpet grey	:14/14 or Dark grey 6/6
Table	: brown 16/14 with turquoise blue drawer 20/24 : grey 42/42
Computers	: cream 80/80
Door	: Brown 48/44

The general colour of the interior is grey except for the chairs and odd file or tray. The greyness accentuates the uniform lighting strategy.

### **5.2.3 The Electric Lighting Installation**

This section will describe:

- i. The lamps used.
- ii. The fittings.
- iii. Location of fitting.
- iv. Control.
- v. Operation.

The offices use linear fluorescent tubes with low brightness louvers fixed recessed into the ceiling. The fluorescent lamps used to provide lighting to all areas. Fluorescent tubes are of type Thorn 36 watts pluslux 3500 white and are on 1200x1200mm grid, and half of that to the walls. Low Power Compact Fluorescent (LPCF) are used for the area near the staircase. On the first floor, the LPCF are fitted on the sunken ceiling which ran down along the office in the middle of the ceiling. This lighting system serves as the emergency lighting. The emergency lighting goes on when the office light is off. The emergency lighting plays no part in the research and is therefore excluded.

As explained in section 5.2.1 each floor represent an open plan office where the office spaces and the circulation corridor is integrated. The lighting circuit in the large open spaces are organised in batches, and there is no local control for individual occupants. The switches are placed at the main staircase. There is no automatic timer nor light sensor employed. There is no evidence of task lighting on any work positions. It is not provided by the establishment nor made available by the occupant personally.

At 8 o'clock every morning, the control, switches on the lighting over the entire building. Generally, this lighting remained switched on all the time during office hours. However, as occupants come in some will change this state of lighting. Thus in some positions the lighting is switched off. As the space is shared by several occupants, the decision about switching on or off the light source is a consensus amongst them<sup>63</sup>.

#### **5.2.4 The Windows And Daylighting**

Generally, there are different window form on each floor of each building wing. There are four basic forms;

- large 5m wide, floor to ceiling windows on the ground floor,
- 1.5m wide, sill to ceiling height in the old wing, on the ground and first floor,
- bay windows on the first floor, and
- vertical slotted windows on the second floors.

Most of the windows are double glazed, although due to cost cutting, there are single glazed windows in the oldest part of the complex. These are gradually being replaced with double glazed unit ( the transmission value of the glass are not available fom Young nor Vaughan. According to Vaughan even the building management does not have information on this).

The ground floor with the floor-to-ceiling windows could have been bright but being adjacent to the pedestrian pathway and due to the need for privacy, the blinds were always down. As a result the interior was made gloomy. The bay window, and 1.5m wide window from sill to ceiling were comparably bright and were brighter than the other two situations. The second floor has small vertical windows and the light level fall fast as a person moved away from the window, into the building. Generally, the work positions do not exceed the 6m away from the windows whereby the lighting design guide specifies that the light level will fall drastically.

---

<sup>63</sup> The problem posed here lies in the fact that the control is by batch which means that when an occupant wants a particular light off the whole batch will be effected.



### 5.2.5 The Light Pattern On The Surfaces

The light pattern on the surfaces is the result of the interaction of the artificial lighting and the natural lighting.

The artificial light is directed downwards to light the horizontal worktops. The ceiling and walls are not given any emphasis. Although the ceiling is not illuminated, it is not dark nor does it introduce a harsh contrast with the luminaries<sup>64</sup>. These surfaces are lit with diffuse reflected light as a result of lighting the horizontal worktops. The artificial lighting gives diffuse lighting of nearly uniform brightness on the different surfaces throughout the entire office. However, for the walls, there is a cut off point which commonly occurs at 2/3 of the height of the wall from the floor. The cut off point, could not be seen clearly.

The resultant light pattern on the surfaces depends on the superimposed daylight. Generally, the effect of daylight diminishes as the surface moves further away from the window<sup>65</sup>. For the horizontal surfaces (ceiling and worktops), areas nearer the windows are brightest and this light level drops gradually as the surface recedes into the building. Meanwhile for the wall the light pattern varies according to the position of the wall in relation to the window. On the external wall, where windows are integrated, there exists a contrast between the bright window area and the wall area. The wall opposite to the external wall has uniform brightness. The daylight that falls on it superimposed on the light caused by the artificial lighting. The two flanking walls have uniform brightness vertically but the brightness level drops gradually as the wall recedes into the building.

The work positions are predominantly artificially lit. Not much light is attributed to daylight. The spaces are gloomy and dark when the artificial light is turned off. The building has low light uniformity across the horizontal plane.

---

<sup>64</sup> From any seated position, the louvers cut off direct view to the light source and thus these do not pose a glare problem. The luminaire prevents glare in two ways:  
i) From any seated position, the louvers cut off direct view to the light source.  
ii) The use of low reflective louvers eluded high contrast between ceiling and the light source.

<sup>65</sup> This pattern in lighting is associated with the drop in light level attributed to daylight which falls off steeply once a person exceeds 6m into the building.

### 5.2.6 The Visual Environment In The Offices

This section is a subjective evaluation of the visual environment in the office.

All the work positions do not look alike. This is not due to decoration, fixture, fittings or finishes. The decoration is very basic. Generally, the work position has the same fixtures and fittings. Overall the interior has a greyish white colour to it. In all these clusters, papers, documents, books etc, constantly cluttered the work surfaces.

Visually the spaces vary in the depth of field of view. Some work positions are enclosed while others are open.

In this study there are 7 clusters which are as follows;

Cluster	Work positions	
1	9,10,11	bright
2	13,14	average, bright
3	12	bright
4	15	gloomy
5	1,2,3,4,5	high contrast, silhouette
6	6,7,8	dark, average, bright
8	16,17,18,19	bright

Visually, the work positions can be divided into three groups; those that are bright and light, those that are gloomy and those that are dark.

In this building, work positions that face the windows are perceived as gloomy (like the overcast weather outside). This is because the big solid angle of the window predominates the interior lighting character. Although gloomy the illuminance is high. The high contrasting effect makes seeing uncomfortable especially when the work position faces the window directly. The contrasting effect is higher when the sky makes a big area of the window (work position 19 against 3). Using a small vertical window reduces the contrast as compared to big windows with similar height (work position 14 against 1 and 3). Seeing is much better and the visual environment is more favourable when the work position is positioned obliquely to the window or with the window to the side. Here, the modelling effect from the daylight is a great advantage (work position 5).

How bright or dark a work position appears is also dependent upon the reflectance of the finishes. Although stated earlier that the fitting and finishes are standard, some work positions tend to have more standard fittings with the dark finishes (work position 13

and 12). This tends to make these work positions to appear darker. The splashes of bright turquoise drawers give the added visual impact to the otherwise dull interiors.

Position of partition is a major determinant of how bright the work position appears. This is more so when the partition is light in colour (there are two types of partitions; the dark grey and light grey). The scallop shape light cast on to it makes an interesting pattern (maybe meaning of lighting is desired here) and this also bounces more light to the occupants eyes (refer work position 8,16 and 7 as compared to 15 and 2).

For work positions that are removed from the windows the artificial lighting installation predominates. The luminances in a field of view are not far apart, and the occupants can see all parts of the scene; nothing is concealed by extreme brightness or darkness, and luminance is limited to the range that the human eye can tolerate. The illumination provided is high enough for acute vision, but it has a high degree of diffusion. This diffusion has a blanketing effect which primarily degrades the effect of shadows (brightness difference). Because of the shadow degradation, the meaningful spatial information created by the light pattern is reduced. An indistinct visual haze hovers over the interior. The outline of objects is softened. Foreground, and background appears as one flat plane. Thus, it is difficult to distinguish objects or planes from one another. As a result, the environment suffers reduced three-dimensional modelling definition of the solid objects, space, volumes and surfaces. In this environment it is difficult to perceive details. The environment lacks visual depth and the space lacks focus and does not maintain visual attention. The environment seems grey, lifeless, uninteresting, dull, bland and boring. The space lacks the animated quality, and is mechanised and sterile.

### **5.3 COLLECTION OF THE DATA**

The data was collected as explained in the methodology (refer to chapter 4). It is presented under the relevant sections that follows.

#### **5.3.1 Work Schedule**

The main questionnaire was distributed in February 1993. The occupants were given one month to respond. The responses came in at various times within the month. Meanwhile, the lighting objective measurements was conducted simultaneously with the other physical objective measurements carried out by LINK, that is from Tuesday 16th

of March to Friday 18th of March 1993 in South Lakeland House, Kendal. It started off at 9.00am on the Tuesday and ended at 2.45pm on the Friday. During the course of the day, the site measurements began at 9am and ended at 4.00pm. The measurements were conducted straight through the lunch breaks.

### **5.3.2 Floors Used In The Lighting Study**

There were three floors and all were used in the LINK study. However, only position in identified clusters were measured for the lighting study. These cluster positions, as illustrated in the floor plan, are taken on each major floor area. Areas that are sensitive are avoided.

### **5.3.3 Problems And Mistakes Encountered In Obtaining The Data.**

One problem relating to the questionnaire is that it was not possible to determine when the occupant filled them in. The occupants would respond depending on the free time available between office hours. As such the condition under which the occupant responded to the questionnaire would vary between one another.

Obtaining the objective data was not problematic. It involved direct reading from a mechanical instrument. The only care required was not to offend the workers, and to be discreet. As a rule of thumb, the researcher proceeded with measurements only when occupants were not occupying their seats. The only problem met was to do the physical measurements for the reading of the light on and the light off alternative. To fix the artificial lighting would be too imposing to the occupants, and this would also modify the actual condition the occupants normally experienced. As it was not possible to switch the light off during office hours, the only option is to do a night reading and a day reading. However, night access is restricted for security reasons. Hence, in some instances, the management is reluctant to allow this. It was very difficult to be precise with the artificial light setting whilst conducting the physical light measurements due to the irregular pattern of artificial light switched on during the day. Occupants sometimes have the light on and at other times off according to their needs. The occupants to a certain extent have direct control to the lighting installation. When the light level dropped to the point where work became difficult, the occupants would then switch it on. This was further complicated by the open floor plan whereby the artificial light spilling from the adjacent area made it difficult to categorise a position, either artificial or naturally lit. A problem integrated in this aspect is that the space was shared by a few

occupants, and the lighting installation was controlled in batches. A person with the more dominant character or superior position in the office might have a stronger say to the disadvantage of the others that might disagree with the lighting arrangement. A similar problem was faced regarding windows blind. The research is concerned with the lighting environment experienced by the occupants, it was considered acceptable to measure the light level as it is.

Concerning the maximum luminance and minimum luminance in the field of view, it was found that this varies with the object in view. Dark colour objects tend to be associated with the attire of the occupants. When most occupants are dressed in dark attire, it lowered the average luminance level. However, as occupants are constantly moving about in the office this changes. When these darkly dressed occupants moved out of the field of view the luminance level seems to have risen. If the occupants attire is disregarded, it was found that the luminance remains constant for a given work position given the external lighting level remains the same.

The percentage of daylight on the work surface was verified using daylight factor obtained from the artificial sky. The figures show high discrepancies between actual measurements and those derived from the laboratory daylight factor. Analysis was carried out but not presented in this thesis shows that in some spaces, the difference of the projected level from the daylight factor, is consistently higher than the actual measurement. These discrepancies could result from two factors. First, it is probably due to variation in cloud cover. Secondly, an error in the percentage of daylight could also occur when subtracting night from the day time average illuminance, whereas the artificial lights are not put on during the daytime i.e as it is, represents the daylight illuminance value. This is shown as very low or even a negative value of the amount of daylight. This subtraction method could also produce errors where the space was artificially lit by day and night. This potentially occurred in spaces that have heavily blinded windows.

There is also a problem of identifying the data group. In the office it was found that the window situation is not as simple as either having one or the other window position. More often than not, a work position has windows in all three positions. Confronted with this dilemma the researcher made a decision that where windows exist in all three positions the frontal position overrides. Thus, the particular work position is categorised as having window in front. Where the work position has the window to the side but due to the long run of the window this could also end up being categorised as having window in front. This is determined by a photograph. A work position is categorised as backing the window only where it has a window in this position and no other.

## **5.4 THE NUMBER AND LOCATIONS OF THE OCCUPANTS SAMPLED**

LINK survey managed to obtain 119 responses. But for this pilot study only 19 samples was allowed to proceed with the objective light measurements (1 was spoilt). The work positions to be measured were determined by the LINK project coordinator. These work positions are located in 7 separate clusters distributed around the buildings, and on different floors. The locations of these eye clusters are identical to the locations of the environmental clusters analysed by the LINK project group (refer figure 5.4).

According to the respondents own categorisation, the sample was drawn from; 1 managerial (male), 7 professional - 4 females and 3 males, 2 executive and administrative category- 1 male and 1 female, 5 from clerical - 2 females and 3 male, 2 male from technical and 1 other - females (refer table 5.4a).

The age groups of the sample is such that for both genders there are none within the age group 16-19. The break down of the age group among the male sample are as follow: 2 males in the age group 20-29, 1 male in the age group 30-39, 5 males in the age group 40-49, 2 males in the age group 50-65. Meanwhile there are 2 females in the age group 20-29, 4 females in the age group 30-39 and 2 females in the age group 40-49 (refer table 5.4b).

On floor 1 there are 5 samples of which 3 are females and 2 are males. On floor 2 there are 11 samples of which 5 are females and 6 are males. On floor 3 there are 3 samples of which 1 is female and 2 are males (refer table 5.4c).

There are three work position orientations, facing the windows, the windows to the side, and with their backs to the windows. There are 7 occupants seated facing the windows, 9 occupants seated with the windows to the side and 2 occupants seated with their backs to the windows in the 18 samples studied.

The locations of these 18 work positions are shown in figure 5.4. The photographs of each work position is shown in Plate 5.4(a and b). The photographs were taken from the work positions at the occupant's sitting position, with the north of the building always positioned to the top of the page.

## **5.5 THE DATA**

This section will explain the data obtained in 4 parts:

1. The distribution of occurrence of eye symptoms in the sample.
2. The measured thermal and pollutant level in the building.
3. The occupants assessments of appearance from the work positions.
4. The measured physical light attributes.

### **5.5.1 The Distribution Of The Occurrences Of Eye Symptoms In The Sample**

The distribution of the occurrence of eye symptoms for each group can be observed in figure 5.5.1a, and the distribution of the eye symptoms for each floor can be seen in figure 5.5.1(b-f). From figure 5.5.1a, the general trend observed from the eye symptoms distribution, for each of the eye symptoms (dry eyes, itching eyes, watering eyes, headache and problems with wearing contact lenses) is that the majority of the occupants suffer a few eye symptoms, and only a small number of occupants suffer many eye symptoms.

#### Eye Health Survey

The eye health questionnaire survey distributed to the 18 samples (in the cluster identified) and 12 other random samples showed that none of the occupants suffer from any kind of eye diseases, developing cataracts, diabetes or glaucoma.

### **5.5.2. The Measured Thermal And Pollutants Levels In The Building**

A variety of environmental parameters were recorded by LINK over short and long term monitoring periods. The equipment was situated in the cluster location as shown in figure 5.4. The measured thermal, relative humidity, air movement and pollutants level can be observed in table 5.5.2.

### **5.5.3. The Occupants Assessments Of The Appearance From The Work Positions**

The occupants assessed the appearance of their work positions on a semantic scale of 0-7. The distribution of the occupants assessment of the appearance of their work position in each group can be observed in figure 5.5.3(a-d). The distribution shows that for all aspects of appearance, each group displayed a similar range of assessments.

### **5.5.4. The Measured Physical Light Attributes**

The distribution of the measured physical light attributes for each group can be observed in figure 5.5.4(a-b), and table 5.5.4(a-b). Comparing the window area and the average luminance of each position, it is shown that work positions facing the windows consistently have bigger window area and average luminance, as compared with work positions with their back to the windows.

## **5.6 THE LOGIC TREE FOR THE ANALYSIS**

- i. The analysis correlates eye symptom to aspects of appearance. The aim is to establish that there is a link between occurrence of eye symptoms and aspects of appearance.
- ii. The study aims to investigate that there is a link between occurrence of eye symptoms, and observed and measured physical correlates.
- iii. If there is a link between occurrence of eye symptoms and aspects of appearance from the work positions, and occurrence of eye symptoms and the measured physical light attributes, then there is bound to be a correlation between measured physical light attributes and aspects of appearance from the work positions. The intention here is to investigate if there is a link between the measured physical light attributes and aspects of appearance from the work positions, because that would help explain the occupants perception of the appearance from the work position.



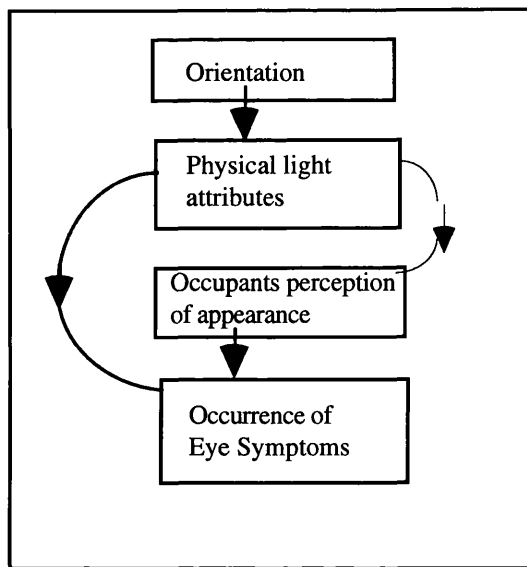


Figure 5.6- Logic tree for analysis

- iv. The research could demonstrate that the appearance of work position is important, and if the designers get this wrong, the office occupants will get more eye symptoms. Whereas, if done well, there would be fewer eye symptoms and the possibility of a pleasant environment. It is known that where buildings are pleasant they promote a healthier living environment to their occupants.

## 5.7 THE ANALYSIS PROCEDURE

From the logic structure it is derived that there are 3 parts in the analysis:

1. Analysis to examine the effect of occupants perception of the appearance from the work position on the occurrence of eye symptoms.
2. Analysis to examine the effect of the measured physical light attributes on the occurrence of eye symptoms.
3. Analysis to examine the effect of measured physical light attributes on occupants perception of the appearance from the work position.

The statistical computation used to examine data was carried out using "Stat View" programme.

To carry out the analysis, it is necessary to first analyse the affect of work position orientation on;

- i. occurrence of eye symptoms,
- ii. occupants perception of appearance of work position,

iii. measured physical light attributes.

Each of the above involve two separate analyses<sup>66</sup>;

- mean and standard deviation comparison, and
- Kruskal-Wallis non-parametric analysis.

### **5.7.1 Comparison Of The Mean Scores**

To checked the variation in the variable, a comparison of the mean scores of the variable was carried out. This was done by simply comparing the mean of the variable assessed for the groups, and rank them.

### **5.7.2 Kruskal-Wallis Non-Parametric Analysis**

The Kruskal-Wallis analysis was carried out to see if the differences observed in the comparison of the mean scores is significant. The Kruskal-Wallis non-parametric analysis was used because the data was suspected to be askewed, has a small sample size, and the number of group is more than 2.

The test involves a comparison of the rankings for each of the categories of the nominal scale variable. The 18 samples were divided according to the seat position with respect to the window; facing the window, with the window to the side or with the window to the back.

The procedure for the analysis is as follows: first the samples are divided according to the orientation. There are three groups: facing the window, with the window to the side or with the window to the back. The orientation is assigned an x variable, and the appearance is assigned a y variable. From the non-parametric analysis, the distribution value "H" is computed. This value determines whether the variables under study vary significantly between different orientations. To determine the significance of H, the chi-square test is used because the sampling distribution of H approximates chi-square distribution. The aim of the chi-square test is to test for significant differences. To determine H, the significance level and the degree of freedom is required. The degree of freedom depends on the number of groups. The degree of freedom is computed using  $k-1$ , where  $k$  is the number of groups compared (The degree of freedom gives the

---

<sup>66</sup>In lighting studies advance statistical methods for data analysis are rarely required - the analyses to some extent require intuition and the results are open to interpretation. Architectural experiments rarely require a precision greater than that given by evaluation of median for an expression of the average and by the interquartile range for the expression of the distribution about the mean (Hopkinson, 1963).

row to refer to in the chi-square table). The desired level of significance,  $p$ , which is taken to be appropriate here as 0.05. The value of  $H$  is then compared with the critical values from the chi-square table. In order to reject the null hypothesis,  $H$  must be equal or larger than the critical value -  $H_0$  (Sarantakos, 1994; Blalock, 1979). But in "Stats View", as indicated in its manual, variables that vary significantly according to the subdivision are automatically given by the significance level with corrections for ties<sup>67</sup>. Therefore, variables that have  $p \leq 0.05$  vary significantly with orientation. In the table, the factors that vary significantly are indicated by bold prints.

Conditions for Chi-square test:

1. Independent random samples.
2. It is required to have at least 5 samples per group (cell). Should a group be any smaller (thin cell), this ought to represent only 25%. In other words, if there are four groups and one group has less than 5 samples, the percentage this group constitutes of the total group is 20%. As this does not exceed the 25% it is possible to carry out the chi-square test.

### **5.7.3 Significance Level**

In social science studies, the significance levels of 0.05, 0.02 and 0.01 are recommended. The significance level gives an idea of the accuracy of the study. The smaller the significance level the more confidence in the observed association and reliability of the finding. Of the three levels stipulated, 0.05 is commonly used and normally accepted. A significance level of 0.05 means that only 5 out of a hundred samples would come out by chance with the association observed in the sample. It is the general consensus that this level gives credibility and this study has adopted this figure as its level of significance. This level is often used in experimental studies. In natural settings it is possible that this level should be raised to 0.1 (the significance level is also dependent on the sample size used in the study, for example if only 10 sample is used in the study a significance level of 0.01 is more appropriate whereas if the sample size is 1000 a significance level of 0.1 is permissible).

---

<sup>67</sup> The Kruskal- Wallis analysis employs the chi-square test.

## **5.8 THE ANALYSIS**

There are 3 parts in the analysis process:

1. Analysis to examine the effect of occupants perception of the appearance from the work position on the occurrence of eye symptoms.
2. Analysis to examine the effect of the measured physical light attributes on the occurrence of eye symptoms.
3. Analysis to examine the effect of measured physical light attributes on occupants perception of the appearance from the work position.

### **5.8.1 Analysis To Examine The Relationship Between The Appearance From The Work Position And The Occurrences Of Eye Symptoms**

Comparing the mean values (refer to table 5.8a) it is observed that occupants in work positions facing the windows have the fewest occurrence of dry eyes. This is followed by the occupants in work positions that have the window to their side. The occupants that sat with their back to the windows have the most occurrences of dry eyes. For itching eyes and headaches, occupants that sat with the windows to their side has the fewest symptom occurrence. This is followed by the occupants that sat with their back to the windows, while the group facing the window has the highest occurrence of both eye symptoms. With watering eyes and problems with wearing contact lenses, occupants that sat with their back to the window have the fewest symptom occurrence whilst those sat with the windows to the side have the highest.

From the comparison of the mean values (refer to table 5.8b), it is observed that occupants in work positions facing the windows assessed their work positions as most relaxing, stimulating, visually warm, colourful and natural compared to occupants in work positions with the windows to their side or back. However, work positions facing the windows are assessed as least homelike, light, cheerful and clean which are opposite to that of work positions with their back to the window. Work positions with their back to the window are assessed as most pleasant, likeable, peaceful, beautiful, friendly, satisfying, inviting, emotionally warm, homelike, airy, light, cheerful, non-glaring and clean. The differences in the occupants assessment for all these aspects of appearance between these two groups (facing and backing the window) are not big. The comparison of the mean values also shows that the semantic assessment for the other two groups would always be one or two tenths of a fraction up or down the scale of a given group e.g if positions with their back to the windows assessed pleasantness of work

position as 5.0 on the scale, position facing and with the windows to the side mean score is 4.5 and 3.9 respectively.

From the Kruskal-Wallis analysis none of the eye symptoms have a significance level of 0.05 (refer table 5.8a). For all the eye symptoms the significance level is always greater than this. The Kruskal-Wallis analysis (refer table 5.8b) also shows that none of the work position appearance have significant level of 0.05.

### **5.8.2 Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms**

The comparison of the mean value on eye symptoms have been related in the above section.

The comparison of the mean value (refer to table 5.8c) shows that occupants that sat with the windows to their side have the biggest depth in isoarea, and occupants with their back to the windows have the smallest. The isoperimeter area follows the isoarea closely. Work positions facing windows have biggest window area while work positions with their back to the windows have the smallest. A similar pattern is also observed for the ratio of the window area to the isoperimeter area. Work positions facing windows have the highest average luminance, and work positions with their back to the windows have the lowest. For the eye illuminance, work positions with the window to the side have the highest amount of light arriving to the occupants eyes, followed by work position with their back to the window. Occupants in work positions facing the window have the lowest amount of light arriving at their occupants eyes. The work top illuminances are not far apart. The ranking follows that of the amount of light arriving at the occupants eyes. For all the above observations, the standard deviation shows that there exists a big difference in the physical attributes between work positions facing the window as compared with work positions with their back to the window.

From the Kruskal-Wallis analysis (refer to table 5.8c) isoarea, isoperimeter area, window area, WA/IPA, and illuminance on the worktop have significance levels smaller than 0.05. Average luminance have a significance level of 0.06 which is marginal to the stipulated significance level adopted for this study. Only the amount of light arriving at the eyes has a significance level greater than 0.05.

### **5.8.3 Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of The Appearance From The Work Positions**

The occupants perception of the work position appearance was related in section 5.8.1, and the measured physical light attributes in the section 5.8.2.

## **5.9 DISCUSSIONS**

The weaknesses of the previous method were identified based upon the presentation and appraisal of the pilot studies to the research committee as well as comparing it to the run with Loe and Mansfield. A re-run with Loe and Mansfield was conducted from Monday 10th of May to Wednesday 12th of May, after the initial pilot study. The day time measurement was done from 8am in the morning till 6pm. This was carried out in the same building as for the pilot study.

### **5.9.1 Discussions On The Variables Measured**

Within the approach of the methodology, average luminance, daylight, and daylight factor (DF) are factors that had concerns with and need to be reconsidered. The reasons for this are as follows.

#### Average Luminance

In the pilot study, this measurements were done manually. The method used is inefficient because it takes 45 minutes to complete a work position's readings. This approach gives a range of value that need to be processed. When these data are processed to give the average value, it would introduce an error. This is because the average value is not representative of the light distribution as the approach adopted introduces a time lag. This time lag is significant because the light level at each specific point is a function of the exterior natural light which could have changed. The other inherent problem with this approach is that it also introduced selective measuring, that is spot measurements and a number of readings done to represent the space. These compound errors in the readings. It becomes complicated and cumbersome in spaces where the luminance ratio varies steeply. Where basic measurements that represent the physical light attributes is concerned, error is possible in obtaining the average luminance. There could be a potential error due to the way averages are arrived at.

Work positions facing windows have maximum luminance level that are very high (especially when it looks on to bright white clouds) but over smaller areas. Those with their back to the windows have luminance levels that are comparatively lower than those facing the windows but nevertheless quite high and covering large areas. Comparing these two situations, however, their average luminance could be the same. In order to rectify this situation, a researcher should consider "area weighted" in obtaining the average luminance. So as to allow for the area weighted and eliminate the subjective selection, a mechanical method of measuring is desired. This is taken care of by obtaining the average luminance using the semi-cylindrical cell as recommended by Loe. This device was developed based on the luminance scanner, (The cylindrical cell was calibrated in the lighting laboratory so that it reads like the light scanner<sup>68</sup>. The scanner is a "one off" research instrument and is not available for this study - The development of the semi-cylindrical cell to measure average luminance is described in detail in appendix 4). Using the cylindrical cell to obtain reading also enables the researcher to use more work positions for the study.

### Percentage Of Daylight

The initial attempt to determine a percentage of daylight in each work position was abandoned because it was intrusive, and involves switching the artificial light sources off which was disruptive to the office work. Developing this further it was thought that it could be determined by repeating all the above measurements when the sun set. Then subtracting the day measurements from the night measurements this would provide the percentage of daylight in the specific work position. These night measurements were carried out mostly in winter times as the building studied had restriction in accessibility later in the evenings. The whole concept of determining the daylight component proved unreliable as it was difficult to determine the lighting pattern. Sometimes part of the lighting installation was switched off by occupants. In fact, the lighting system was switched on or off at random according to the occupants needs and preference. On top of that, this reading would not be reliable as the illuminance levels could vary drastically as a function of the external illumination level. Thus, the idea to determine the percentage of daylight was eliminated.

---

<sup>68</sup> In the pilot study, where the outside sky was overcast and the interval readings throughout the day showed stable comparative readings the time lapse was not significant. The luminance scanner would determine brightness pattern in the visual field of the occupant. The scanner gives a better measuring time (12min) and this gives more readings (7200) within the visual field and a better representation of the luminance distribution. The light scanner reads as described above in the pilot study, except that its grid is much finer. Unfortunately, it was not available to the researcher.

## Daylight Factor (DF)

After discussion with Loe and a further literature review the researcher decided that space appraisal is not linked to DF on the horizontal. What would be useful is the DF on the vertical plane in the field of view (as has been discussed in the literature review, an individual's perception of space appearance is related to the vertical plane). However, this is a complicated process, because the DF involves not only one value as there could be a different number of planes receding in the field of view. The problem here is to determine in advance the planes involved.

## Additional Variables To Be Measured

From the presentation to the committee it was found that the physical measurements that described the lighting environment were inadequate and additional variables were needed. The additional variables that are required are added by the agreement and advice of the lighting research team in University College of London (UCL).

The additional variables to be measured were as follows:

1. luminance ratio.

This is obtained from already considered variables the maximum luminance and the minimum luminance.

2. ratio of solid angle.

- Solid angle of window.
- Solid angle of sky.

### **5.9.2 Instruments**

As a result of the adjustment to the approach for the average luminance and added variables, the instruments used for the specific physical measurement are as follows:-

- i) Average luminance - Hagner lux meter and semi-cylindrical cell  
(refer plate 5.9.2a)
- ii) Solid angle - solid angle slide ruler (refer plate 5.9.2b)

All other measurements uses the same instrument initially listed.



### **5.9.3 Approach**

This describes the few adjustments made on the approach of the methodology. It is deliberated under appropriate headings where the adjustments are made.

#### Average Luminance

The work position average luminance for the case studies was measured with the adapted semi-cylindrical cell. The cylindrical cell was mounted on the tripod stand and was levelled using a spirit level. The cell was constructed with a 40° mask (to avoid reading directly from the lighting installed immediately above the subject's head). This was then attached to a Hagner lux meter to enable a reading to be taken. This was done once for each work position.

#### Luminance Ratio

Luminance for the brightest and dimmest point on the vertical surfaces were taken in the field of view, as seen from occupants position to where these angles intersect with the boundaries of their work positions created by partitions or cabinets.

### **5.9.4 Sample Size**

As the analysis has pointed out, another weakness of the initial methodology lies in the cluster sample that is too small. The small sample size is highlighted as a potential problem in the non-parametric analysis. Thus, no significant difference is observed because the analysis involves two samples that represent thin cell (that is cell with number of samples less than 5). Where a process of elimination is called for, the sample then becomes too small to be reliable.

The problem with small samples is that it could not be statistically representative of the group. Besides, it is important to note here that the perception that is critical in this study is not of the individual but the population. Therefore, the investigation aims to include occupants in all occupied space on all floors. Where an organisation is particular regarding access to office areas, the number of floors accessible may be limited, floors with large number of occupants are chosen. This selection is negotiated

with LINK research group and the number of floors accessible will depend on this negotiation.

It was agreed by the research committee that the sample ought to be extended out of the cluster samples to a wider number of occupants. From the analysis studied it was shown that there was no necessity to be confined by the cluster monitored area as there was no need to correlate it as such. As a result of this sample consideration, the cluster strategy previously adopted is dropped.

### **5.9.5 Locations For The Measurements**

The physical data should logically be at regular intervals in an area. However, not all the spaces in the building can be monitored. Nevertheless, the researcher aims to conduct the physical measurements at such regular intervals as rendered possible.

The sample will be selected randomly. The occupants selection is randomised to receive either occupants facing or with their back towards the windows. Care is taken to ensure that every occupant has the same chance as any other to be selected. The random sampling gives every individual equal chances. The sampling method is analogous to "simple random sampling" that is sampling without replacement. The simple random sampling gives equal probability for all remaining individuals to be selected regardless of the individual being selected. In effect there is an independence from one draw to the next except for the fact that no individual can be selected twice.

The randomisation procedure, is established by the occupants vacating their seats thus allowing light measurement of their work position. By this manner, it is possible to ensure that any unmeasured compounding factors are equally distributed in both groups. This procedure also ensures unbiased effect-estimates and valid confidence intervals (there is a potential of skewing in the sampling i.e not sampling people whom are always occupying their seat. This is significant as the area under study is potentially more significant to these group of people) .

## **5.10 CONCLUSIONS**

From the discussions, it is concluded that on the whole the methodology is acceptable and remains the same. The weaknesses of the initial methodology lie in:

1. The method to obtain average luminance of the interior.

2. The sample size.
3. Inadequate physical measurements to described the lighting environment and existing variables that are inappropriate and need to be eliminated.

These problems will be addressed in the following case studies.

The method of obtaining the average luminance will be rectified using the semi-cylindrical cell.

In the following studies, the sample size is extended to all the occupants that responded to the survey questionnaire. Thus, the researcher is to conduct physical measurements for all these work positions where possible. However, the number of samples was limited by the time taken to complete measurements (which work out to be 7min per area). To facilitate mapping to the LINK physical environmental measurements it was preferable that all the lighting samples are executed within the defined area for the LINK monitoring. However, there exists a constraint imposed by LINK. LINK dictates that the eye health survey could only be conducted on 30 occupants so as not to jeopardise their position in the research due to frequent questionnaire distribution (as it was, the occupants had to keep diary for LINK). This stipulated condition deemed the survey obsolete. Reinforced by the pilot study that most office occupants do not experience problems with their eyes and are conscientious to check them regularly (every 3 years) this step in the analysis is abandoned.

The variables that are abandoned are:

- Percentage of daylight
- Daylight factor

The new list of variables required are:

- Luminance ratio.
- Solid angle of window.
- Solid angle of sky.
- Ratio of solid angle of window to solid angle of sky.

For both eye and worktop illuminance, only one measurement (the north reading as it proves to be the most significant) was measured instead of West, North-west, North, North-east and East.

Meanwhile, the analysis remains the same. Like the pilot study, the analysis consists of the same three levels.

## Chapter 6

### **CASE STUDY 1: Welsh Development Authority (WDA), Pearl Assurance House, Cardiff**

#### **6.0 INTRODUCTION: A Brief Description Of The Building**

Pearl Assurance House is a speculative 23 storey square shaped tower building (refer to figure 6.0 (1 and 2) and plate 6.0-1) built in the 1960's located in Cardiff city centre. The building is rented out to a number of organisations of which the Welsh Development Agency (WDA) is the major tenant (The WDA is a government funded body whose principal aims are the regeneration of the economy and the improvement of the environment of Wales). The WDA occupies half of the 4th and 8th floors, the whole of the 9th, 10th, 11th, 15th, 16th, 17th and 18th floors.

##### **6.0.1 Reasons For The Choice Of Building**

The building has been selected from those listed for LINK SBS study, so the building is appropriate from all other environmental aspects.

This building has been selected for this case study because it was speculatively built and was designed to have a uniform lighting in all occupied areas. The uniform lighting system has been achieved by:

- i) A linear array of fluorescent tubes<sup>69</sup> recessed into the ceiling.
- ii) A downward lighting luminaire<sup>70</sup>.

---

<sup>69</sup> In the literature review the study the study has identified that perception varies with light pattern on VWS. As the offices have integrated lighting the light pattern on the VWS is affected by the artificial and daylight sources. Where both factors vary, it is difficult to determine which changes that cause the variance in perception. Therefore, one of the factors has to be normalised. As most offices are speculatively built and the artificial lighting employs the uniform lighting concept and uses fluorescent lamps, it is easier to make this factor (the artificial lighting) constant rather than the source of the daylighting - the window opening.

<sup>70</sup> Specifying this luminaire category is important to ensure same light pattern distribution (different luminaires would give a different light pattern distribution on all planes), because a different light pattern distribution would give rise to a different environment and consequently change the occupants perception of the appearance from the work position.

## **6.1 THE DETAILED DESCRIPTION OF THE BUILDING**

This section is divided into 6 parts:

- i) The spatial organisation.
- ii) The room surfaces.
- iii) The electric lighting installation.
- iv) The window and daylighting.
- v) The light pattern on the surfaces.
- vi) The visual environment in the offices.

### **6.1.1 The Spatial Organisation** (refer to figure 6.3)

The basic arrangement of each of the floor is identical, consisting of a shallow ring of office accommodation surrounding a staircase, lift, WC and service central core, accessed by means of a north-south corridor. The overall dimension of the floor is small, giving an area of 772m<sup>2</sup> within the envelope of the external walls. Of this, 211m<sup>2</sup> is occupied by the central core. Effectively, nearly a third of the area is taken up by the core facilities.

The area between the circulation and the external walls is taken up by a mixture of single person offices, enclosed meeting rooms, and open plan office areas. The depth of the open plan office areas are a maximum of two work positions. The office accommodation is of equal width (6.2m) on three of the four sides of the building, slightly increases on the south side (9.0m). The extended office space adjacent to the services core on the south side is generally used for storage.

### **6.1.2 The Room Surfaces**

Using the reflectance card the interior reflectances were noted as follow:

wall	: white
Ceiling	: 58/58
Carpet grey	: 14/14 or dark grey 6/6
Table	: brown 16/14 or grey 42/42, red trays
Computers	: cream 80/80
Door	: Brown 48/44

The general colour of the interior is grey except for the chairs and the odd file or tray. The greyness accentuates the uniformity created by the lighting.

### 6.1.3 The Electric Lighting Installation

This section will describe:

- i. The lamps used
- ii. The fittings
- iii. Location of fitting
- iv. Control
- v. Operation

Being a speculative building, all floors have similar lighting installations except for the reception space. The study will ignore the reception as there is only one person there.

The offices use linear fluorescent tubes recessed in the ceiling. The fluorescent lamps are used to provide lighting to all areas. The fluorescent lamps are Thorn 36 watts pluslux 3500 white and are on a 1200x1200mm grid. On the internal walls, these same fluorescent tubes are placed on the vertical wall at the junction where this wall abuts the ceiling (refer plate 833, 1125, 1205, 2219, 2203 - this is a standard feature on all floors). These fluorescent lights are used as the emergency lighting. The emergency lighting is off during office hours, it goes on only when the office light is off. Thus, the emergency lighting plays no part in the research and it is excluded.

As explained in section 6.1.1 the office space occupies the outer ring. This continuous ring is interrupted now and again by individual office spaces. Otherwise the circulation corridor and open office space are one large open space divided by partitions that are head high. For the individual offices the control for the lighting is placed near the door. Meanwhile, the circulation corridor and open office spaces share a common control. The lighting circuit in the large open spaces is organised in batches and there is no local control for an individual occupant. The lighting circuits in each large open space are treated as one batch and the switch is placed on the internal wall near that particular open space. For both the individual office and open space there are no automatic timer nor light sensor employed. Some of the work positions (in individual offices and open space alike) have task lighting but this is not provided by the establishment. It was observed that these task lights are not used at all throughout the office hours.

At 8 o'clock every morning, the control, switches on the lighting over the whole of the building. Generally, this lighting remained switched on all the time during office hours. However, as occupants come in some of them start modifying this state of lighting. Thus, in some positions the lighting is switched off. As the space is shared by several

occupants the decision about switching on or off the light source is a consensus amongst them<sup>71</sup>.

#### **6.1.4 The Window And Daylighting**

The windows on each floor are the same. The windows are continuous on the outer wall and start at 1200mm from floor level and meet the ceiling. The height of the windows is 1200mm. The windows are unopenable single glazed with internal blinds to the south and west faces ( the transmission value of the glass are not available from Young nor Vaughan. According to Vaughan even the building management does not have information on this).

Due to the shallow depth of the building, the office spaces are expected to be predominantly daylit (maximum distance of the external wall to the internal wall defining the service core is 6.5m). However, this is not observed in the offices due to the screening<sup>72</sup> of the windows. In fact, even when blinds are not employed, only work positions immediately next to the window are predominantly daylit. This is due to the numerous number of partitions put up which obstruct daylight. This is observed more clearly for work positions below the 8th floor. This is because these positions look out onto an adjacent building that is 10m away, which tend to block out much of the daylight.

#### **6.1.5 The Light Pattern On The Surfaces**

The light pattern on the surfaces is the result of the interaction of the artificial lighting and the natural lighting.

The artificial light is directed down to light the horizontal worktops. The ceiling and walls are not given any emphasis. Although the ceiling is not illuminated, it is not dark

---

<sup>71</sup> The problem posed here lies in the fact that the control is by batch which means that when an occupant wants a particular light off the whole batch will be effected.

<sup>72</sup> Regarding the blinds on the windows, as the office is of open plan there exists a conflict of interest between occupants sitting besides the window and those sitting further away but facing it. The occupants in spaces near the window may desire to shut off the daylight due to intolerable light intensity when occupants further away welcome the mere idea of daylight. On the other hand occupants further away may desire to screen the window as the bright daylight introduces a glaring contrast and is the source of disabling glare. As the space was shared by several occupants the decision about blinds was a consensus amongst them.

nor does it introduce a harsh contrast with the luminaries<sup>73</sup>. These surfaces are lit with diffuse reflected light as a result of lighting the horizontal worktops. The artificial lighting gives diffuse lighting of nearly uniform brightness on the different surfaces throughout the entire office. However, for the walls, there is a cut off point which commonly occurs at 2/3 of the height of the wall from the floor. The cut off point is a blur.

The resultant light pattern on the surfaces depends on the superimposed daylight. Generally, the effect of daylight diminishes as the surface moves further away from the window<sup>74</sup>. For the horizontal surfaces (ceiling and worktops), areas nearer the windows are brightest and this light level drops gradually as the surface recedes into the building. Meanwhile, for the wall the light pattern varies according to the position of the wall in relation to the window. On the external wall, where windows are integrated, there exists a contrast between the bright window area and the wall area. The wall opposite to the external wall has uniform brightness. The daylight that falls on it superimposed on the light caused by the artificial lighting. The two flanking walls have uniform brightness vertically but this brightness level drops gradually as the wall recedes into the building.

#### **6.1.6 The Visual Environment In The Offices**

This section is a subjective evaluation of the visual environment in the office.

Although all the work positions are designed with uniform lighting they do not project the same visual environment - they do not look alike. The difference in the visual environment is not due to decoration, fixtures, fittings or finishes. The decorations are very basic. Generally, the work positions have the same fixtures and fittings. In all the work positions, the work surfaces are constantly cluttered with documents, books and papers.

The work positions vary in term of;

- varieties of colour in the field of view,
- complexity of surfaces in the field of view,

---

<sup>73</sup> From any seated position, the louvers cut off direct view to the light source and thus these do not pose a glare problem. The luminaire prevents glare in two ways:

- i) From any seated position, the louvers cut off direct view to the light source.
- ii) The use of low reflective louvers eluded high contrast between ceiling and the light source.

<sup>74</sup> This pattern in lighting is associated with the drop in light level attributed to daylight which falls off steeply once a person exceeds 6m into the building.



- distribution of light pattern.

Upon entering the office space the overall perception of the offices is dark and gloomy. The work positions are sectioned out into small corners with head high partitions. Most of the work positions has an arms length field of depth and looks up on to a partition. These partitions are then filled up with notes or personal effects. Now and again there are red chairs and red paper trays that brighten up the dull interior. Sometimes the whole front view is blocked by a huge computer monitor.

Colour wise the colour of the partition which is dark brown dictates the overall colour of the office. The photographs do not depict the true visual feel of the office due to technical limitation. There were no yellow walls as shown in the photos. The wall was painted beige.

However, the photographs do catch the way the lighting is distributed in the field of view. There is a wide range of lighting pattern observed. The building is shallow, therefore much of the lighting pattern is strongly influenced by the daylight. However the lighting for a space and slightly removed is visually different as the light level falls drastically as the distance away from the window gets bigger. A factor that contributes significantly to this effect is the highly partitioned work positions. However, most of the work position has the advantage of the daylight and as such shadows are casted and helps cue the space.

For work positions where the occupants are seated facing the windows, the luminances in the field of view are far apart and luminance goes limited to the range that the human eye can tolerate and the occupant can not see all parts of the scene; some things are concealed by extreme brightness or darkness.

However, there are still spaces that suffer low reflectance and luminance especially on the vertical surfaces. The illumination provided is high enough for acute vision, but it has a high degree of diffusion. This diffusion has a blanketing effect which primarily degrades the effect of shadow (brightness difference). Because of the shadow degradation the meaningful spatial information created by the light pattern is reduced. An indistinct visual haze hovers over the interior. The outlines of objects are softened. Foreground and background appear as one flat plane. Thus, it is difficult to distinguish objects or planes from one another. As a result, the environment suffers reduced three-dimensional modelling of solid objects, space, volume and surfaces. The environment lacks visual depth, and the space lacks focus and does not maintain visual attention. The environment seems grey, lifeless, uninteresting, dull, bland and boring. It lacks the

animated quality and is mechanised and sterile. In this environment it is also difficult to perceive details.

## **6.2 COLLECTION OF THE DATA**

The data was collected as explained in the methodology (refer to chapter 4). It is described under the relevant sections that follows.

### **6.2.1 Work Schedule**

The study was carried out from the Monday 2nd to Friday 6th of August 1993 in Pearl Assurance House. It started at 9.00am on the Monday and ended at 2.45pm on the Friday. The site measurements were continuous and begins at 9am and ended at 4.00pm. The measurements were conducted straight through the lunch breaks.

### **6.2.2 Floors Used In The Lighting Study**

The floors used in this study were those occupied by WDA and one of the minority tenant, Cardiff City Council which occupies only a single floor (floor 22). Thus the floors used in the study were 8, 11,12,14,15, 16, 17 and 22. On the 9th and 10th floors the questionnaire survey was carried out but it was not possible to carry out physical measurements. This was because these floors were undergoing refurbishment at the time of study. Additionally, for reasons of sensitivity no investigations were carried out on the 18th floor, which was occupied by the senior personnel of the WDA.

### **6.2.3 Problems And Mistakes Encountered In Obtaining The Data**

The errors and mistakes encountered in obtaining the data are similar to that discussed in chapter 5 (pilot study).

### **6.3 THE NUMBER AND LOCATIONS OF THE OCCUPANTS SAMPLED**

LINK survey managed to obtain 168 responses. Meanwhile 125 work positions were measured in the lighting study. On mapping the 125 physical measurements samples on to the 168 LINK questionnaire samples only 122 samples were obtained with both measurements and questionnaire. These 122 samples were then used in the study.

According to respondents own category the sample was drawn from 28 managerial - 7 females and 21 males, 32 professional - 17 females and 15 males, 29 executive and administrative - 20 females and 9 males, 16 from clerical - 15 females and 1 male, 10 from technical - 4 females and 6 males and 7 others - 6 females and 1 male (refer table 6.3a).

The sample was drawn from most groups in the working age range. There was one male within the age group 16-19, 14 males in the age group 20-29, 13 males in the age group 30-39, 18 males in the age group 40-49, 6 males in the age group 50-65. Meanwhile, there were 4 females in the age group 16-19, 33 females in the age group 20-29, 19 females in the age group 30-39, 6 females in the age group 40-49, 4 females in the age group 50-65 (refer table 6.3b).

On floor 8 there were 14 samples of which 4 were females and 10 were males. On floor 11 there were 18 samples of which 7 were females and 11 were males. On floor 12 there were 17 samples of which 13 were females and 4 were males. On floor 14 there were 4 samples of which 2 were females and 2 were males. On floor 15 there were 18 samples of which 10 were females and 8 were males. On floor 16 there were 16 samples of which 11 were females and 5 were males. On floor 17 there were 12 samples of which 7 were females and 5 were males. On floor 22 there were 23 samples of which 15 were females and 8 were males (refer table 6.3c).

There are three work position orientations: facing the windows, with the windows to the side and with the occupants back to the windows. There are 45 occupants seated facing the windows, 51 occupants seated with the windows to the side and 26 occupants seated with their backs to the windows in the 122 samples studied.

The locations of these 122 work positions are shown in figure 6.3. The photograph of each work position is shown in Plate 6.3(a-f). The photographs were taken from the work positions at the occupant's sitting position and the building is always positioned north to the top of the page.

## **6.4 THE DATA**

This section explains the data in 4 parts:

1. The distribution of the occurrences of eye symptoms in the sample.
2. The measured thermal and pollutants levels in the building.
3. The occupants assessments of appearance from the work positions.
4. The measured physical light attributes.

### **6.4.1 The Distribution Of The Occurrences Of Eye Symptoms In The Sample**

The distribution of the occurrence of eye symptoms for each group can be observed in figure 6.4.1(a and b) and the distribution of the eye symptoms occurrences on the floor plan can be seen in figure 6.4.1(c-g). The general trend observed from the eye symptoms distribution, for each of the eye symptoms (dry eyes, itching eyes, watering eyes, headache and problems with wearing contact lenses) is that the majority of the occupants suffer a few eye symptoms and only a small number of occupants suffer many eye symptoms.

### **6.4.2 The Measured Thermal And Pollutants Levels In The Building**

A variety of environmental parameters were recorded by LINK over short and long term monitoring periods. The equipments were situated in positions shown in figure 6.4.2. The measured thermal, relative humidity, air movement and pollutant level can be observed in table 6.4.2.

### **6.4.3 The Occupants Assessment Of The Appearance From The Work Positions**

The occupants assessed the appearance from the work position on a semantic scale of 0-7. The distribution of the stratified data on the occupants assessment of the appearance from the work position in each group can be observed in figure 6.4.3(a-c). The distribution shows that for all aspects of appearance each group displayed a similar range of assessments.

#### **6.4.4 The Measured Physical Light Attributes**

The distribution of the measured physical light attributes for each group can be observed in figure 6.4.4 (a-b) and table 6.4.4. Consistently, work positions facing the windows have higher measured physical light attributes.

### **6.5 THE LOGIC TREE FOR THE ANALYSIS**

Refer to section 5.6

### **6.6 THE ANALYSIS**

Refer to section 5.8.

#### **6.6.1 Analysis To Examine The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms**

Comparing the mean value (refer to table 6.6a), it is observed that occupants in work positions facing the windows have the lowest occurrences of dry eye. This is followed by the occupants in work positions that have the window to their side. The occupants that sat with their back to the windows have the most occurrences of dry eye. For itching eyes, occupants that sat with the windows to their side have the lowest symptom occurrence. This is closely followed by the occupants that sat facing, and those occupants with their back to the windows. For watering eyes, occupants that sat facing the windows have the lowest symptom occurrence whilst those who sat with the windows to their side have the highest. Fewer accounts of headaches were observed when occupants sat facing the window and with the window to their side. Where occupants sat with their back to the window a higher occurrences of headaches were reported. Problem with wearing contact lenses is highest for those occupants that sat with their back to the windows and least when occupants sat facing the windows.

From the comparison of the mean values (refer to table 6.6b), it is observed that occupants who work in positions facing the windows assessed their work positions as most pleasant, sociable, friendly, relaxing, inviting, homelike, spacious, airy, hot, and uncluttered compared to occupants in work positions with their back to the windows.

However, work positions facing the windows were assessed as least beautiful, interesting, emotionally warm, ordinary, private, cheerful, stimulating, visually warm, non-glaring, colourful, quiet, and clean which are opposite to that of work position where occupants were seated with their back to the windows except for ordinary and visually warm. Work positions where occupants were seated with their back to the window were also assessed as most satisfying, functional and light. The difference in the occupants assessment for pleasant, likeable, beautiful, inviting, functional, light, non-glaring, quiet, cold, clean and natural between these two groups (facing and with their back to the window) is not big. The comparison of the mean values also shows that the semantic assessment for the other two groups would always be one or two tenths of a fraction up or down the scale of a given group e.g if positions with their back to the windows assessed pleasantness of work position as 3.8 on the scale, the mean values for positions facing the widows and with the windows to the side are 4.1 and 3.7 respectively.

From the Kruskal-Wallis analysis, none of the eye symptoms has a significance level of 0.05 (refer table 6.6a). The Kruskal-Wallis analysis (refer table 6.6b) also showed that, only how ordinary the work positions appeared to the occupants has a significance level of 0.05. The other aspects of appearance have significance level greater than this.

### **6.6.2 Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms**

The comparison of the mean values on eye symptoms has been related in the above section.

The comparison of the mean value (refer to table 6.6c) shows that occupants that sat with the windows to their side have the biggest depth in isoarea and occupants with their back to the windows have the smallest. The comparison of the mean values shows that occupants in positions facing the window have the largest window solid angle projected to their eyes while occupants with their back to the window have the least. The ranking of the sky solid angle follows the same order, that is work positions facing the window have the biggest sky solid angle. Occupants in positions facing the window have the biggest ratio of the solid angles and those with their back to the window have the smallest. The analysis also shows that occupants in positions facing the windows have the highest average luminance, maximum luminance and luminance ratio. Occupants in these positions also have the highest amount of light arriving at their eyes. However, occupants with the windows to the side have the highest illuminance level on the work

top and higher minimum luminance values. For all the above observations, the standard deviation shows that there exists a big difference in the physical attributes between work positions facing the windows as compared to work positions with their back to the windows.

From the Kruskal-Wallis analysis (refer to table 6.6c) isoarea, the solid angle of the sky and window projected to the eyes of the occupants', the ratio of these solid angles, the average luminance (brightness of the field of view in the work position), the amount of light arriving at the occupants eyes, the maximum luminance (brightest spot in the field of view) and the luminance ratio have significance level smaller than 0.05. The worktop illuminance (DWT(E)), and minimum luminance have significance level greater than this.

### **6.6.3 Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of The Appearance From The Work Positions**

The occupants perception of the work position appearance has been related in the section 6.6.1 while the measured physical light attributes has been related in the section 6.6.2.

## **6.7 DISCUSSIONS**

### **6.7.1 The Data**

The bar chart of the eye symptom occurrence shows (refer to all of figure 6.4.1) that the distribution of number of occupants against the number of dry eye occurrence of each group has the same pattern. The number of occupants experiencing dry eyes more than 50 times a year is always considerably less than the number of occupants experiencing dry eyes less than 50 times a year (refer to appendix 5). The number of occupants experiencing dry eyes less than 50 times a year represents the largest group of people. All three groups (facing the windows, occupants with the windows to the side and occupants with their back to the windows) display some high occurrences of symptom, that is some occupants do have more than 50 occurrences of dry eye. Similar observations are observed for the other 3 symptoms considered. Only the headache group comparison has a problem of difference in the group of occupants experiencing different numbers of symptoms. Groups with the windows to the side and with their

back to the windows have occupants displaying high occurrence of symptom while the group facing the windows does not have any occupant that experienced dry eyes more than 50 times. When the group of occupants that experienced less than 50 symptoms over the last 12 months was analysed, no obvious pattern was observed. The bar chart of the occurrence of eye symptom shows that there is no difference in the occurrence of symptoms between occupants that sat facing the windows, with the windows to the side or with their back to the windows. Because of the bigger sample, however, the group with the window to the side is observed to have the largest number of occupants that do not experience any eye symptom. Otherwise the general trend in the occurrence of symptom distribution in the groups (facing the windows, the windows to the side and with their back to the windows) is the same.

The fact that some groups displayed high symptoms and others do not, in itself is not a problem, provided the samples have been screened and occupants that have eye health problems have been filtered out. Otherwise, when comparing the means, the result could be erroneous due to the fact that some groups have a high symptom score while others do not. This could lie in the fact that some of the occupants have some eye health problems which could not be isolated nor eliminated due to the methodology adopted. If these samples are constantly occurring in the group facing the windows, it will alter the mean value drastically and it will indicate as if occupants facing windows are having more eye symptoms. Whereas the true situation may have been the opposite.

#### **6.7.2 Discussion On The Relationship Between Thermal/Pollutants Levels And The Occurrences Of Eye Symptoms (refer table 6.4.2)**

The fresh air supply was satisfactory as compared to 8l/s as recommended by CIBSE. The temperature differences between the areas are comparable to each other. The temperature coupled with low air movement monitored suggest potential thermal discomfort.

Where Carbon dioxide (CO<sub>2</sub>) is concerned, it is generally accepted that the level needs to reach 1000ppm for adverse effects, such as headaches to occur. From the monitoring it was found that the building CO<sub>2</sub> level did not exceed this limit .

The WHO's long term limit for carbon monoxide (CO) is 50ppm and 500 for short term exposure. From the monitoring it was found that the building CO level did not exceed this limit.



Measurements taken during office hours showed that relative humidity to be around 50%. The critical relative humidity is 20%. Relative humidity below this level is said to threaten occupants well being. Thus the readings show that the relative humidity was far higher than the critical limit.

No recommended maximum level of volatile organic compounds has been set, however, different authors quote figures of 0.3-5 parts per million (ppm) as an appropriate maximum level. The maximum reading recorded is related to use of aerosol sprays when cleaners were around and this is not a constant problem.

For formaldehyde, the most stringent of the various international standards is the Swedish, set at 0.08ppm. However, the World Health Organisation's (WHO) concentration of concern is set at 0.1ppm. Scandinavian values is also 0.1ppm. From the monitoring it was found that the building formaldehyde does not exceed this limit.

The maximum level of dust recommended by the Canadians is  $0.1\text{mgm}^{-3}$ . Typical value of dust mite is 500 per gram of dust. In both case the LINK monitoring found it below described limits.

As a conclusion:

1. LINK's monitoring indicated a reasonably satisfactory environment within the recommended levels.
2. The examination shows that although the thermal environment, relative humidity and ventilation are comparable on all floors the occurrence of eye symptoms differs.
3. The close proximity of the symptomatic and asymptomatic areas indicates that the cause of eye symptom occurrence is not likely to be due to environmental factors.

### **6.7.3 Discussions On The Relationship Between Uniform Lighting And The Occurrences Of Eye Symptoms**

1. The case study is a speculative built building, it employs uniform lighting strategy and has standard office finishes. In the review of literature on SBS it has been argued that occurrence of eye symptoms is contributed to by the uniform lit environment. If the occurrence of eye symptoms is caused by uniform lighting it would be expected that all the occupants would be experiencing the same number of eye symptoms or there about.

2. The case study found that in a uniformly lit office building the occupants do not display similar occurrences of eye symptoms. This is demonstrated when the occurrence of eye symptoms was plotted out on the floor plan (refer figures 6.4.1(c-g)). This could be seen clearly especially when comparing occupants occupying the same office space or in close proximity to each other. In fact, some occupants do not experience eye symptoms at all.
3. This variation is not accountable by the distance from the window. The occurrence of eye symptoms also differs among occupants that are seated next to the windows.

#### **6.7.4 Discussions On The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms**

From the mean analysis it could be observed that occupants in work positions facing window have the least occurrence of dry eyes, watering eyes, headaches and problems wearing contact lenses. The comparison of the mean values also shows that the occupants perception of appearance from the work position varies with the occupants orientation with respect to the window. However, work positions facing windows do not constantly have the better perception in all aspects of appearance. In the analysis, work positions with their back to the windows have a better perception of certain aspects of the appearance from the work position.

Merging the above observations together suggests that work positions facing window have the least occurrence of dry eye, watering eye, headache and problems wearing contact lenses potentially as a result of them being assessed by the occupants as most pleasant, sociable, friendly, relaxing, inviting, homelike, spacious, airy and uncluttered. This suggests that occurrence of eye symptoms is associated with occupants perception of appearance of their work positions.

In "Stats View", as indicated in its manual, by using Kruskal-Wallis analysis variables that vary significantly according to the sub-division will automatically be given by the 0.05 significance level with correction for ties. However, the Kruskal-Wallis comparison shows that none of the comparisons of eye symptoms between the different work position orientations have a significance level of 0.05. This means that there are no significant differences for any of the five eye symptoms when the work positions are oriented differently towards the window. The Kruskal-Wallis comparison also shows that none of the comparisons for the aspects of appearance from the work position have

a significance level of 0.05 except for ordinary. This means that there are no significant differences for any of the aspects of appearance from the work positions except for ordinary.

The findings from the Kruskal-Wallis analysis are reliable as the analysis has made allowances for the askew in distribution and also the inequality in the number of sample. Besides, the Kruskal-Wallis analysis does not have a thin cell as each group (cell) consists of more than 5 sample<sup>75</sup>.

### **6.7.5 Discussions On The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms**

The discussion on the effect of orientation on occurrence of eye symptom has been discussed in the above section.

The comparison of the mean values shows that the light attributes of the work positions vary with its orientation with respect to the window. It shows that work positions facing the windows have higher reading of light attributes. The main governing attribute is the solid angle of window projected to occupants eyes. Logically, work positions facing the window has a window in view while those with their back to the windows do not. However, due to the configuration of the building these work positions sometimes look into a corner space that allow them some window areas projected to the eyes. However, where this does occur the solid angle is small. Thus, the solid angle of the window projected to the eyes of the occupants facing the window will always be greater than occupants with their back to the windows. As all the other variables are coupled with the presence of the window it is logical that the other variables vary in the same order. For instance, coupled with the window is the sky area. Thus work positions facing window will have a bigger sky area than work positions with their back to the windows. From here the ratio of the solid angle follows. The solid angle ratio of the sky to that of the window indicates the proportion the view of the sky that makes up the composition of the window. The ratio ranges from 0 to 1. When the ratio approaches 1 it means that the whole window is made up of the view of the sky and the ratio 0 means that there is no view of sky. Therefore, like the solid angle of window, work positions facing the window will have a bigger ratio than work positions backing the window.

---

<sup>75</sup> Should a group be small (thin cell) this ought to represent only 25%. In other words, if there are four groups and one group has less than 5 samples, the percentage this group constitutes of the total group is 20%. As this does not exceed the 25% it is possible to carry out the chi-square test.

In the comparison of the mean values, it is observed that occupants that sat with the windows to the side had the highest illuminance level on the work top and minimum luminance reading. The illuminance level could potentially be explained due to more occupants in these seat orientation were located nearer to the windows compared to work positions facing the window. Meanwhile, the higher minimum luminance is explained by the higher reflectance of the surrounding. In positions facing the windows, the artificial lighting is often switched off, and the light pattern adheres to external environment which has a big range of brightness. This is substantiated by the big luminance ratio for these work positions.

From the mean analysis it could be observed that occupants in work positions facing the window have the least occurrence of dry eye, watering eye, headache and problems wearing contact lenses. It is also observed that occupants in work positions facing the window have the highest reading on the solid angle of window projected to the occupants eyes, the solid angle of sky area projected to the occupants eyes, the ratio of solid angle, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. Merging these two observations together suggest that work positions facing the window have least occurrences of dry eye, watering eye, headache and problems wearing contact lenses potentially as a result of these work positions having the highest reading on the solid angle of window projected to the occupants eyes, the solid angle of sky area projected to the occupants eyes, the ratio of solid angle, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. This suggests that the occurrence of eye symptom is associated with the measured physical light attributes. Therein, occupants that are seated facing the window do have fewer eye symptoms as compared to the other two positions and they also have better measured physical lighting attributes as compared to the other two positions.

The Kruskal-Wallis comparison on eye symptom has been deliberated in section 6.7.4. The Kruskal-Wallis<sup>76</sup> comparison on the measured physical light attributes shows that the isoarea, the solid angle of the sky and window projected to the eye of the occupants', the ratio of these solid angles, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio have a significance level equal to or smaller than 0.05. This means that there are significant differences in these measured lighting attributes for the different orientations in work positions. The light level on the worktop denoted by  $Dwt(E)$  and the minimum luminance do not have

---

<sup>76</sup> In "Stats View", as indicated in its manual, by using Kruskal-Wallis analysis variables that vary significantly according to the sub-division will automatically be given by the 0.05 significance level with corrections for ties.

a significance level smaller or equal to 0.05, thus they do not vary significantly whether the work position faces the window, have the windows to their side or the windows to their back. In other words the work positions displayed similar light level on the worktop and minimum brightness.

From the Kruskal-Wallis comparison on the measured physical light attributes the only finding that does not seem sensible is that the significant difference in isoarea is due to the orientation of the work position. There are two potential reasons for this. The first reason is related to the shape of the building which has a shallow depth. Because of this, it was expected work positions with the windows to their side to have the biggest isoarea, for the reason that the open floor plan allows for the full run of the view of the building and also turns round corners. As shown by the comparison of the mean values, the seats with their back to the windows have the biggest field of view. The second reason is tied to the way the occupants choose to arrange the tables. In this building it is observed that the seats are arranged such that work positions facing the external wall and side walls are placed close to it thus allowing for a shallow depth in field of view. Meanwhile, for work positions with their back to the windows, the seats are placed far from the walls which allows for the depth in the field of view.

The Kruskal-Wallis analysis shows that there are no significant differences for any of the five eye symptoms when the work positions are oriented differently towards the window. The Kruskal-Wallis analysis also show that there are significant differences in solid angle of the sky and window projected to the eye of the occupants, the ratio of these solid angles, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio for the different orientations in work positions.

#### **6.7.6 Discussions On The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of Appearance From The Work Positions**

The study shows that work positions facing windows have higher luminance ratio than those with their back to the windows. Chapter 3 has argued that higher luminance ratio is associated with perception of interest. As such, work positions facing windows are anticipated to be more interesting. Yet, the study has shown that occupants in work positions facing the window assessed their work positions as least interesting. The analysis does not substantiate that high luminance ratios determine how interesting the work positions appear to their occupants. This opposed the finding established by Loe

et al (1994). Although a big luminance ratio is a criteria for projecting positive perception of appearance from the work position, an extremely large luminance ratio will cause eye fatigue and induces eye symptoms as the eyes have to adapt quickly over too wide a range.

As windows are the source of daylight it is expected that work positions facing windows would yield the highest physical reading of average brightness. Site measurements showed that work positions facing windows do have highest average luminance. However, the comparison of the mean values shows that occupants in these positions tend to assess their work positions as least light. This observation defies the argument that the occupants perceive their work positions as light because their work positions have higher average luminance. In this case the occupants do have higher average luminance but do not perceive their work positions as the lightest. The explanation for this potentially lies in the adaptation mechanism in connection with the fact that most of the occupants that sat facing the window are seated further away. As discussed in Chapter 3, the eye is naturally drawn to a bright surface. This bright surface dictates the adaptation level. Thus in work positions facing the windows the sky becomes the focus. As the window brightness remains constant irrespective of the occupants position, this results in the area below the adaptation level to be perceived as dark even if the actual physical quantity of light is not low. As such instead of perceiving the space positively it is conceived as not only as less light but also dark and gloomy. This is more so, when the window is a small but exceedingly bright area in the occupants central field of view (The distance of the occupant to the window makes the proportion of wall area greater than the window area).

The discussion on the perception of appearance has been related in section 6.7.4. From the mean analysis it is observed work positions facing the window were assessed by their occupants as most pleasant, sociable, friendly, relaxing, inviting, homelike, spacious, airy and uncluttered. The discussion on the measured physical light attributes has been related in section 6.7.5. In the mean analysis, it is also observed that occupants in work positions facing the window have the highest reading on the solid angle of the window projected to the occupants eyes, the solid angle of sky area projected to the occupants eyes, the ratio of solid angle, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. Merging these two observations together suggest that occupants in work positions facing the window assessed their work position as most pleasant, sociable, friendly, relaxing, inviting, homelike, spacious, airy and uncluttered because they have the highest reading on the solid angle of window projected to the occupants eyes, the solid angle of sky area projected to the occupants eyes, the ratio of solid angle, the average luminance, the

amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio.

The Kruskal-Wallis comparison shows that there are no significant differences on occupants perception for any of the aspects of appearance from the work positions except for ordinary. Work positions facing the window are least ordinary and work positions with the window to the side are the most ordinary. The Kruskal-Wallis comparison also shows that there are significant differences in the isoarea, the solid angle of the sky and window projected to the eye of the occupants, the ratio of these solid angles, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio for the different orientations in the work positions. Merging these two sets of observations, it is derived that occupants perception for any of the aspects of appearance from the work positions do not vary significantly although the measured physical lighting attributes do vary significantly between the work positions. This suggests that occupants perception of appearance from the work position is not significantly related to the measured physical light attributes. Therein, occupants that are seated facing the window do not have a significantly better perception of any of the aspects of appearance from the work positions as compared to the other two positions although they have significantly better measured physical lighting attributes as compared to the other two positions.

## **6.8 CONCLUSIONS**

- The occurrences of eye symptoms do not differ significantly with the different work position orientation. Occupants that are seated facing the window do not have fewer eye symptoms as compared to the other two positions
- Appearance from the work positions do not vary significantly with the different work position orientation. Occupants that are seated facing the window do not necessarily have better perception of appearance from the work position as compared to the other two positions.
- Light attributes vary significantly with the different work positions orientation

The occurrence of the eye symptoms is related to the occupants perception of appearance from the work position. The occurrences of the eye symptoms between the work positions do not vary significantly because occupants perceptions of appearance from the work position do not vary significantly with the occupants orientation with respect to the window.

The occurrence of the eye symptoms between the work positions do not vary significantly although the measured physical lighting attributes do vary significantly between the work positions. This implies that the occurrence of the eye symptoms is independent of the physical light attributes. Therein, occupants that are seated facing the window do not have significantly fewer eye symptoms as compared to the other two positions although they have significantly higher measured physical lighting attributes as compared to the other two positions.

As a conclusion, this case study finds that:

- i. Occupants perception of the appearance from the work position potentially has an effect on eye symptom occurrences. The mean comparison analysis suggests that occupants with a better perception of the appearance from the work position experience fewer eye symptom occurrences.

However, findings in the case study refute the hypothesis that :

- i. The appearance from the work position is affected by the work position orientation in relation to the windows
- ii. The appearance from the work position is related to the physical lighting attributes
- iii. Occupants in work positions facing the windows have a better perception of their work position appearance.
- iv. Occupants in work positions facing the windows have fewer symptom occurrences.



## Chapter 7

# CASE STUDY 2: Inland Revenue, Sapphire Plaza, Reading

## 7.0 INTRODUCTION: A Brief Description of The Building

The Sapphire Plaza building is a speculative five storey building located in a medium sized provincial city just east of Reading city centre (refer figure 7.0(1 and 2) and plate 7.0(1 and 2)). The building was constructed in 1988. The building is occupied by a single organisation, the present government department, in April 1990.

### 7.0.1 Reasons For The Choice Of Building

Refer section 6.0.1

## 7.1 THE DETAILED DESCRIPTION OF THE BUILDING

This section is divided into 6 parts:

- i) The spatial organisation.
- ii) The room surfaces.
- iii) The electric lighting installation.
- iv) The window and daylighting.
- v) The light pattern on the surfaces.
- vi) The visual environment in the offices.

### 7.1.1 The Spatial Organisation (refer to figure 7.3)

The overall form of the building is an irregular octagon, with four long and four short facades. An octagonal atrium is located in the centre of the building, which extends throughout the five floors. The basic form and layout of each of the floors is similar, each floor consists of a doughnut ring of office accommodation, interrupted by service cores located on the east and west sides of the building. The main core is located on the west side which consists of a pair of wall climber glazed lifts which project into the atrium, a small balcony to the atrium, a pair of WCs and a staircase. The secondary core is made up of a service lift, a plant room and staircase. On each floor the layout is a

mixture of open plan areas, single person enclosed spaces and fully enclosed rooms shared by a few occupants. The central part of the office accommodation (generally equidistant from the external and internal walls) is used as a circulation passage, which extends all the way around the building, passing through the cores.

The open plan areas are laid out with a proprietary furniture system. Most work positions are placed in blocks of four, with some two person blocks, and the odd single work position. Almost all the work positions are located along the external walls of the hexagon, giving views out while the inner walls are lined by storage cabinets. Apart from the storage units which are head high there are no further partitions or subdivisions within the open plan spaces. The single person spaces are enclosed by high partitions and doors, giving the appearance of an individual room, but with a gap near the ceiling. The fully enclosed rooms (for one or two persons ) are based on a mixture of permanent walls and demountable partitions. Single person spaces and enclosed rooms are located along both the internal and external walls of the building.

The ground floor differed from the others in the provision of the entrance foyer along the west elevation. Adjacent to this, in the south west corner there was a small public enquiry office. The north west external corner has two fully enclosed rooms. One is occupied by a typing pool, while the other held the switchboard, post and office service department. The remainder of the north side has single person spaces, while the south side has an open plan area. The atrium space is accessible from the ground floor and consisted of some landscaped seating areas, with a water feature.

The first and second floors are very similar, with open plan areas on the north and south sides of the building, and single person enclosed spaces on the north eastern corner. The third floor differed, in that the whole north side is occupied by single person enclosed spaces. Lastly, the fourth floor consisted of an open plan area on the north side of the building, enclosed interview rooms on the west side, a large seminar room in the south west side, a large seminar room in the south west corner, while the main plant room occupied the south east corner.

### **7.1.2 The Room Surfaces**

Using the reflectance card, the interior reflectances are noted as follow:

wall	: white
Ceiling	: 58/58
Carpet grey	: 14/14 or Dark grey 6/6
Table	: timber yellow with dark blue chairs and yellow doors
Computers	: cream 80/80
Door	: Brown 48/44

The general colour of the interior is grey except for the chairs and the odd file or tray. The greyness accentuates the uniformity created by the lighting.

### **7.1.3 The Electric Lighting Installation**

This section will describe:

- i. The lamps used.
- ii. The fittings.
- iii. Location of fittings.
- iv. Control.
- v. Operation.

Being a speculative building, all floors have similar lighting installations except for the reception space. Here, the study will ignore the lighting of the reception as there is only one person there.

The offices use linear fluorescent lamps encased in louvered luminaire fixed recessed into the ceiling (lighting installation flush with the ceiling). The fluorescent lamps are of type Thorn 36 watts pluslux 3500 white, and are on a 1200x1200mm grid. The fluorescent lamps are used to provided lighting to all areas. There are no wall washers or other type of remedial lighting is installed.

The single person enclosed spaces and fully enclosed rooms shared by a few occupants are totally separated from the corridor and each has a control for the lighting to itself and this is located near the door. For the open plan office areas, the corridor and open office space are one large open space divided by partitions that are head high. The lighting circuit in the large open spaces is organised in batches and there is no local control for the individual occupants. The lighting circuit in each large open space is

treated as one batch, and shares a common control which is placed on the internal wall nearby that particular open space. For both the individual office and open space there is no automatic timer nor light sensor employed. There is no evidence of task lighting on any work positions. It is not provided by the establishment nor made available by the occupant personally.

At 8 o'clock every morning some control switches on the lighting over the entire building. Generally, this lighting remained switched on all the time during office hours. However, as occupants come in they will change this state of lighting. Thus in some positions the lighting is switched off. As the space is shared by several occupants, the decision about switching on or off the light source is a consensus amongst them<sup>77</sup>.

#### **7.1.4 The Windows And Daylighting**

The windows on first four floors starting from ground level are all the same. The windows are continuous on the outer wall. It starts at 1200mm from floor level and meets the ceiling. The height of the windows is 1200mm. The window's dimension is the same on the fifth floor except it is tilted 20° to the vertical.

The windows are double glazed and tinted throughout (the transmission value of the glass are not available from Young nor Vaughan. According to Vaughan even the building management does not have information on this)

The office spaces are generally daylit as;

- i. the building has a shallow depth,
- ii. adjacent buildings do not obstruct daylight,
- iii. all work positions are placed radially adjacent to the external windows not exceeding 6.7m away from the external wall and there are few partitions employed. Where, partitions are put up, they do not obstruct natural light for two reasons. First reason is that these are placed parallel with the direction of light (perpendicular to the external wall). Secondly, these are placed further into the building, beyond the work positions, and nearer the internal wall.

However, some work positions are not day lit due to the screening on the windows. Work positions with screening on the windows are predominantly artificially lit but due

---

<sup>77</sup> The problem posed here lies in the fact that the control is by batch which means that when an occupant wants a particular light off the whole batch will be effected.

to visual link with adjacent spaces they have some component of daylight. Regarding the screening of windows, as the office is of open plan, there exists a conflict of interest between occupants sitting besides the window to those sitting further away but facing it. As the open plan office is large the occupants at the furthest distance have no control about screening of certain windows in their field of view although it might cause discomfort.

### 7.1.5 The Light Pattern On The Surfaces

The light pattern on the surfaces is the result of the interaction of the artificial lighting and the natural lighting.

The artificial light is directed downwards to light the horizontal worktops. The ceiling and walls are not given any emphasis. Although the ceiling is not illuminated, it is not dark nor does it introduce a harsh contrast with the luminaries<sup>78</sup>. These surfaces are lit with diffuse reflected light as a result of lighting the horizontal worktops. The artificial lighting gives diffuse lighting of nearly uniform brightness on the different surfaces throughout the entire office. However, for the walls, there is a cut off point which commonly occurs at 2/3 of the height of the wall from the floor. The cut off point is a blurr.

The resultant light pattern on the surfaces depends on the superimposed daylight. Generally, the effect of daylight diminishes as the surface moves further away from the window<sup>79</sup>. For the horizontal surfaces (ceiling and worktops), areas nearer the windows are brightest and this light level drops gradually as the surface recedes into the building. Meanwhile for the wall the light pattern varies according to the position of the wall in relation to the window. On the external wall, where windows are integrated, there exists a contrast between the bright window area and the wall area. The wall opposite to the external wall has uniform brightness. The daylight that falls on it superimposed on the light caused by the artificial lighting. The two flanking walls have uniform brightness vertically but the brightness level drops gradually as the wall recedes into the building.

---

<sup>78</sup> From any seated position, the louvers cut off direct view to the light source and thus these do not pose a glare problem. The luminaire prevents glare in two ways:

- i) From any seated position, the louvers cut off direct view to the light source.
- ii) The use of low reflective louvers eluded high contrast between ceiling and the light source.

<sup>79</sup> This pattern in lighting is associated with the drop in light level attributed to daylight which falls off steeply once a person exceeds 6m into the building.

### 7.1.6 The Visual Environment In The Offices

This section is a subjective evaluation of the visual environment in the office.

Although all the work positions are designed with uniform lighting they do not project the same visual environment - they do not look alike. The difference in the visual environment is not due to decoration, fixtures, fittings or finishes. The decorations are very basic. Generally, the work positions have the same fixtures and fittings. In all the work positions, the work surfaces are constantly cluttered with documents, books and papers. The obvious difference in the work positions is the lighting and the extent and depth of field of view.

The first impression of the overall visual environment is bright and official. However, it is not an uplifting environment that one feels delighted with or moved by it. In fact, the strip lighting on the ceiling has a feeling of a run way to it. Fortunately, much of this view is cut off by the geometry of the building. No high level partitions are employed in this office. Very few low ones are used. Most of the time the visual divisions are achieved by the file racks placed in front of the occupants on the tables. Personalization of the work position is kept to the minimum. Rarely are there work positions that face a wall (with scallop light pattern on it) that abut the lighting installation.

Colour variation in the work positions are also minimum. The difference in colour of objects are very much determined by the colour of files in the display racks. As such the reflectance and luminance also do not vary a great deal between the work positions. Some work positions has black face computer monitor and this makes up for the low luminance level. In other instances this low luminance level is a dark cabinet.

The cellular offices for the executive officers are much lighter visually as much of this dark objects are absent from view.

As in the first two case studies the work positions vary in term of;

- complexity of surfaces in the field of view,
- distribution of light pattern.

Most of the work positions has a large field of view provided the occupants craned their necks above the file racks. As such there are a range of complexity of surfaces in the field of view.

As most of the offices have access to a window the work positions are not lacking of shadow degradation and the lighting is not diffused. They have good three-

dimensional modelling of solid objects, space, volume, and surfaces. In most the luminances in the field of view are not far apart, and the occupant can see all parts of the scene rather than just some; nothing is concealed by extreme brightness or darkness, and luminance is limited to the range that the human eye can tolerate. However, the space lacks focus and does not maintain visual attention.

## **7.2 COLLECTION OF THE DATA**

The data was collected as explained in the methodology (refer to chapter 4). It is described under the relevant sections that follows.

### **7.2.1 Work Schedule**

The study was carried out from the 1st to 3rd of December 1993, and again on the 6th and 15th of December in Sapphire Plaza. It started at 9.00am on the Monday and ended at 2.45pm on the Friday. The objective measurements were done continuously between 9am and 4.00pm and were conducted straight through the lunch breaks.

### **7.2.2 Floors Used In The Lighting Study**

Office areas on all floors are included in the study. However, only part of floor 4 is measured. This is because it accommodates senior officers and also the remaining spaces are used as seminar or conference room.

### **7.2.3 Problems And Mistakes Encountered In Obtaining The Data.**

The errors and mistakes encountered in obtaining the data are similar to that discussed in chapter 5.

### **7.3 THE NUMBER AND LOCATIONS OF THE OCCUPANTS SAMPLED**

LINK survey managed to obtain 227 responses. Meanwhile 180 work positions were measured in the lighting study. On mapping the 180 physical measurements samples on to the 227 LINK questionnaire samples only 132 samples were obtained with both measurements and questionnaires. These 132 samples were then used in the study.

According to respondents own category the sample was drawn from 14 managerial - 9 females and 5 males, 10 professional - 5 females and 5 males, 5 executive and administrative category - 2 females and 3 males, 64 from clerical - 47 females and 17 male, 20 from technical - 5 females and 15 males and 1 others females (refer table 7.3a).

The age groups of the sample is such that there were none males within the age group 16-19, 5 males in the age group 20-29, 20 males in the age group 30-39, 14 males in the age group 40-49, 8 males in the age group 50-65. Meanwhile there was 1 females in the age group 16-19, 21 females in the age group 20-29, 18 females in the age group 30-39, 19 females in the age group 40-49, 26 females in the age group 50-65 (refer table 7.3b).

On the ground floor there were 44 samples of which 31 were females and 13 were males. On floor 1 there were 33 samples of which 20 were females and 13 were males. On floor 2 there were 26 samples of which 18 were females and 8 were males. On floor 3 there were 21 samples of which 11 were females and 10 were males. On floor 4 there were 8 samples of which 5 were females and 3 were males. (refer table 7.3c).

There are three work position orientations: facing the windows, with the windows to the side, and with their back to the windows. There are 61 occupants seated facing the windows, 56 occupants seated with the windows to the side, and 14 occupants seated with their back to the windows.

The locations of these 132 work positions are shown in figure 7.3. The photograph of each work position is shown in plate 7.3(a-h). The photos were taken from the work position at the occupant's sitting position, with the north of the building is always positioned to the top of the page.



## **7.4 THE DATA**

This section explains the data obtained in four parts.

1. The distribution of the occurrence of eye symptoms in the sample.
2. The thermal and pollutants levels in the building.
3. The occupants assessments of appearance from the work positions.
4. The measured physical light attributes.

### **7.4.1 The Distribution Of The Occurrences Of Eye Symptoms In The Sample**

The distribution of the occurrences of eye symptoms for each group can be observed in figure 7.4.1(a and b) and the distribution of the eye symptoms occurrences for each floor can be seen in figure 7.4.1(c-g). The general trend observed from the eye symptoms distribution, for each of the eye symptoms (dry eyes, itching eyes, watering eyes, headache and problems with wearing contact lenses) is that the majority of the occupants suffer a few eye symptoms, and only a small number of occupants suffer many eye symptoms.

### **7.4.2 The Measured Thermal And Pollutants Levels In The Building**

A variety of environmental parameters were recorded by LINK over short and long term monitoring periods. The equipments were situated in positions shown in figure 7.4.2. The measured thermal, relative humidity, air movement and pollutant level can be observed in table 7.4.2.

### **7.4.3 The Occupants Assessment Of The Appearance From The Work Positions**

The occupants assessed the appearance from the work position on a semantic scale of 0-7. The distribution of the occupants assessment of the appearance from the work position in each group can be observed in figure 7.4.3(a-c). The distribution shows that for all aspects of appearance, each group displayed a similar range of assessments.

#### **7.4.4 The Measured Physical Light Attributes**

The distribution of the measured physical light attributes for each group can be observed in figure 7.4.4 (a-b) and table 7.4.4. Consistently, work positions facing the windows have higher measured physical light attributes.

### **7.5 THE LOGIC TREE FOR THE ANALYSIS**

Refer to section 5.6

### **7.6 THE ANALYSIS**

Refer to section 5.8

#### **7.6.1 Analysis To Examine The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptom**

When comparing the mean values (refer table 7.6a) it is observed that occupants in work positions facing the windows have more occurrences of dry eye (21.6), headache (27.9) and problems when wearing contact lenses (8.9) than work positions with their back to the window. Work positions where the occupants are seated with their back to the window have the least occurrences of dry eye (2.6), itching eye (3.7), watering eye (0.9), headache (18.8) and problems with wearing contact lens (0.4). The work positions with the window to the side have the most occurrences of itching eye (15.1) and watering eye (3.7).

From comparing the mean values (refer table 7.6b), it is observed that occupants in work positions with their back to the windows assessed their work positions as most pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, clean, uncluttered and natural compared with occupants in work positions facing the windows and with the windows to the side. Work positions facing the windows are observed as least interesting, relaxing, inviting, ordinary, spacious and private. Meanwhile, work positions facing the windows are assessed as most peaceful, beautiful, sociable, emotionally warm, light and stimulating. The difference in the occupants

assessment between these two groups (facing and backing the window) is not big. The comparison of the mean values also shows that the semantic assessment for the other two groups would always be one or two tenth of a fraction up or down the scale of a given group e.g if positions with their back to the windows mean value on pleasantness of work position is 5.5 on the semantic differential scale, the mean value for positions facing and with the windows to the side is 4.7 and 4.9 respectively.

From the Kruskal-Wallis analysis none of the eye symptoms has significance level of 0.05 (refer table 7.6a), the significance level is always greater than this. From the Kruskal-Wallis analysis (refer table 7.6b) how quiet and uncluttered the work position appeared to the occupants have significant level of 0.05. The other aspects of appearance have a significance level greater than this.

### **7.6.2 Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms**

The comparison of the mean values on eye symptoms have been related in the above section.

The comparison of the mean values (refer to table 7.6c) shows that occupants that sat facing the windows have the biggest depth in isoarea, and those with their back to the windows have the smallest. The comparison of the mean values also shows that occupants in work positions facing a window have the largest window solid angle projected to their eyes while occupants with their back to the windows have none. Coupled with the window is the sky area, thus work positions facing windows have a large sky solid angle and those with their back to the windows have none. Occupants in work positions facing the windows also have the highest maximum luminance, minimum luminance, and its ratio. However, work positions facing the window do not have the highest average luminance, and amount of light arriving at the occupants eyes. Meanwhile, work positions with the windows to the side have the highest ratio of sky to window solid angle, average luminance, and amount of light arriving at the occupants eyes. The analysis shows that occupants in work positions with their back to the windows have the highest illuminance levels on the work top. For all the above observations, the standard deviation shows that there exists a big difference in the physical attributes between work positions facing the window as compared with work positions with their back to the windows.

From the Kruskal-Wallis non-parametric analysis (refer to table 7.6c) comparing the three different seat orientations, it was found that the isoarea, the solid angle of the sky, the area of window projected to the eye of the occupants', the average luminance and the amount of light arriving at the occupants eyes have a significance level smaller than 0.05. Meanwhile, the ratio of sky solid angle to window solid angle, the light level on the worktop denoted by  $Dwt(E)$ , the maximum and minimum brightness surface, and the luminance ratio have a significance level greater than 0.05.

### **7.6.3 Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of The Appearance From The Work Positions**

The occupants perception of the work position appearance was related in section 7.6.1, and the measured physical light attributes in the section 7.6.2.

## **7.7 DISCUSSIONS**

### **7.7.1 The Data**

Figure 7.4.1 shows that the number of occupants in each group differ. Group facing the window has the largest number of occupants and the group with their back to the windows has the least number of occupants.

The bar chart of the eye symptom occurrences (refer to figure 7.4.1) shows that the distribution of number of occupants against the number of dry eye occurrences for each group has the same pattern. The number of occupants that experienced dry eye more than 50 times a year is considerably less than the number of occupants that experienced dry eye less than 50 times a year. The number of occupants that experienced dry eyes less than 50 times a year has the largest group of people. Groups facing the windows and with the windows to the side have occupants displaying high occurrences of eye symptom while the group with their back to the windows does not have any occupants that have more than 50 occurrences of dry eye. Similar observations are observed for the other 4 symptoms considered. Only the headache group comparison does not have the problem of difference in number of occupants experiencing a different number of symptoms in the different groups.

The fact that some groups displayed high symptoms and others do not in itself is not a problem provided these samples have been screened and occupants that have eye health problem has been filtered out. Otherwise, when comparing the means the result could be erroneous due to the fact that some groups have a high symptom score while others do not. This could lie in the fact that some of the occupants have some eye health problems which could not be isolated nor eliminated due to the methodology adopted. If these samples are constantly occurring in the group facing the windows, it will alter the mean value drastically and it will indicate as if occupants facing windows are having more eye symptoms. Whereas the true situation may have been the opposite.

### **7.7.2 Discussions On The Relationship Between Thermal/Pollutants Levels And The Occurrences Of Eye Symptoms (refer table 7.4.2)**

The fresh air supply was satisfactory as compared to 8l/s as recommended by CIBSE. The temperature differences between the areas are comparable to each other. The air movement is sufficient and there was no thermal discomfort as the temperature was within the comfort zone.

Where CO<sub>2</sub> is concerned, it is generally accepted that the level needs to reach 1000 parts per million (ppm) for adverse effects, such as headaches to occur. From the monitoring it was found that the building CO<sub>2</sub> level did not exceed this limit.

The WHO's long term limit for carbon monoxide is 50ppm and 500ppm for short term exposure. From the monitoring it was found that the building CO level did not exceed this limit.

Measurements taken during office hours showed that relative humidity to be around 50%. The critical relative humidity is 20%. Relative humidity below this level is said to threaten occupants well being. Thus the readings show that the relative humidity was far higher than the critical limit.

No recommended maximum level of volatile organic compounds has been set, however, different authors quote figures of 0.3-5 (ppm) as an appropriate maximum level. The maximum reading recorded is related to use of aerosol sprays when cleaners were around and this is not a constant problem.

For formaldehyde, the most stringent of the various international standards is the Swedish, set at 0.08ppm. However, the World Health Organisation's (WHO) concentration of concern is set at 0.1ppm. Scandinavian values is also 0.1ppm. From the monitoring it was found that the building formaldehyde does not exceed this limit.

The maximum level of dust recommended by the Canadians is 0.1mgm<sup>-3</sup>. Typical value of dust mite is 500 per gram of dust. In both case, the LINK monitoring found it below described limits.

As a conclusion:

1. LINK's monitoring indicated a reasonably satisfactory environment within the recommended levels.
2. The examination shows that although the thermal environment, relative humidity and ventilation are comparable on all floors the occurrence of eye symptoms differs.
3. The close proximity of the symptomatic and asymptomatic areas indicates that the cause of eye symptom occurrence is not likely to be due to environmental factors.

### **7.7.3 Discussions On The Relationship Between Uniform Lighting And The Occurrences Of Eye Symptoms**

1. The case study is a speculative built building, it employs uniform lighting strategy and has standard office finishes. In the review of literature on SBS it has been argued that occurrence of eye symptoms is contributed to by the uniform lit environment. If the occurrence of eye symptoms is caused by uniform lighting it would be expected that all the occupants would be experiencing the same number of eye symptoms or there about.
2. The case study found that in a uniformly lit office building the occupants do not display similar occurrences of eye symptoms. This is demonstrated when the occurrence of eye symptoms was plotted out on the floor plan (refer to all figures 7.4.1. This could be seen clearly especially when comparing occupants occupying the same office space or in close proximity to each other. In fact, some occupants do not experience eye symptoms at all.
3. This variation is not accountable by the distance from the window. The occurrence of eye symptoms also differs among occupants that are seated next to the windows.

#### **7.7.4 Discussions On The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms**

For all the comparison of the mean values the means are very close to each other. The comparison of the mean values shows that when occupants sat with their back to the windows all five eye symptoms occurred less often. Meanwhile, occupants in work position facing the windows have more occurrences of 3 out of the 5 eye symptoms considered.

The mean analysis shows that occupants in work positions with their back to the windows assessed their work position as most pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, clean, uncluttered and natural compared to occupants in work position facing and with the windows to the side. Work positions facing windows are observed as least interesting, relaxing, inviting, ordinary, spacious and private. Meanwhile, work positions facing the windows are assessed as most peaceful, beautiful, sociable, emotionally warm, light and stimulating. The comparison of the mean values shows that the occupants perception of appearance from the work positions varies with the occupants orientation with respect to the window. This finding shows that work positions facing the windows do not constantly have a better perception in all aspects of appearance. In the analysis, work positions with their back to the windows have better perception of certain aspects of the appearance from the work position.

From the mean analysis it could be observed that for occupants in work positions with their back to the windows all five eye symptoms occur less often. These positions are also assessed by the occupants as most pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, clean, uncluttered and natural. Merging these two observations together suggest that work positions with their back to the windows have least occurrences of eye symptoms potentially as a result of them being assessed by the occupants as most pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, clean, uncluttered and natural. This suggests that occurrences of eye symptoms is correlated to occupants perception of appearance of their work positions.

The Kruskal-Wallis comparison shows that none of the comparisons of eye symptoms between the different work position orientations have a significance level of 0.05. This

means that there is no significant difference for any of the four eye symptom when the work positions are oriented differently towards the window. The Kruskal-Wallis comparison also shows that none of the comparisons for the aspects of appearance from the work position have a significance level of 0.05 except for quiet and uncluttered. This means that there are no significant differences for any of the aspects of appearance from the work positions except for quiet and uncluttered.

### **7.7.5 Discussions On The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms**

The discussion on the effect of orientation on symptom occurrence has been discussed in the above section.

The comparison of the mean values shows that the light attributes of the work positions vary with its orientation with respect to the window. Work positions facing the windows have higher reading of light attributes. The main governing attribute is the solid angle of the window projected to occupants eyes. Logically work positions facing the window have a window in view while those with their back to the windows do not. Thus, solid angle of the window projected to the eyes of occupants facing the windows will always be greater than occupants with their back to the windows. As all the other variables are coupled with the presence of the window it is logical that the other variables vary in the same order. For instance, coupled with the window is the sky area. Thus, work positions facing the window will have a bigger sky area than work positions with their back to the windows. The analysis shows that occupants in work positions facing the windows have the highest maximum luminance and its ratio. In positions facing windows the light pattern adheres to the external environment and this can vary significantly.

However, work positions facing the window do not have the highest average luminance and amount of light arriving at the occupants eyes. Meanwhile, work positions with the windows to the side have the highest, ratio of sky to window solid angle, average luminance and amount of light arriving at the occupants eyes (The solid angle ratio of the sky to that of the window indicates the proportion the view of the sky that makes up the composition of the window. The ratio ranges from 0-1. When the score approaches 1 it means that the whole window is made up of the view of the sky and the score 0 mean there is no view of sky). Work positions with the windows to the side have the biggest luminance ratio as these positions see a bigger area of the sky. In the



comparison of the mean values, it is also observed that occupants in work positions with their back to the windows have the highest illuminance level on the work top and minimum luminance. The illuminance level could potentially be explained due to the superimposed artificial lighting on the daylight component while work positions facing the windows and with the windows to the side have only daylight component due to the fact that they have the artificial light switched off. Meanwhile, the higher minimum luminance is explained by the higher reflectance of the surrounding.

From the mean analysis (refer back to figure 7.6a) it could be observed that occupants in work positions with their back to the windows have the least occurrence of all five eye symptoms considered. It is also observed that occupants in work positions with their back to the windows have the lowest reading on the solid angle of window projected to the occupants eyes, the solid angle of sky area projected to the occupants eyes, the ratio of solid angles, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. Merging these two observations together suggest that occupants in work positions with their back to the windows have least occurrence of eye symptoms potentially due to these work positions having the lowest reading on the solid angle of window projected to the occupants eyes, the solid angle of sky area projected to the occupants eyes, the ratio of solid angle, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. This suggests that occurrence of eye symptoms is associated with the measured physical light attributes. Therein, occupants that are seated facing the window do not have fewer eye symptoms as compared to the positions with their back to the windows because they have higher measured physical lighting attributes.

The Kruskal-Wallis<sup>80</sup> analysis on eye symptoms has been deliberated on in section 7.7.4. The Kruskal-Wallis comparison on the measured physical light attributes shows that the isoarea, the solid angle of the sky, the area of window projected to the eye of the occupants', the average luminance and the amount of light arriving at the occupants eyes have a significance level equal to or smaller than 0.05. This means that there are significant differences in these measured lighting attributes for the different orientations in work position. The ratio of sky solid angle to window solid angle, the light level on the worktop denoted by  $Dwt(E)$ , the maximum and minimum brightness surface, and the luminance ratio do not have a significance level smaller or equal to 0.05, thus these variables do not vary significantly with the work positions orientation. In other words the work positions displayed a similar ratio of sky solid angle to window solid angle,

---

<sup>80</sup> In "StatsView", as indicated in its manual, by using Kruskal-Wallis analysis variables that vary significant according to the sub-division will automatically be given by the 0.05 significance level with corrections for ties.

light level on the worktop denoted by  $Dwt(E)$ , maximum and minimum brightness surface, and luminance ratio.

From the Kruskal-Wallis comparison on the measured physical light attributes the only finding that does not seem sensible is that the significant difference in isoarea is due to the orientation of the work positions. There are two potential reasons for this. The first reason is related to the shape of the building which has a shallow depth. Because of this, it was expected that work positions with the windows to their side to have the biggest isoarea, for the reason that the open floor plan allows for the full run of the view of the building and also turns round corners. However, the comparison of the mean values shows that occupants that sat facing the windows have the biggest depth in isoarea, and those with their back to the windows have the smallest. This is because in these building partitions were put up at close intervals that cut off the view of the building. The second reason is tied to the way the occupants choose to arrange the tables. In this building it is observed that the seats are arranged such that work positions facing the internal wall are placed close to it, thus allowing for a shallow depth in field of view. Meanwhile, for work positions facing the windows, the seats are placed far from the walls which allows for the depth in the field of view.

The Kruskal-Wallis analysis shows that there are no significant differences for any of the five eye symptoms when the work positions are oriented differently towards the window. The Kruskal-Wallis analysis also show that there are significant differences in the solid angle of the sky, area of window projected to the eye of the occupants', average luminance and the amount of light arriving at the occupants eyes for the different orientations in work positions.

#### **7.7.6 Discussions On The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of Appearance From The Work Positions**

The study shows that work positions facing windows have higher luminance ratio than those with their back to the windows. Chapter 3 has argued that higher luminance ratio is associated with perception of interest. As such, work positions facing windows are anticipated to be more interesting. Yet, the study has shown that occupants in work positions facing the window assessed their work positions as least interesting. The analysis does not substantiate that high luminance ratios identify how interesting the work positions appear to their occupants. This opposed the finding established by Loe et al.

As windows are the source of daylight it is expected that work positions facing the windows would yield the highest reading of average brightness and the literature note that due to this average brightness the occupants would perceive their work positions as light. Site measurements shows that work positions facing the windows do not have the highest average luminance. However, analysis shows that these occupants tend to assess their work positions as the lightest. This observation defies the argument that the occupants perceive their work positions as light because their work positions have higher average luminance. In this case the occupants do not have higher average luminance but perceive their work positions as the lightest. The only explanation that can explain this effect is the adaptive mechanism in the human eye. As there was no drastic contrast and all the luminance were in the same range it does not result in some parts of the area to be perceived as dark and being below the adaptation level even if the actual physical quantity of light is not high. As such instead of perceiving the space negatively the space is conceived as light.

The mean analysis on the aspects of appearance has been deliberated in section 7.7.4. While the analysis on the measured physical light attributes is deliberated in section 7.7.5.

The mean analysis shows that occupants in work positions with their back to the windows assessed their work positions as most pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, clean, uncluttered and natural compared to occupants in work positions facing the windows and with the windows to the side. The comparison of the mean values on the physical light attributes show that occupants in work positions with their back to the windows have the lowest reading on all the physical light attributes considered, namely the solid angle of the window projected to the occupants eyes, the solid angle of sky area projected to the occupants eyes, the ratio of solid angle, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. Merging these two observations together suggest that occupants in work positions with their back to the windows assessed their work position as most pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, clean, uncluttered and natural potentially due to these work position having the lowest reading on the solid angle of window projected to the occupants eyes, the solid angle of sky area projected to the occupants eyes, the ratio of solid angle, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. This suggests that occupants perception of the appearance of their work positions is

associated with the measured physical light attributes. Therein, occupants that are seated facing the windows do not have better perception of the appearance of their work positions as compared to the positions with their back to the windows although they have higher measured physical lighting attributes.

The Kruskal-Wallis comparison on the aspect of appearance is deliberated in section 7.7.4 while the Kruskal-Wallis comparison on the measured physical light attributes is deliberated in section 7.7.5. The Kruskal-Wallis comparison on the aspect of appearance shows that there are no significant differences on the occupants perception for any of the aspects of appearance from the work positions between the three different seat orientations except for quiet and uncluttered. Work positions facing the windows are least uncluttered but most quiet. The Kruskal-Wallis comparison on the measured physical light attributes shows that there are significant differences in the isoarea, the solid angle of the sky, the area of window projected to the eye of the occupants', average luminance and the amount of light arriving at the occupants eyes for the different orientations in work positions. Merging these two sets of observations, it is derived that occupants perceptions for any of the aspects of appearance from the work positions do not vary significantly although the measured physical lighting attributes do vary significantly between the work positions. This suggests that occupants perceptions of appearance of work position is not significantly related to the measured physical light attributes. Therein, occupants that are seated facing the windows do not have a significantly better perception for any of the aspects of appearance from the work positions as compared to the other two positions although they have significantly better measured physical lighting attributes as compared to the other two positions.

## **7.8 CONCLUSIONS**

- The occurrences of eye symptoms do not differ significantly with the different work position orientation. Occupants that are seated with their back to the windows do not have significantly fewer eye symptoms as compared to the other two positions (The mean analysis shows that occupants with their back to the windows have the least occurrences of eye symptoms).
- Appearance from the work positions do not vary significantly with the different work position orientation. Occupants that are seated facing the window do not have a significantly better perception of appearance from the work position as compared to the other two positions.

- Light attributes vary significantly with the different work position orientation. Occupants that are seated facing the window have significantly higher measured physical lighting attributes as compared to the other two positions.

The occurrence of the eye symptoms is related to the occupants perception of appearance from the work position. The eye symptoms between the work positions do not vary significantly potentially because the occupants perceptions of appearance from the work position do not vary significantly with the occupants orientation with respect to the windows.

The occurrence of the eye symptoms between the work positions does not vary significantly although the measured physical lighting attributes do vary significantly between the work positions. This implies that the occurrence of the eye symptom is independent of the physical light attributes.

As a conclusion, this case study finds that:

- i. Occupants perception of the appearance from the work position has an effect on eye symptom occurrences. The mean comparison analysis suggests that occupants with a better perception of the appearance from the work position experience fewer eye symptom occurrences.

However, findings in the case study refute the hypothesis that :

- i. The appearance from the work position is significantly affected by the work position orientation in relation to the windows.
- ii. The appearance from the work position is significantly related to the physical lighting attributes
- iii. Occupants in work positions facing the windows have a significantly better perception of their work position appearance.
- iv. Occupants in work positions facing the windows have significantly fewer symptom occurrences.

## Chapter 8

# **CASE STUDY 3: Oversea Development Agency (ODA), ODA Building, Victoria Street, London**

## **8.0 INTRODUCTION: A Brief Description of The Building**

The building, which is located in central London (refer to figure 8.0(1 and 2) and plate 8.0 (1, 2 and 3)) was constructed in 1962. The building is an inverted "T" shape speculative 15 storey office building consisting of one long and two short wings. The two short wings, referred to as the east and west wings, are of 10 storeys. There is also a basement, which is given over partly to offices and partly to car parking.

The building is occupied by a government agency who moved into the building in 1991 following an interior refurbishment. The agency occupies part of the basement, all of the ground floor, the first floor except the tower and west wing, all of the second to the sixth floor and the seventh floor, except on the east wing.

### **8.0.1 Reasons For The Choice Of Building**

Refer section 6.0.1

## **8.1 THE DETAILED DESCRIPTION OF THE BUILDING**

This section is divided into 6 parts:

- i) The spatial organisation.
- ii) The room surfaces.
- iii) The electric lighting installation.
- iv) The window and daylighting.
- v) The light pattern on the surfaces.
- vi) The visual environment in the offices.

### **8.1.1 The Spatial Organisation** (refer to figure 8.3)

Except for the first floor, all the floors are of the same basic configuration. The building is narrow in plan, with a central circulation corridor running down each of the wings. Cellular offices, with full height walls, are located on both sides of the corridor. The main core consisting of lifts, WC's and staircase are located at the apex of the "T". Additional fire escape stairs are located at the extremity of each of the wings, with a goods lift being located in the corner of the east wing.

On each of the floors, the offices varied in size. The location of walls is governed by the location of the window mullions. Consequently, the rooms varied from those which are two window modules wide, to those which are five or more. However, their depth is constant (5.5m), based on the distance from the external walls to the central corridor. An allocation policy based on employee grade is applied. The least senior staff shared rooms and have low space standards. Higher grade personnel occupied small individual rooms, which gradually increased in size according to rank. The most senior staff have large individual rooms, which are approached via an anti-chamber office for a secretary or personal assistant. A variety of furniture types are employed, with senior staff generally having more furnitures which are of higher quality, than that assigned to junior staff.

The organisation consists of many small, generally self-contained departments. The rooms occupied by each department tend to be located adjacently on the same floor. Small and large rooms are located adjacently to each other, with the mixture of rooms varying from floor to floor, and from wing to wing.

### **8.1.2 The Room Surfaces**

Using the reflectance card, the interior reflectances are noted as follow:

Wall : white  
Ceiling : 58/58  
Carpet grey : 14/14 or Dark grey 6/6  
Table : grey 42/42 with turquoise  
Computers : cream 80/80  
Door : Brown 48/44

The general colour of the interior is grey except for the chairs and odd file or tray. The greyness accentuate the uniformity created by the lighting.

### 8.1.3 The Electric Lighting Installation

This section will describe:

- i. The lamps used.
- ii. The fittings.
- iii. Location of fitting.
- iv. Control.
- v. Operation.

Being a speculative building, all floors has similar lighting installations except for the reception space. The study will ignore the reception as it is occupied by only one person.

The offices use linear fluorescent lamps recessed in the ceiling. The fluorescent lamps are of type Thorn 36 watts pluslux 3500 white and were on a 600 x 600mm grid, and half of that to the walls. The fluorescent lamps used to provided lighting to all areas.

As explained in section 8.1.1, on each floor there is a central circulation corridor running down each of the wings. Cellular offices, with full height walls, are located on both sides of this corridor. Some of these cellular offices are for individual while others are shared by a few occupants. On each wing, the single stretch of corridors is divided by fire doors. Each division of the corridor has the lighting installations set in a batch, controlled by one switch. Meanwhile, in each of the cellular offices there is no local control or switch but one main switch placed at the door to the cellular office. There is no automatic timer nor light sensor employed. There are no evidence of task lighting on any work positions as it is not provided by the establishment nor made available by the occupants personally.

At 8 o'clock every morning, the control, switches on the lighting over the entire building. The lighting on the corridor and the offices are switched on all the time throughout the office hours. However, in the offices, as occupants come in some will change this state of lighting. Thus in some positions the lighting is switched off. As the space is shared by several occupants, the decision about switching on or off the light source is a consensus amongst them<sup>81</sup>.

---

<sup>81</sup> The problem posed here lies in the fact that the control is by batch which means that when an occupant wants a particular light off the whole batch will be effected.



#### **8.1.4 The Window And Daylighting**

The windows on each floor are the same, double glazing with blinds between panes (the transmission value of the glass are not available from Young nor Vaughan. This makes the window quite recessed. According to Vaughan even the building management does not have information on this). The windows are continuous on the outer wall and start at 1200mm from floor level and meet the ceiling. The height of the window is 1200mm.

Due to the shallow depth which is less than 6m and the large window area, the office spaces have a big component of daylight. The windows do not employ much screening. However, work positions further away from the windows in some instances do not get much daylight as a result of the partitions put up which obstruct daylight.

#### **8.1.5 The Light Pattern On The Surfaces**

The light pattern on the surfaces is the result of the interaction of the artificial lighting and the natural lighting.

The artificial light is directed downwards to light the horizontal worktops. The ceiling and walls are not given any emphasis. Although the ceiling is not illuminated, it is not dark nor does it introduce a harsh contrast with the luminaries. These surfaces are lit with diffuse reflected light as a result of lighting the horizontal worktops. The artificial lighting gives diffuse lighting of nearly uniform brightness on the different surfaces throughout the entire office. However, for the walls, there is a cut off point which commonly occurs at 2/3 of the height of the wall from the floor. The cut off point is a blurr.

The resultant light pattern on the surfaces depends on the superimposed daylight. Generally, the effect of daylight diminishes as the surface moves further away from the window. So, for the horizontal surfaces (ceiling and worktops) areas nearer the windows are brightest and this light level drops gradually as the surface recedes into the building. Meanwhile, for the wall, the light pattern varies according to the position of the wall in relation to the window. On the external wall, where windows are integrated, there exists a contrast between the bright window area and the wall area. The wall opposite to the external wall has uniform brightness. The daylight that falls on it superimposed on the light caused by the artificial lighting. The two flanking walls have uniform brightness vertically but the brightness level drops gradually as the wall recedes into the building.

### **8.1.6 The Visual Environment In The Offices**

Although all the work positions are designed with uniform lighting they do not project the same visual environment - they do not look alike. The difference in the visual environment is not due to decoration, fixtures, fittings or finishes. The decorations are very basic. Generally, the work positions have the same fixtures and fittings. In all the work positions, the work surfaces are constantly cluttered with documents, books and papers.

On the whole the building is bright and light. The building is shallow thus all the work position are closed to a window. As the windows are recessed this makes the light level fall quite drastically. As such work positions that are located slightly away do have lower light level and seems much gloomier as compared to those placed immediately to a window.

The colour effect is minimal in this building. Mostly due to the rare one or two red files. On the whole the building is very grey as this is the colour for all the fixtures and fittings.

The depth of field of view for the work positions are mostly about 6m. This is because all the work positions are contained in small rooms. The largest room is approximately 6 by 10m. No high level partitions are employed. The set up of the work positions is similar to Reading Sapphire Plaza. Most of the time the visual divisions are achieved by the file racks placed in front of the occupants on the tables. Personalization of the work position is kept to the minimum.

Work positions facing the window have a big range of luminance. Fortunately these windows are often positioned obliquely to the work positions. As such these work positions suffer to a lesser degree the problem of contrast. In work positions not facing the windows, the luminances in the field of view are not far apart, and the occupant can see all parts of the scene rather than just some; nothing is concealed by extreme brightness or darkness, and luminance is limited to the range that the human eye can tolerate.

As all work positions are close to a window, they do not suffer shadow degradation. As a result, the environment have reasonable three-dimensional modelling of solid objects, space, volume and surfaces.

## **8.2 COLLECTION OF THE DATA**

The data was collected as explained in the methodology (refer to chapter 4). It is described under the relevant sections that follows.

### **8.2.1 Work Schedule**

- The survey questionnaire was conducted in the first week of March 1994. The occupants were given 1 week to respond<sup>82</sup>.
- Long term temperature monitoring was conducted between 8th April and 5th May.
- Diary studies were conducted over four weeks between 11th April and 5th May. (refer figure 7.1)
- The physical light measurements were carried out on Tuesday and Wednesday 24th and 25th of May 1994. It started off at 10.00am on the Tuesday and ended at 5.00pm on the Wednesday. During the course of the day, the site measurements began at 9am and ended at 4.00pm. The measurements were conducted straight through the lunch breaks. The eye health questionnaires were distributed and collected on 6th October 1994.

### **8.2.2 Floors Used In The Lighting Study**

Since the management was particular about security and access, LINK not wanting to jeopardise their study allowed the researcher limited access. As the result of this condition a compromise was made with the LINK project coordinator. It was agreed that the researcher could have access to 4 floors for the lighting studies and this was limited to some rooms, basically avoiding personnels offices. The researcher opted to use floors 2, 3, 4 and 6 because it contained bigger offices shared by many occupants thus giving a bigger sample number.

---

<sup>82</sup> The respondents filled the questionnaires according to their own available time while at work. Thus, occupants responses were at different time.

### **8.2.3 Problems And Mistakes Encountered In Obtaining The Data.**

The errors and mistakes encountered in obtaining the data are similar to that discussed in chapter 5 (pilot study).

## **8.3 THE NUMBER AND LOCATIONS OF THE OCCUPANTS SAMPLED**

LINK survey managed to obtain 376 responses. These 376 responses represent 64 percent of the organisation's employees occupying the building who took part in the survey by completing the LINK questionnaire. Meanwhile, 68 work positions were measured in the lighting study. This is the result of the constraint imposed as mentioned in 8.2.2, the light physical measurements were conducted for occupants that had responded to the LINK questionnaire survey only. As LINK was not able to identify the positions that responded to the LINK questionnaire due to lagging in data processing, this was ascertained by asking the room occupant. On mapping the 68 physical measurements samples on to the 376 LINK questionnaire samples only 44 samples were obtained with both measurements and questionnaires. These 44 samples were then used in the study.

According to the respondents own category the sample was drawn from 11 managerial - 7 females and 4 males, 4 professional - 1 females and 3 males, 17 executive and administrative category - 4 females and 13 males, 9 clerical - 3 females and 6 males, none from technical and 3 others of which all are females (refer table 8.3a).

The sample is drawn from most groups in the working age range. None of the sample is in the age group of 16-19. There are 8 males in the age group 20-29, 6 males in the age group 30-39, 5 males in the age group 40-49, 6 males in the age group 50-65 and one that did not specify his age. Meanwhile, there are 5 females in the age group 20-29, 6 females in the age group 30-39, 1 female in the age group 40-49, 3 females in the age group 50-65 and 3 females that did not specify their age (refer table 8.3b).

On floor 2 there are 8 workers of which 5 are females. On floor 3 there are 3 samples of which 2 are females. On floor 4 there are 15 samples of which 4 are females. On floor 6 there are 18 samples of which 7 are females (refer table 8.3c).

There are three work position orientations: facing the windows, with the windows to the side and with the occupants back to the windows. There are 23 occupants seated facing

the windows, 15 occupants seated with the window to the side and 2 occupants seated with their back to the windows in the 44 samples studied.

The location of these 44 work positions is shown in figure 8.3. The photograph of each work position is shown in plate 8.3(a-d). The photographs were taken from the workplace at the occupant's sitting position and the north of the building is always positioned to the top of the page.

## **8.4 THE DATA**

This section will explain the data obtained in four parts.

1. The distribution of the occurrence of eye symptoms in the sample.
2. The measured thermal and pollutants levels in the building.
3. The occupants assessments of appearance from the work positions.
4. The measured physical light attributes.

### **8.4.1 The Distribution Of The Occurrences Of Eye Symptoms In The Sample**

The distribution of the occurrence of eye symptoms for each group can be observed in figure 8.4.1(a and b), and the distribution of the occurrence of eye symptoms for each floor can be seen in figure 8.4.1(c-f). The general trend observed from the eye symptoms distribution, for each of the eye symptoms (dry eyes, itching eyes, watering eyes, headache and problems with wearing contact lenses) is that the majority of the occupants suffer a few eye symptoms, and only a small number of occupants suffer many eye symptoms.

### **8.4.2 The Measured Thermal And Pollutants Levels In The Building**

A variety of environmental parameters were recorded by LINK over short and long term monitoring periods. The equipment was situated in positions shown in figure 8.4.2. The measured thermal, relative humidity, air movement and pollutant level can be observed in table 8.4.2.

### **8.4.3 The Occupants Assessments Of The Appearance From The Work Positions**

The occupants assessed the appearance from the work position on a semantic scale of 0-7. The distribution of the occupants assessment of the appearance of their work position in each group can be observed in figure 8.4.3(a-c). The distribution shows that for all aspects of appearance, each group displayed a similar range of assessments.

### **8.4.4 The Measured Physical Light Attributes**

The distribution of the measured physical light attributes for each group can be observed in figure 8.4.4 (a-b), and table 8.4.4. Consistently work positions facing the windows have higher measured physical light attributes.

## **8.5 THE LOGIC TREE FOR THE ANALYSIS**

Refer section 5.6.

## **8.6 THE ANALYSIS**

Refer section 5.8.

### **8.6.1 Analysis To Examine The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptom**

From the mean value (refer to table 8.6a) is observed for all the eye symptoms, occupants seated facing the window have the most occurrences. For dry eyes, occupants seated with the windows to their side have less than half the amount of dry eyes occurrences compared to those seated facing the windows. Occupants seated with their back to the windows have less than a quarter of dry eye occurrences compared to occupants seated facing the windows. With respect to headaches, occupants seated with the windows to their side have one third less dry eyes occurrences compared to those seated facing the windows. Meanwhile, occupants seated with their back to the window have two-third less dry eyes occurrences compared to those seated facing the windows.

Where itching eye, watering eye, and problems with wearing contact lenses are concerned, it is observed that the number of occurrences of symptom for those occupants that were seated with the windows to their side are close to that of the occupants that sat facing the window. Occupants that sat with their back to the windows fare better and displayed no symptom occurrences.

From the comparison of the mean values (refer to table 8.6b), it is observed that occupants in work positions with their back to the windows assessed their work positions as most pleasant, likeable, interesting, sociable, friendly, relaxing, ordinary, homelike, spacious, cheerful and natural compared to occupants in the other two positions. Work positions facing the windows are assessed as most beautiful, interesting, satisfying, inviting, emotionally warm, airy, functional, light, stimulating, visually warm, non-glaring, colourful, hot, clean and uncluttered. The comparison of the mean values consistently shows that when a group give their assessment in a certain band of the semantic differential scale the other two groups would move a fraction of a scale up or down e.g if positions with their back to the windows assessed pleasantness of work position as 5.5 on the scale, position facing the windows and with the windows to the side mean value is 5.0 and 4.4 respectively. Having said that, it is observed that private and uncluttered displayed greater difference in the semantic assessment.

From the Kruskal-Wallis analysis none of the eye symptoms have a significance level of 0.05 (refer table 8.6a). The significance level is always greater than this. The Kruskal-Wallis analysis (refer table 8.6b) also shows that only how likeable and satisfying the work positions appeared to the occupants have a significance level of 0.05. The other aspects of appearance have significance level greater than this.

### **8.6.2 Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms**

The comparison of the mean values on eye symptoms has been related in the above section.

The comparison of the mean values (refer to table 8.6c) shows that occupants that sat facing the windows have the biggest depth in isoarea and occupants with the windows to the side have the smallest. Occupants that sat facing the windows also have the biggest window solid angle projected to their eyes while occupants with their back to the windows have the least. The ranking of the sky area follows the same order that is work

positions facing window have the biggest sky solid angle. Occupants in positions facing the window have the biggest ratio of sky to window solid angle and those with their back to the windows have the smallest ratio. The analysis also shows that occupants who work in positions facing the windows have the highest average luminance, illuminance level on the work top, amount of light arriving at the occupants eyes, maximum luminance and luminance ratio. The mean analysis consistently shows that work positions with their back to the windows constantly have the least reading on all the physical light attribute variables. For all the above observations the standard deviation shows that there exists a big difference in the physical attributes between work positions facing the window as compared to work positions with their back to the windows.

From the Kruskal-Wallis analysis (refer to table 8.6c) the solid angle of the sky and window projected to the eye of the occupants', the amount of light arriving at the occupants eyes and the maximum luminance have significant levels smaller than 0.05. Meanwhile, the isoarea, the ratio of these solid angles, the average luminance, illuminance level on the work top, minimum luminance, and luminance ratio have a significance level greater than this.

### **8.6.3 Analysis To Examine The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of The Appearance From The Work Positions**

The occupants perception of the work position appearance has been related in the section 8.6.1, while the measured physical light attributes has been related in the section 8.6.2.

## **8.7 DISCUSSIONS**

### **8.7.1 The Data**

For dry eyes the group facing the window has a range of symptom occurrences 0-50, 50-100, 100-150 and 200-250, group with the windows to the side the sample has two ranges of symptom occurrences; 0-50 and 150-200, while group with their back to the windows the sample has only one range of symptom occurrences that is 0-50. For itching eyes, the ranges of symptoms for each group are the same except that range 200-250 for groups facing the window is missing. For watering eyes, all groups only register 0-50 range of symptom occurrences. For headache and watering eyes, group



facing the windows have occupants that display high symptom occurrences while the group with their back to the windows and with the windows to the side do not have any occupants that have more than 50 dry eye occurrences. Due to the small sample size for the group with their back to the windows this could not be observed. All group comparisons except for watering eyes, have a difference in the number of symptoms experienced by the occupants. The group facing the windows, consistently has occupants that display high occurrences of eye symptom, the group facing the windows in some instances have high occurrences of eye symptom, while the group with their back to the windows consistently does not have any occupants that have more than 50 dry eye occurrences.

The fact that some groups displayed high symptoms and others do not in itself is not a problem provided these samples have been screened and occupants that have eye health problem have been filtered out. The problem in this case is that occupants that displayed these high symptoms could have problem with eye health as these could not be isolated nor eliminated due to the methodology adopted. Thus, when comparing the mean the result could be erroneous due to the fact that the groups that have a high symptom score could be because of the fact that some of the occupants have some kind of eye health problems. If these sample are constantly occurring in the group facing the windows, it will alter the mean value drastically and it will indicate as if occupants facing windows are having more eye symptoms. Whereas the true situation may have been the opposite.

### **8.7.2 Discussions On The Relationship Between Thermal/Pollutants Levels And The Occurrences Of Eye Symptoms**

The fresh air supply was satisfactory compared to 8l/s as recommended by CIBSE. The temperature differences between the areas are comparable to each other (refer table 8.7.2a). The temperature coupled with low air movement monitored suggest potential thermal discomfort.

Where CO<sub>2</sub> is concerned, it is generally accepted that the level needs to reach 1000 parts per million (ppm) for adverse effects, such as headaches to occur. From the monitoring it was found that the building CO<sub>2</sub> level did not exceed this limit (refer table 8.7.2b).

The WHO's long term limit for carbon monoxide is 50ppm and 500ppm for short term exposure. From the monitoring it was found that the building CO level did not exceed this limit (refer table 8.7.2b).

Measurements taken during office hours showed that relative humidity to be around 50%. The critical relative humidity is 20%. Relative humidity below this level is said to threaten occupants well being. Thus the readings show that the relative humidity was far higher than the critical limit.

No recommended maximum level of volatile organic compounds has been set, however, different authors quote figures of 0.3-5ppm as an appropriate maximum level. The maximum reading recorded is related to use of aerosol sprays when cleaners were around and this is not a constant problem.

For formaldehyde, the most stringent of the various international standards is the Swedish, set at 0.08ppm. However, the World Health Organisation's (WHO) concentration of concern is set at 0.1ppm. Scandinavian values is also 0.1ppm. From the monitoring it was found that the building formaldehyde does not exceed this limit.

The maximum level of dust recommended by the Canadians is  $0.1\text{mgm}^{-3}$ . Typical value of dust mite is 500 per gram of dust. In both case the LINK monitoring found it below described limits.

As a conclusion:

1. LINK's monitoring indicated a reasonably satisfactory environment within the recommended levels.
2. The examination shows that although the thermal environment, relative humidity and ventilation are comparable on all floors the occurrence of eye symptoms differs.
3. The close proximity of the symptomatic and asymptomatic areas indicates that the cause of eye symptom occurrence is not likely to be due to environmental factors.

### **8.7.3 Discussions On The Relationship Between Uniform Lighting And The Occurrences Of Eye Symptoms**

1. The case study is a speculative built building, it employs uniform lighting strategy and has standard office finishes. In the review of literature on SBS it has been argued that occurrence of eye symptoms is contributed to by the uniform lit environment. If occurrence of eye symptoms is caused by uniform lighting it would be expected that all the occupants would be experiencing the same number of eye symptoms or there about.
2. The case study found that in a uniformly lit office building the occupants do not display similar occurrences of eye symptoms. This is demonstrated when the occurrence of eye symptoms was plotted out on the floor plan (refer figures 8.4.1-II (c-f)). This could be seen clearly especially when comparing occupants occupying the same office space or in close proximity to each other. In fact, some occupants do not experience eye symptoms at all.
3. This variation is not accountable by the distance from the window. The occurrence of eye symptoms also differs among occupants that are seated next to the windows.

### **8.7.4 Discussions On The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms**

The comparison of the mean values shows that on the account of all five eye symptoms, occupants that sat facing the windows have more symptoms compared to occupants that sat with their back to the windows.

The comparison of the mean values shows that occupants in work positions with their back to the windows assessed their work positions as most pleasant, likeable, interesting, sociable, friendly, relaxing, ordinary, homelike, spacious, cheerful and natural compared to occupants in the other two positions. Work positions facing the windows were assessed as most beautiful, interesting, satisfying, inviting, emotionally warm, airy, functional, light, stimulating, visually warm, non-glaring, colourful, hot, clean and uncluttered. The comparison of the mean values shows that the occupants perception of appearance of their work positions varies with the occupants orientation with respect to the window. However, work positions facing the windows do not constantly have a better perception in all aspects of appearance. In the analysis, work positions with their

back to the windows have a better perception of certain aspects of the appearance from the work position.

Merging the above observations together suggest that work positions with their back to the windows have least occurrence of all the eye symptoms potentially as a result of them being assessed by the occupants as most pleasant, likeable, interesting, sociable, friendly, relaxing, ordinary, homelike, spacious, cheerful and natural. This suggests that occurrences of eye symptoms are associated with occupants perception of the appearance from the work position.

The Kruskal-Wallis<sup>83</sup> comparison shows that none of the comparisons of eye symptoms between the different work position orientations have a significance level of 0.05. This means that there are no significant differences for any of the five eye symptom when the work positions are oriented differently towards the window. The Kruskal-Wallis comparison also shows that none of the comparisons for the aspects of appearance from the work position have a significance level of 0.05 except for likeable and satisfying. This means that there are no significant differences for any of the aspects of appearance from the work positions except for likeable and satisfying. The variable "light" does not differ significantly at the significance level of 0.05, however comes close to it at 0.06.

#### **8.7.5 Discussions On The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms**

The discussion on the effect of orientation on symptom occurrence has been discussed in the above section.

The comparison of the mean values shows that the light attributes of the work positions vary with its orientation with respect to the window. It shows that work positions facing the window have higher reading of light attributes. The main governing attribute is the solid angle of window projected to occupants eyes. Work positions facing the window have a window in view while those with their back to the windows do not. Thus, the solid angle of the window projected to the eyes of the occupants facing the windows will always be greater than occupants with their back to the windows. As all the other variables are coupled with the presence of the window it is logical that the other

---

<sup>83</sup> In "StatsView", as indicated in its manual, by using Kruskal-Wallis analysis variables that vary significantly according to the sub-division will automatically be given by the 0.05 significance level with corrections for ties.

variables vary in the same order. For instance, coupled with the window is the sky area. Thus, work positions facing the windows will have a big sky area while work positions with their back to the windows have none. From here the ratio of the solid angle follows (The solid angle ratio of the sky to that of the window indicates the proportion the view of the sky that makes up the composition of the window. The ratio ranges from 0 to 1. When the score approaches 1 it means that the whole window is made up of the view of the sky and the score 0 mean there is no view of sky). Like the solid angle of window, work positions facing the window will have a bigger ratio while work positions with their back to the windows have none.

Occupants in work positions with their back to the windows have the least occurrences of all five eye symptoms. The mean analysis also shows that occupants in work positions with their back to the windows have the lowest reading on all accounts of the measured physical light attributes considered. Merging these two observations together suggest that work positions with their back to the windows have least occurrences of the eye symptoms potentially as a result of these work positions having the lowest reading on the solid angle of window projected to the occupants eyes, solid angle of sky area projected to the occupants eyes, the ratio of solid angle, average luminance, amount of light arriving at the occupants eyes, maximum luminance, and luminance ratio. This suggests that the occurrences of eye symptoms is associated with the measured physical light attributes. Therein, occupants that are seated facing the window have more eye symptoms as compared to the other two positions because they have higher measured physical lighting attributes as compared to the other two positions.

The Kruskal-Wallis<sup>84</sup> comparison on eye symptom has been deliberated in section 8.7.3. The Kruskal-Wallis comparison on the measured physical light attributes shows that the solid angle of the sky and window projected to the eye of the occupants', the window solid angle projected to the occupants eyes, the sky solid angle projected to the occupants eyes, the amount of light arriving at the occupants eyes and the maximum luminance (brightest spot in the field of view) have a significance level equal to or smaller than 0.05. This means that there are significant differences in these physical attributes for the different orientations in work positions. The average luminance, light level on the worktop denoted by  $D_{wt}(E)$ , the minimum luminance and luminance ratio do not have a significance level smaller or equal to 0.05, thus they do not vary significantly whether the work position faces, back or side the window. In other words

---

<sup>84</sup> In Statsview, as indicated in its manual, by using Kruskal-Wallis analysis variables that vary significantly according to the sub-division will automatically be given by the 0.05 significance level with corrections for ties

the work positions displayed similar average luminance, light level on the worktop and minimum brightness.

The Kruskal-Wallis analysis shows that there are no significant differences for any of the five eye symptoms when the work positions are oriented differently towards the windows. The Kruskal-Wallis analysis also shows that there is a significant difference in the solid angle of the sky and window projected to the eye of the occupant, the amount of light arriving at the occupants eyes and the maximum luminance for the different orientations in work positions.

#### **8.7.6 Discussions On The Relationship Between The Measured Physical Light Attributes And The Occupants Perception Of Appearance From The Work Positions**

The discussion on the perception of appearance has been related in section 8.7.3. The discussion on the perception of appearance has been related in section 8.7.4.

The study shows that work positions facing windows have higher luminance ratio than those with their back to the windows. Chapter 3 has argued that higher luminance ratio is associated with perception of interest. As such, work positions facing windows are anticipated to be more interesting. But the comparison of the mean values of appearance assessment showed that occupants in work positions facing the windows and with their back to the windows have similar appreciation of how interesting the work position appeared to them. The analysis does not substantiate that high luminance ratios identify how interesting the work positions appear to their occupants. This opposed the finding established by Loe et al.

As windows are the source of daylight it is expected that work positions facing windows would yield the highest physical reading of average brightness. Site measurements showed that work positions facing windows do have the highest average luminance. The comparison of the mean values shows that occupants in these positions do assess their work positions lightest (bright). This observation confirms the argument that the occupants perceive their work positions as light because their work positions have higher average luminance.

The comparison of the mean values shows that occupants in work positions backing the windows assessed their work position as most pleasant, likeable, interesting, sociable, friendly, relaxing, ordinary, homelike, spacious, cheerful and natural compared to

occupants in the other two positions. It is also observed that occupants in work positions with their back to the windows have the lowest reading on all accounts of the measured physical light attributes considered. Merging these two observations together suggest that occupants in work positions with their back to the windows assessed their work position as most pleasant, likeable, interesting, sociable, friendly, relaxing, ordinary, homelike, spacious, cheerful and natural because these work positions have lowest reading on all accounts of the measured physical light attributes considered.

The Kruskal-Wallis comparison shows that there is no significant difference for any of the aspects of appearance of work position except for likeable and satisfying. However, the Kruskal-Wallis analysis shows that there is a significant difference in the solid angle of the sky and window projected to the eye of the occupants', the window solid angle projected to the occupants eyes, the sky solid angle projected to the occupants eyes, the amount of light arriving at the occupants eyes and the maximum luminance (brightest spot in the field of view) for the different orientations in work position. Merging these two sets of observations, it is derived that the occupants perception for any of the aspects of appearance from the work positions do not vary significantly although the measured physical lighting attributes do vary significantly between the work positions. This suggests that occupants perception of appearance from the work position is not significantly associated with the measured physical light attributes. Therein, occupants that are seated facing the window do not have a significantly better perception of appearance as compared with the other two positions although they have significantly better measured physical lighting attributes.

## **8.8 CONCLUSIONS**

- The occurrences of eye symptoms do not differ significantly with the different work positions orientation. Occupants that are seated with their back to the windows do not have significantly fewer eye symptoms as compared to the other two positions (The mean analysis shows that occupants with their back to the windows have the least occurrences of eye symptoms).
- Appearance from the work positions do not vary significantly with the different work position orientation. Occupants that are seated facing the window do not have a significantly better perception of appearance from the work position as compared to the other two positions.
- Light attributes vary significantly with the different work position orientation. Occupants that are seated facing the window have significantly higher measured physical lighting attributes as compared to the other two positions.

The occurrence of the eye symptoms is related to the occupants perception of appearance from the work position. The eye symptoms between the work positions do not vary significantly potentially because the occupants perceptions of appearance from the work position do not vary significantly with the occupants orientation with respect to the windows.

The occurrence of the eye symptoms between the work positions does not vary significantly although the measured physical lighting attributes do vary significantly between the work positions. This implies that the occurrence of the eye symptom is independent of the physical light attributes.

As a conclusion, this case study finds that:

- i. Occupants perception of the appearance from the work position has an effect on eye symptom occurrences. The mean comparison analysis suggests that occupants with a better perception of the appearance from the work position experience fewer eye symptom occurrences.

However, findings in the case study refute the hypothesis that :

- i. The appearance from the work position is significantly affected by the work position orientation in relation to the windows.
- ii. The appearance from the work position is significantly related to the physical lighting attributes
- iii. Occupants in work positions facing the windows have a significantly better perception of their work position appearance.
- iv. Occupants in work positions facing the windows have significantly fewer symptom occurrences.



## Chapter 9

# **COMPARISON OF CASES STUDIED, CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH**

## **9.0 INTRODUCTION**

This chapter is divided into 4 sections.

1. Comparison of the three cases studied.
2. General conclusion.
3. Review the study.
4. The implication of this study on future research.

The first section compares the three case studies to determine whether the observation is consistent. The results from all the case studies are compiled to arrive at an overall finding as distinct from each individual case studies. Consequently a general conclusion is drawn.

## **9.1 COMPARISON OF THE THREE CASE STUDIES**

The logic tree for the analysis is the same as that related in each case study. Thus the comparison is related in the same order. It compares the underlying observation and not the detail because the buildings have only the artificial lighting installation normalised but with varying organisational climate and environmental factors. This will then make it difficult to identify the cause of the differences in the occurrence of the eye symptoms.

### **9.1.1 Comparison On The Relationship Between The Appearance From The Work Positions And The Occurrences Of Eye Symptoms**

The results of comparing the mean values show, in case study 1, that work positions facing windows have fewer occurrences of dry eyes, watering eyes and headaches. The study suggests that these positions have fewer occurrences of the eye symptoms is related to the occupants having assessed the appearance of their work positions as

favourable. Here, favourable is associated with being pleasant, sociable, friendly, relaxing, inviting, homelike airy, hot and uncluttered. In case study 2, it was observed that work positions with the window to the back of the occupants have fewer occurrences of all five eye symptoms (dry eyes, itching eyes, watering eyes, headaches and problem when wearing contact lenses). The study suggests that these positions have fewer occurrences of the eye symptoms is related to having assessed the appearance of their work positions as favourable. Here, favourable is associated with being pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, hot, clean, uncluttered and natural. In case study 3, it was observed that work positions with the window to the back of the occupants have fewer occurrences of all five eye symptoms. The study suggests that these positions have fewer occurrences of the eye symptoms is related to the occupants having assessed the appearance of their work positions as pleasant, likeable, interesting, sociable, friendly, relaxing, ordinary, homelike, spacious, cheerful, clean and natural.

In the Kruskal-Wallis analysis, for all three cases studied, there are no significant differences in the occurrence of the eye symptoms when comparing the three work position orientations. When comparing aspects of appearance of work position, in case study 1, the Kruskal-Wallis analysis showed that only how ordinary the work positions appeared to the occupants vary significantly according to the work positions orientation. In case study 2, how quiet and uncluttered the work positions appeared to the occupants vary significantly according to the work positions orientation, and in case study 3 how likeable and satisfying the work positions appeared to the occupants vary significantly according to the work positions orientation.

### **9.1.2 Comparison On The Relationship Between The Measured Physical Light Attributes And The Occurrences Of Eye Symptoms**

The results of comparing the mean values, in case study 1, show that work positions facing windows have fewer occurrences of dry eyes, watering eyes and headaches. The study suggests that these positions have fewer occurrence of the eye symptoms is related to them having the highest reading for the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the ratio of solid angles, the average luminance (apparent brightness of the field of view), the illuminance on the worktop, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. In case study 2, it was observed that

work positions with the window to the back of the occupants have fewer occurrences of all five eye symptoms. The study suggest that these positions have fewer occurrences of the eye symptoms is related to their work positions having the lowest reading for the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the ratio of solid angles, average luminance (apparent brightness of the field of view), the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. Case study 3 has similar observations.

In the Kruskal-Wallis analysis, in all three cases studied, there are no significant differences in the occurrences of the eye symptoms when comparing the three different work position orientations. When comparing the measured physical light attributes, in case study 1 it is showed that the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the ratio of solid angles, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio vary significantly according to the work position orientation. In case study 2, the Kruskal-Wallis shows that the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the average luminance, the amount of light arriving at the occupants eyes and the luminance ratio vary significantly according to the work position orientation. In case study 3, the Kruskal-Wallis shows that the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the amount of light arriving at the occupants eyes and the maximum luminance vary significantly according to the work position orientation.

### **9.1.3 Comparison On The Relationship Between The Measured Physical Light Attributes And Occupants Perception Of Appearance From The Work Positions**

The results of comparing the mean values show, in case study 1, that occupants in work positions facing the windows assessed their work positions as pleasant, sociable, friendly, relaxing, inviting, homelike airy, hot and uncluttered. The study suggests that these positions were assessed as most pleasant, sociable, friendly, relaxing, inviting, homelike airy, hot and uncluttered is related to the fact that these work positions have the highest reading on the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the ratio of solid angles, the average luminance, the illuminance on the worktop, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. In case study 2, it is observed that occupants in work positions with windows to their back assessed their

work positions as pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, hot, clean, uncluttered and natural. The study suggests that these positions were assessed as most pleasant, likeable, interesting, friendly, satisfying, inviting, ordinary, homelike, spacious, private, airy, functional, cheerful, stimulating, visually warm, non-glaring, colourful, hot, clean, uncluttered and natural is related to the fact that these work positions have the lowest readings for the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the ratio of solid angles, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio. In case study 3, it is observed that occupants in work positions with windows to their back assessed their work positions as pleasant, likeable, interesting, sociable, friendly, relaxing, ordinary, homelike, spacious, cheerful, clean and natural. The study suggests that these position were assessed as most pleasant, likeable, interesting, sociable, friendly, relaxing, ordinary, homelike, spacious, cheerful, clean and natural is related to the fact that these work positions had the lowest readings for the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the ratio of solid angles, the average luminance, the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio.

When analysing the effect of physical light attributes on perception of appearance using the Kruskal-Wallis analysis, in case study 1, it is observed that only how ordinary the work positions appeared to the occupants vary significantly according to the work positions orientation meanwhile the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the ratio of solid angles, the average luminance (apparent brightness of the field of view), the amount of light arriving at the occupants eyes, the maximum luminance and the luminance ratio vary significantly according to the work positions orientation. In case study 2, how quiet and uncluttered the work positions appeared to the occupants vary significantly according to the work positions orientation while the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the average luminance (apparent brightness of the field of view), the amount of light arriving at the occupants eyes and the luminance ratio vary significantly according to the work positions orientation. In case study 3, how likeable and satisfying the work positions appeared to the occupants vary significantly according to the work positions orientation while the solid angle of window area subtended to the occupants eyes, the solid angle of sky area subtended to the occupants eyes, the amount of light arriving at the occupants eyes and the maximum luminance vary significantly according to the work positions orientation.

## 9.2 GENERAL CONCLUSIONS

The findings from case study 1 and 2 are considerably reliable as the groups do not have any thin cells (sample is less than 5). In case study three, the findings are to be accepted with caution as the group with the back to the window represents a thin cell. However, in this case the observations are accepted as the underlying observation is consistent with case studies 1 and 2.

In all three case studies, it has been shown that the occurrence of eye symptoms is not the result of the thermal problem or pollutants in the environment. Having said that, the review of literature on the effect of indoor environment gives threshold limiting values for people exposed to high pollution level over long period of time eg. in factories or in atmospheres where there are high concentration of pollutants. Whereas values measured in offices are generally much lower than that indicated as threatening.

Figure 9.1: Comparison of work position with least Eye Symptom using mean value for cases studied

<b>Case Study (CS)</b>	<b>Work Position Orientation</b>	<b>Assessment of Appearance</b>	<b>Light Measurements</b>
CS 1	Facing the window	Most Favourable	High reading
CS 2	with the back towards the window	Most Favourable	Low reading
CS 3	with the back towards the window	Most Favourable	Low reading

The comparison of the mean value of the eye symptom occurrence shows that in 2 out of 3 cases, occupants in work positions with their back towards the window have fewer symptoms. In all three cases, occupants in work position having least eye symptoms consistently assessed their work position as most favourable on most of the appearance variables. Good perception of the appearance of their work position is conducive to fewer occurrence of eye symptoms. Comparing physical light measurement, the study shows that favourable perception is not necessarily associated with either high or low readings of the light measurement. However, light intensity variations over a work position does influence the perception by providing either interesting/pleasant or bright/glaring light pattern.

It is found that the occurrence of eye symptoms is related to the light attributes. Where there is bright light in the field of view, especially if that bright light is in the centre,

then occupants will experience eye symptoms. On the other hand where the light is low and highly uniform occupants will also experience eye symptoms. The study has shown that occupants with lighting environment that causes visual problems could not have a favourable perception. Favourable perception as argued in Chapter 3 requires high luminance and luminance ratio. The study suggests that both luminance and luminance ratio have a lower and upper limit. Where the lower limits is not satisfied or the upper limit is exceeded, favourable perception ceases to exist. Furthermore, for favourable perception, both high luminance and luminance ratio must occur simultaneously. When either one of the condition is not satisfied, favourable perception ceases to exist. There can be a number of combinations for this to occur.

1. Both luminance and luminance ratio exceeded the upper limit.
2. Both luminance and luminance ratio are below the lower limit.
3. Luminance is high but luminance ratio is low.
4. Luminance is low but luminance ratio is high.

From field observation, a mix of favourable and unfavourable condition exists. Example where the lower limit is not satisfied are in situation where the occupants work positions look out onto a wall of an adjacent building or when facing an internal wall. The upper limit is exceeded when the work positions facing a window with a view of the sun or other glaring sources. In work positions facing away from the window, the lighting installation seen against the total uniform lighting scene can give high luminance ratio but low luminance. In instances where the occupants face the internal wall that is bright, the high luminance could be satisfied but the luminance ratio is low.

The Kruskal-Wallis analysis showed, in all three cases studied, the score indicating the occurrence of eye symptoms does not vary significantly with the orientations of the work positions. However, it shows that some appearance variables, and the physical light measurement vary significantly with the work position orientation.

Figure 9.2: Comparison of work position orientation using Kruscall-Wallis for cases studied

Case Study	Eye Symptoms	Assessment of Appearance	Light Measurements
C1	All do not vary significantly	ordinary vary significantly	Win solid <, Sky solid < ave Lum eye E Lum ratio
C2	All do not vary significantly	quiet & uncluttered vary significantly	Win solid <, Sky solid < ave Lum eye E Lum ratio
C3	All do not vary significantly	likeable & satisfactory vary significantly	Win solid <, Sky solid < eye E max Lum

The case studies show that:

- Occurrences of eye symptoms do not vary significantly with work positions orientation
- Aspects of appearance do not vary significantly with work positions orientation
- Light physical attributes vary significantly with work positions orientation.

The findings in the thesis supports the hypotheses that ;

- i. the occurrences of eye symptom are related to the occupants perception of the appearance from the work position. The mean analysis shows that occupants with better perception of the appearance from the work position experience fewer eye symptom occurrences.

However, findings in the case study refutes the hypothesis that ;

- i. the number of eye symptoms that an occupant experiences vary with the occupants orientation with respect to the window,
- ii. the perception of appearance from the work position varies with the occupants orientation with respect to the window,
- iii. occupants in work positions facing the windows have a better perception of their work position appearance,

- iv. occupants seated facing window have better physical light attributes,
- v. occupants in work positions facing windows have fewer symptom occurrences.
- iii. the appearance from the work position is influenced by the physical lighting attributes.

This study shows that occupants facing the windows does not necessarily have fewer eye symptoms, and that all occupants should not necessarily be seated facing the window. It does suggest, that work positions which have good perceptions of the appearance from the work position are conducive to fewer occurrences of eye symptoms. Good appearance from lighting literature implies good lighting attributes. The fact that the study shows no significant relationship between lighting and appearance could potentially be because the daylight component was not coordinated to an effect. The light pattern distribution was happening at random.

Consequently, it is imperative that lighting design should give a favourable perception. In order to achieve this, the designer must ensure that the vertical surfaces have lighting that would give high luminance and luminance ratio, and both these variables must satisfy the lower limit and do not exceed the upper limit. It is important to stress here that the designers must pay particular attention to the vertical surfaces - the walls. As long as the vertical surface satisfies the luminance condition, the orientation of the work positions become irrelevant. It is not necessary that the occupants field of view must consist of the view of the sky or external view. As long as a gradient of light intensity exists when the eye scans the field of view the criteria for luminance ratio is satisfied.

Luminance and luminance ratio can be created by using various reflectances (but specular surfaces are best avoided) or lighting. Assuming the reflectances do not vary significantly, as in most offices situations, this would mean that the wall is given a wall-washed lighting. This will help make sure that the walls have high luminance. Next, the designers must introduce variance of light intensities. This can be achieved by using spot light or dichroic light source. However, it is necessary to bear in mind that the eyes can only perform efficiently within a limited range of brightness at a particular time. It is then necessary to first identify this range and make sure that the light in the field of view is within this range. It is necessary to ensure that the occupants do not have a direct view of the source of glare such as the view of the sun or the lighting installation. So, it is important that the designers must make sure that these light sources used for the highlights (to introduce a sense of sparkle) face towards the walls, so that they do not shine into the occupants eyes and cause glare. If black surfaces are integrated in the field of view, as in situations where horizontal surfaces are projected as part of the



vertical view, the range of brightness must be calibrated using the dark surface as a reference level.

### **9.3 REVIEW OF THE STUDY**

From the experience gained in conducting the research, several improvements could be made in the methodology and analysis technic employed. Recommendations to improve these in future research will be deliberated in the next section. Prior to this, a review of the methodology and analysis technic employed will be reviewed.

#### **9.3.1 Review Of The Methodology**

Initially, the methodology consisted of three parts, occupants survey, physical measurements, and eye health survey. Eye health questionnaires are necessary to eliminate occupants that have eye health problems. This make certain that all occurrences of eye symptoms are related to the lit environment and not eye health. However, after the pilot study the eye health survey was abandoned as a result of the constraint imposed by the LINK programme (as surveying only 30 people defeats the purpose to exclude occupants with eye health from the samples used in the study). Besides, the pilot study has shown that it is rare that occupants suffer from serious eye health problems. The most common problems were short-sightedness or long-sightedness and these are normally corrected with the right refraction (glasses).

Henceforth, the methodology only sets out to collect 3 types of data; eye symptoms, appearance assessments, and physical light attributes. The data on occupants eye symptoms and appearance assessments are gathered by the questionnaire while the physical attributes were measured on site. The data on eye symptoms and appearance assessments refer to longterm data while physical light attributes refer to spot measurements.

From the brief summary above, the first problem with the methodology lies in abandoning the eye health survey. However, this left to chance whether there were occupants that had serious eye health problems. If there were, then the mean value for eye symptoms in the group where these occupants are placed will naturally be raised. Thus, in all three cases studied there is a possible error due to the group sampled having occupants with eye health problems brought about by the individual state of health

rather than the lit environmental condition. The second weakness is the sample size. When the sample is too small it is not representative of the group.

Further improvement can be made to the quality of data obtained. They can be divided into two category:

- i. Data gathering.
- ii. Compatibility of the data.

### **9.3.1-I Data Gathering**

The problem with obtaining the data will be discussed in two parts:

- i. Problems with obtaining objective data.
- ii. Problem with obtaining subjective data.

#### Obtaining Subjective Data

1. The aspect of appearance and occurrence of symptoms both involved assessment of long term effect. Hence, care was taken to address questions that were meant for long term rather than instantaneous assessment. The question here, was the appraisal made with regards to the long term or short term effect? It is suspected that occupant's assessment of the appearance from the work position would be strongly affected by the lit environment at that particular time.

#### Obtaining Objective Data:

1. Daylight varies with the sun's altitude and azimuth throughout the year and was further complicated by variance in cloud covers. The site measurement was a "one off" reading, therefore it did not describe a typical condition experience throughout the day and year. A spot measurement is inadequate as it will not tell if the maximum tolerable by the human body is exceeded at any particular time during the day. It does not tell if the level determined persisted for a long time sufficient to cause a health hazard. It does not determine how this pattern changes, the way the light pattern changes could be the cause that contributes to the ill health effects. The health effect could be a function of the longitudinal mode i.e duration of one year, month, one week or daily cycle.

2. As the work positions were not measured simultaneously there is an element of error as the conditions are not constant and there is a diurnal difference<sup>85</sup> (at what time of day the was measurement executed).
3. Seeing involves three basic ingredients: illuminance, luminance and reflectance. These three factors are closely interrelated so that changes in one affects the others. For instance where the reflectance is kept constant, changes in illumination level will vary the effect of luminance. It would be easy to determine the effect of each variable if the other two could be kept constant, but in the real life situation all three factors operate simultaneously therefore, it is hard to isolate the effect.
4. The inadequate capability of the physical measurements to represent the actual lighting condition or the subtle differences, for instance, how the light is actually distributed; where it is accentuated. For example, luminance ratio measurement does not give a clear picture of the areas involved regarding the maximum and minimum light level and how they are distributed. Probably area weighted luminance ratio would be a more appropriate approach although it is cumbersome and complicated.

### **9.3.1-II Compatibility Of Objective And Subjective Data**

1. Essentially subjective evaluations and the physical measurements should be made simultaneously so that the physical measurements describe the condition the occupants are assessing. However, working within the constraint of the LINK project this was not possible. This is due to the impossibility of executing all phases of the study simultaneously due to limited access to the building and its overwhelming effect. The researcher assumed that the questionnaire data was obtained under overcast conditions based on the fact that 80% of the year in Britain is overcast. The physical measurements are then comparable as they were obtained under overcast conditions. However, in the methodology, the questionnaire was left with the participant for a week to respond. Thus the data obtained is not specific as to the actual time the participant responded. If the questionnaire survey was conducted on a sunny day, then the questionnaire data would not be comparable to the measured physical data which was obtained for overcast days as stipulated in the methodology.

---

<sup>85</sup> There is a time lapse between one measurement to the next. This measurement is dependent on the illuminance level outside. Therefore the physical measurement of the work position would vary with the time of day that the measurement was taken. However, in an earlier study it was shown that under overcast conditions and for places that are designed to be dependent on artificial lighting the variation is very slight and could almost be ignored.

2. The problem of correlating the longterm subjective data to the spot measurements of physical data.

### **9.3.2 Review Of The Analysis**

The weakness of the analysis method employed lies in the stratification (grouping) of data according to the work positions orientation. In the office, the conditions are not as simple as having one window in a room with four walls. Especially in an open plan office where the office occupies a whole floor, in any orientation an occupant faces a window. It is observed that not all work positions facing the window have better lighting conditions. Some positions facing the windows have similar lighting conditions as those with their back towards the windows. Besides some work positions facing the windows looked directly towards the sun, and this causes glare which evidently has been shown to strongly correlate to occurrence of eye symptoms. The group facing the window should then be sieved to filter out occupants with glare and lighting conditions similar to those backing the window for example when the windows are totally blinded. Having said that, it is difficult to categorise as these work position could have a spill of daylight from adjacent work positions. It is the lighting conditions that should determine the grouping, and not the work positions orientation with respect to the window. The inherent problem here is that there is no easy way to categorise the environment, there is no definite boundary indicating good or bad lighting conditions. Besides the environment is continually varying. This categorisation is easier if the environment is on the extreme end, however, environments in offices are in the average as designers tend to operate by the design guidelines.

With hindsight, the analyses should use the raw data. This will allow for occupants facing the window to have physical light attributes similar to that of a work positions with the back towards the windows. However, it is recommended to consider using a standard significance level. This makes the correlation loading comparable, as an example a factor with significance level 0.01 and correlation loading 0.4 would be more strongly correlated than a factor with significance level 0.05 and correlation loading of 0.4. But how much correlated it is difficult to determine. Reviewing on social science studies it is found that the significance level employed in this study is too high. Thus, this needs reviewing.

## 9.4 RECOMMENDATIONS FOR FUTURE RESEARCH

In order to substantiate the finding in this study, further research ought to be conducted with the following corrections:

1. Integrate the eye health survey in the main occupants survey questionnaire.
2. Increase the sample size. The sample size for each group is preferably of the same size. There are no fixed rules on sample size but based on the experiments conducted it is preferred that each group should consist of a minimum of 30 samples. This sample should be the effective sample size that is after eliminating samples that are defective, and also the exclusion criteria. In view of this, it is best that the study starts of with a larger sample size.
3. The nature of the data is all the same, long term longitudinal nature. The nature of all data used in the study is determined by the nature of the eye symptoms data which is the core data. As the questionnaire is assessing the occurrence of eye symptoms over a year, the assessment of appearance and the physical light attributes must also be measured throughout that year.
4. Continuous monitoring of the physical light attributes during the office hours for one whole year would take into account sunny and overcast conditions, and it is this composite effect that contributes to the occurrence of the eye symptoms. The conditions described require the use of data logger.
5. Two appearance assessments, one for sunny days and one for overcast days.
6. When analysing using stratified data it is necessary to filter out occupants that have glare and similar lighting attributes in their work positions with their back to the windows from those facing the windows first before comparing the groups.
7. It is recommended to analyse using raw data as it is difficult to interpret cross analysis when using stratified data.

This research cannot be transferred to the laboratory as the eye symptoms data required a life situation. Abstracting real environments into controlled experiments runs the risk of eliminating features that may in fact be the determinants of the phenomenon being investigated (Shepherd, 1989). This study is not possible without serious backing with equipment and cooperation from office management. This is especially true where the study is to be taken a step further to demonstrate that different lighting installations give different light patterns on the wall which in turn would give rise to different occurrences of eye symptoms. The study should take only occupants with their back to the windows in different building and compare the effect of different lighting. However, this has the problem of different organisational climate, thermal environment, and pollutant environment. From here, the only other logical path to show that changing the lighting would cause different perception and thus effect the occurrence of eye symptoms, is by

using the same building but changing the lighting installation. This could identify if the change of the lighting installation varies the light pattern on the wall, and thus projects different perceptions which in turn give rise to different occurrences of eye symptoms. Selecting occupants facing away from the window in this building will then normalise the effect of daylight. This study could be taken a step further by specifically manipulating the light to give definite variance in light pattern, and to see how this effects perception and how perception correlates with occurrence of eye symptoms.

## BIBLIOGRAPHY

- 1• Ackerley R.O, 1948, **An Introduction To The Science Of Artificial Lighting**, E.& F.N. Spon Ltd, London.
- 2• Allen R.J, Fletcher R and Atill D.C, **Eye Examination And Refraction**, Blackwell Scientific, London.
- 3• Allsop J,1984, **Health Policy And The National Health Service**, Longman, London, p145.
- 4• Anderson L and Noell E, 1994 **The Aging Population**, Lighting Design and Application, p 32-36, March.
- 5• Andres P, 1995, **People And Light**, Design and Light, 1/95 volume 5/April.
- 6• Baker N, 1987, **Passive And Low Energy Building Design For Tropical Island Climates**, Commonwealth Science Council, London.
- 7• Bean A.R, Bell R.I, 1992, **The CSP Index: A Practical Measure Of Office Lighting Quality As Perceived By The Office Workers**, Lighting Research Technol ogy 24(4) pp215-225.
- 8• Becker F, 1990, **The Total Workplace**, Van Nostrand Reinhold, New York.
- 9• Bedwell C.H, 1972, **The Eye, Vision And Visual Discomfort**, LRT, vol 4(3), p151.
- 10• Bedwell C.H, 1982, **Visual Fields: A Basis For Efficient Investigation**, Butterworth, London.
- 11• Bell J, 1987, **Expressive Lighting: CIBSE Lighting Division Chairman's Address 985/6** Lighting Research Technology 119 pp15-20.
- 12• Bell R, 1990, **Efficient And Effective Lighting**, Energy efficient Edition, Roaf and Hancock, London.
- 13• Ben Bova, 1988, **The Beauty Of Light**, John Wiley and Sons, New York.
- 14• Benett C.A, 1986, **Lighting, Comfort And Performance In The Workplace: Human - VDT Interaction Requires Special Considerations**, Lighting Design and Application, Vol 16, No 8, pp 40-44, August.
- 15• Benjamin H, 1974, **Better Sight Without Glasses**, Thorsons, England.
- 16• Beral G, Evans S, Shore H and Milton G, 1980, **Malignant Melanoma And Exposure To Fluorescent Lighting At Work**, Lancet pp 290-293.
- 17• Berger J, 1987, **Ways Of Seeing**, British Broadcasting Cooperation, London.
- 18• Berman E.L, Greenhouse D.S, Bailey I.L, Clear R.D and Rasch T.W, 1991, **Human Electroretinogram Responses To Video Displays, Fluorescent Lighting And Other Frequency Sources**, Optometry and Vision Science, No 68, pp 645-662.
- 19• Binnie C.D, de Korte R.A and Wisman T, 1979, **Fluorescent Lighting And Epilepsy Epilepsia**, 20(6) pp725-727.
- 20• Blackwell H.R, 1985, **Effects Of Light Source Spectral Distribution Upon Visual Function**, Ann. New York Acad. Sci. No 453, pp 341-353.
- 21• Bodmann H.W, 1967, **Quality Of Interior Lighting Based On Luminance**, Trans Illum Soc 32(1) pp22-40, London.

- 22• Boubekri M, Boyer L.L, 1992, **Effect Of Window Size And Sunlight Presence On Glare**, Lighting Research Technology 24(2) pp69-74.
- 23• Boud J, 1973, **Lighting Design In Buildings**, Peter peregrinus Ltd, Stevenage.
- 24• Boyce P.R, 1978, **Under The Influence Of Lighting**, in Lynes (ed), Development in Lighting 1, Applied Science Publication Ltd, London, pp47-76.
- 25• Boyce P.R, 1987, **Lighting Research And Lighting Design; Bridging The Gap**, Lighting Design and Application, 17(5) pp10-12 and 50-55.
- 26• Boyce P.R, 1989, **Studying Sick Buildings**, Proceedings Of Conference On Designing For Environmental Quality Conference, Birmingham Polytechnic.
- 27• Boyce P.R,1981, **Human Factors In Lighting**, Applied Science Publisher, London.
- 28• BRE Notes, 1980, **Building In Hot Climates**.
- 29• BRE, 1981, **Office Lighting For Good Visual Task Conditions**, Building Research Establishment Digest, CI/SfB 1976 (32) N, Digest 256, December.
- 30• Bruce V and Green P.R, 1993, **Visual Perception: Physiology, Psychology And Ecology**, 2nd(ed), Lawrence Erlbaum Associates, London.
- 31• Brundrett G.W, 1974, **Human Sensitivity To Flickers**, Lighting Research Technology, Vol 6, No 3, pp127-143.
- 32• BUS, 1987, **The Office Environment Survey: Study Of Building Sickness**, London, Building Use Studies.
- 33• Campbell A, 1994, **An Investigation Into The Brightness Contrast Necessary To Achieve A Particular Subjective Effect, Considering Luminance, Illuminance And Reflectance**, MSc in Architecture (light and Lighting), UCL, London.
- 34• Campbell F, Rothwell S and Perry M, 1987, **Bad Light Stop Play**, Ophthal, Physio Opt 7(2)165-167.
- 35• Canter D and Lee T (ed), 1974, **Psychology And The Built Environment**, Architectural Press, England.
- 36• Canter D and Stringer P, 1975, **Environmental Interaction: Psychological Approaches To Our Physical Surroundings**, International Universities Press, New York.
- 37• Canter D, 1974, **Psychology For Architects**, Applied Science, London.
- 38• Carter R, 1995, **What Is Stress**, SHE, March.
- 39• Casey, 1990, **Sick Building Syndrome - Fact or Fantasy?**, Energy World, March, pp9-10.
- 40• Cawthorne, 1991, **Building Lighting And The Biological Clock**, Building Technical Files, No 32, Jan, pp25-34.
- 41• Chalkley J.N and Cater H.R, 1968, **Thermal Environment For The Student Of Architecture**, Architectural Press, London.
- 42• **CIBS Code For Interior Lighting**, 1984, The Chartered Institution of Building Services, London.
- 43• **CIBSE Code For Interior Lighting**, 1994, The Chartered Institution of Building Service Engineers, London.



- 44• **CIBSE National Lighting Conference**, Conference Proceeding, 1990.
- 45• CIBSE, 1993, **Healthy Workplaces**, CIBSE Guidance Notes, GN2.
- 46• CIBSE, 1993, **Lighting For Offices**, Lighting Guide LG7.
- 47• CIBSE, 1994, **Applying The Cibse Code For Interior Lighting**, CIBSE Conference Proceeding, February.
- 48• CIBSE, 1995, **The Future Of Office Lighting**, CIBSE Conference Proceeding, March.
- 49• Coath R and Hoffman R, 1973, **Does Artificial Light Affect Our Health?** Lighting Design and Application, November.
- 50• Collin B.L, Fisher W.S, Gillette G.L. and Marans R.W, 1989, **Evaluating Office Lighting Environments: second analysis**. National Institute Standards And Technology (NISTIR) 89-4069, USA.
- 51• Collin B.L, Fisher W.S, Gillette G.L. and Marans R.W, 1990, **Second Level Post Occupancy Evaluation Analysis**, J. Illum. Eng. Soc., Vol 19 no 2, p 21-44.
- 52• Collins B.L, 1976, **Review Of The Psychological Reaction To Windows**, Lighting Research Technol, 8(2) 80-88.
- 53• Corth R, 1983, **What Is "Natural" Light?** Lighting Design and Application 13, pp34-40.
- 54• Cronly-Dillon J, Rosen E.S and Marshall J (ed), 1986, **Hazards Of Light: Myths And Realities**, Pergamon Press, Oxford.
- 55• Cronolly E, 1993, **Health And Lighting**, Course Essay for O'Sullivan, University College of London.
- 56• Croth and Hoffman, 1973, **Photobiology: Artificial Light And Health**, Lighting Design and Application, November.
- 57• Curwell S., March C. and Venables E.A, 1990, **Health And Buildings: Rosehaugh Guide**, Architectural Press, London.
- 58• Cuttle C and Boyce P.R, 1988, **Kruithof Revisited: A Study Of Peoples's Responses To Illuminance And Colour Temperature Of Lighting**, Lighting in Australia, Vol 8 no 6 p17-28.
- 59• Daly A, 1989, **Way Of Seeing**, Lighting Dimension, Vol 13, No 4, May/June, pp 62-65, 77, 79-80.
- 60• Davis D and Malone M, 1984, **Offices of The Future**, Newsweek, May 14.
- 61• Davis R.G and Geithner D.N, 1990, **Correlated Colour Temperature, Illuminance Level And The Kruithof Curve**, J. Illum. Eng. Soc. Vol 19, no 1, p 27-38.
- 62• Davis R.G, 1987, **Closing The Gap: Research, Design And The Psychological Aspects Of Light**, Lighting Design and Application, May.
- 63• Day C, 1990, **Places Of The Soul: Architecture And Environmental Design As A Healing Art**, The Aquarian Press, London.
- 64• de Boer J.B and Fisher D, 1978, **Interior Lighting**, Phillips Technical Library, Macmillan Press Ltd, London.
- 65• Deasy C.M and Lasswell T.E, 1985, **Designing Places For People: A Handbook On Human Behaviour For Architects, Designers And Facility Managers**, Watson-Guptill, New York.

- 66• Dinneen R.A, 1978, **Light, Architecture And Aesthetic: Notes On Architectural Lighting**, Lighting Design and Application, November.
- 67• Drownowski J, 1974, **On Measuring And Planning The Quality Of Life**, (loc: Geography D66DRE)
- 68• Duffy F, 1989, **The Changing Workplace**, Architects Journal, 27 September.
- 69• Durrant D.W, Eng T and Illum F (ed), 1977, **Interior Lighting Design**, Published jointly by Lighting Industry Federation and Electricity Council, London.
- 70• Electricity Council, **Better Office Lighting**, Sfb32(63)- EC 3917/12.83
- 71• Electricity Council, n.d, **Better Office Lighting**.
- 72• Elwood J.M, 1986, **Could Melanoma Be Caused By Fluorescent Light? A Review Of Relevant Epidemiology In; Recent Result In Cancer Research**, vol 102 pp127-136, Heidelberg, Berlin, Springer.
- 73• English D.R, Rouse I.L, Xu Z, Watt J.D, Holman C, Heenan P.J and Armstrong B.K, 1985, **Cutaneous Malignant Melanoma And Fluorescent Lighting**, J. Nat Cancer Inst. 74, pp 1191-1197.
- 74• Erhart L, 1994, **Views On The Visual Environment**, Lighting Design and Application, p 34 and 36, February.
- 75• Erharth, 1992, **Views Of The Visual Environment**, Lighting Technology & Applications, September.
- 76• Eysel U.T and Burandt U, 1984, **Fluorescent Tubes Light Evokes Flicker Resposes**, Vision Research vol 24, No 9, pp 943-948.
- 77• Fanger P.O, 1972, **Thermal Comfort: Analysis And Application In Environmental Engineering**, MacGraw Hill, New York.
- 78• Favie J.W, Damen C.P, Hietbrink G and Quaedflieg, 1962, **Lighting**, Philips Technical Library, Holland.
- 79• Finnegan M.J, Pickering C.A.C and Burges P.S, 1984, **The Sick Building Syndrome: Prevalence Studies**, British Medical Journal No 289, pp 1573-1575.
- 80• Fletcher B.C, 1992, **Work, Stress, Diseases and Life Expectancy**, John Wiley and Sons, New York.
- 81• Flynn J, Segil A.W, Steffy G.R, 1988, **Architectural Interior System: Lighting, Acoustic And Air Conditioning**, 2nd Ed, Van Nostrand Reinhold Co, New York.
- 82• Flynn J.E and Mills S.M, 1962, **Architectural Lighting Graphics**, Reinhold Publishing, New York.
- 83• Flynn J.E and Spencer T.J, 1977, **The Effect Of Light Source Colour On User Impression And Satisfaction**, JIES, vol 6, no 3, pp 167-179, April.
- 84• Flynn J.E et al, 1973, **Interim Study Of Procedures For Investigating The Effect Of Light On Impressions And Behavior**. JIES, October.
- 85• Flynn J.E, 1972-73, **The Psychology Of Light**, Electrical Consultant, 88:12 thru 89:7, (series of 8 articles).
- 86• Flynn J.E, 1974, **Lighting Design Decision As An Intervention In Human Visual Space** (The Role of CIE Study Group A), Paper presented at Symposium - 1974/CIE Study Group A, Montreal Canada, August.

- 87• Flynn J.E, 1975, **A Study Of Lighting As A System Of Spatial Cues**, EDRA-6 workshop on the Psychological Potential of Illumination, Univ of Kansas, April.
- 88• Flynn J.E, 1977, **A Study Of Subjective Responses To Low Energy And Non-Uniform Lighting System**, Lighting Design and Application 7(2):pp6-15.
- 89• Flynn J.E, Hendrick C, Spencer T and Martyniuk, 1979, **A Guide To Methodology Procedures For Measuring Subjective Impressions In Lighting**, IIES, no 8, p95-110, January.
- 90• Flynn J.E, Spencer TJ, Martyniuko and Hendrick C, 1975, **The Influence Of Spatial Light On Human Judgement**, Proceedings of CIE 18th Session, CIE, no 36, pp39-46, London.
- 91• Foort de Roo,1988, **Master Plan Of Interrelations Between Indoor Environmental Parameters** in Berglund B. and Linvall T., Healthy Buildings, Vol 2, Planning physical and climate Technology for healthier buildings, Swedish Council for Building Research, Stockholm, Sweden.
- 92• Freund, 1987, **Development Of A New Jersey IaQ Standard**, in ASHRAE, IAQ87: Practical Control of Indoor Air Problem, Proceeding of ASHRAE Conference IAQ87, May 18-20, Arlington, Virginia.
- 93• Gatchel R.J, Baum A and Krantz D.S, 1989, **An Introduction to Health Psychology**, (2nd ed), McGraw-Hill, New York.
- 94• Gerald M, 1995, Vol III, **Central Nervous System And Eye Infections**, UCL, London.
- 95• Gillette G, 1987, **Evaluating Office Lighting Environments**, Lighting Design and Application, Vol 17, No 5, pp 4-6, 16-47, May.
- 96• Glaspool M, 1984, **Eyes: Their Problems And Treatments**, Martin Dunitz, London.
- 97• Goldstein E.B, 1989, **Sensation And Perception**, (3rd ed), Brooks/Cole Publishing Co, California.
- 98• Gradjean E (ed), 1984, **Ergonomic And Health In Modern Offices, Section A: The Ambient Environment In Offices**, Taylor & Francis, London.
- 99• Gregory R.L, 1994, **Eye And Brain: The Psychology Of Seeing**, 4th Edition, Oxford University Press, New York.
- 100• Grenald R, 1986, **The Name Of The Game, Architecture Lives In The Seeing**, Lighting Design and Application, Vol 16, No 7, pp 47-51, July.
- 101• Grewjewski T, 1992, PhD Thesis, University College Of London.
- 102• Grundy J.W, 1992, **A Question Of Lighting**, Part 1, Optometry Today, 10 February: pp 18-22.
- 103• Grundy J.W, 1992, **A Question Of Lighting**, Part 2, Optometry Today, 9 March: pp 14-16.
- 104• Guth S. K, 1973, **Some Observation On The Biological Effects Of Light**, Lighting Design and Application, November.
- 105• Hall J.F, 1974, **Indicator Of Environmental Quality And Life Satisfaction: A Subjective Approach**,UCL, London.
- 106• Harber L.C, Whitman G.B, Armstrong R.B and Deleo V, 1985, **A Photosensitivity Diseases Related To Interior Lighting**, ann NY Acad. Sci. Vol 453 p 37-327.
- 107• Harvard C.W.H, 1990, **Black's Medical Dictionary**, 36th(ed).A&C Black, London.

- 108• Haubner P.A, 1969, **Method Of Scaling Judgments**, Lighting Res Technol, Vol 1 no 3.
- 109• Hawkes R.J, Loe D.L and Rowland E, 1979, **A Note Towards The Understanding Of Lighting Quality**, JIES Vol 8:pp111-120.
- 110• Hedge A, 1984a, **Evidence Of A Relationship Between Office Design And Self-Reports Of Ill-Health Among Office Workers In The United Kingdom**, Architectural and Planning Research Journal, No 3, pp 163-174.
- 111• Hedge A, 1984b, **Ill-Health Among Office Workers: An Examination Of The Relationship Between Office Design And Employee Well-Being**, Edited by Gradjean, Ergonomics and Health In Modern Offices, Taylor and Francis.
- 112• Hedge A, 1991, **Healthy Office Lighting For Computer Workers: A Comparison Of Lensed-Indirect And Direct Systems**, Proceedings Of IAQ '91-Healthy Buildings, Washington D.C, USA, pp 61-66, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta.
- 113• Heerwagen J and Heerwagen D.R, 1986, **Lighting And Psychological Comfort**, Lighting Design and Application, Vol 6, No 4, pp 47-51, April.
- 114• Heimstra N.W and McFarling, 1974, **Environmental Psychology**, Brooks/Cole Publishing Co, California.
- 115• Helm R.N, 1980, **Illumination Engineering For Energy Efficient Luminous Environments**, Englewood Cliff, N.J, Prentice-Hall.
- 116• Helman C.G, 1990, **Culture Health And Illness**, 2nd ed, Wright, London.
- 117• Herzlich C, 1972, **Health And Illness: A Socio-Psychological Approach**, in Smith G.T, Measuring Health : A Practical Approach, Academic Press, John Wiley and Sons, New York, 1988.
- 118• Hesselgren S, 1969, **The Language Of Architecture**, 2nd (ed), Studentlitteratur, Lund, Sweden.
- 119• Hesselgren S, 1975, **Perception Of Man-Made Environment: An Architectural Theory**, Hutchinson and Ross, USA.
- 120• HMSO, 1974, **Health And Safety At Work Act**, Health and Safety Commission, London.
- 121• HMSO, n.d, **Lighting In Offices, Shops And Railway Premises**, Series 39, London.
- 122• Holdsworth B and Sealey A.F, 1992, **Healthy Buildings: A Design Primer For A Living Environment**, Longman Group, England.
- 123• Holick F et al, 1982, **The Photochemistry And Photobiology Of Vitamin D3**. In Regan J.D and Parrish J.S (ed), Photomedicine, Plenum, New York.
- 124• Hollwich F and Dieckhues B, 1980, **The Effect Of Natural And Artificial Light Via The Eyes On The Hormonal And Metabolic Balance Of Animal And Man** Ophthalmologica 180(4) :pp188-197.
- 125• Hopkins R G, 1961, **Apparent Brightness: The Measure Of What We See**, Light and Lighting, November, pp330-333.
- 126• Hopkins R.G and Collin J.B, 1970, **The Ergonomic Of Lighting**, Macdonald Technical and Scientific, London.
- 127• Hopkins R.G and Kay J.D, 1972, **Lighting Of Building**, Revised Edition, Faber and Faber, London.

- 128• Hopkinson R.G, 1963, **Architectural Physic: Lighting**, Her Majesty's stationery Office, London.
- 129• Hopkinson R.G, 1969, **Lighting And Seeing**, Willian Heinemann, Medical Books Ltd, London.
- 130• Hughes P.C, 1983, **An Examination Of The Beneficial Action Of Natural Light On The Psychobiological System Of Man**, Proceeding CIE 20th Session, D603/1-D603/4, Amsterdam.
- 131• Hunt and McLeaod, 1988, **Health And Behaviour Change: Some Lay Perspective**, Community Medicine, 9, 1987 in Smith G.T, **Measuring Health : A Practical Approach**, Academic Press, John Wiley and Sons, New York, pp 68-76.
- 132• Hunt S, 1988, **Measuring Health In Clinical Care And Clinical Trials**, in Smith G.T, **Measuring Health : A Practical Approach**, Academic Press, John Wiley and Sons, New York, pp 7-9.
- 133• Hunter R.S and Harold R.W, 1987, **The Measurement Of Appearance**, 2nd Edition, John Wiley and Sons Publication, New York.
- 134• Ibrahim M.N, 1995, **Development Of The Methodology For The Measurement Of The Indoor Pollutants In Problem-Solving Research: As Applied To The Assessment Of Health Hazards In Office Building**, Ph.D Dissertation, University College of London.
- 135• Ittelson W.H, 1960, **Visual Space Perception**, Springer, New York.
- 136• Jablonski S, 1987, **Jablonski's Dictionary Of Syndromes And Eponymic Diseases**, Krieger Publishing Co., Florida.
- 137• Jay P, 1971, **Lighting And Visual Perception**, Lighting Research Technology, 3(1) pp133-146.
- 138• Julian W, 1981, **The Effect Of Low Surface Reflectances In Modern Buildings**, Proc. CEI IV Lux Europa.
- 139• Julian W, 1982, **Modern Trends In Building Finishes And Their Influence On Lighting Quality**, Lampetten, 17(1) pp32-43.
- 140• Julian W, 1987, **Lighting: An Urgent Case For A Major Research Effort In Architectural Science**, Building and Environment, 22(3)155-161.
- 141• Julian W, 1988, **Consideration In Modern Lighting Design**, Lighting in Australia, 14-23, August.
- 142• Kalff L.C, 1970, **Creative Light**, Phillips Lighting, London.
- 143• Kanaya S, Hashimoto K and Kichize E, 1979, **Subjective Balance Between General Colour Rendering Index, Colour Temperature And Illuminance Of Interior Lighting**, Proc CIE19thsession pp 274-278, Kyoto.
- 144• Kosky R.J, Eshkevari H.S and Carr V.J, 1991, **Mental Health And Illness- A Textbook For Students Of Health Science**, Butterworth-Heinemann, Australia.
- 145• Kuller R, 1972, **A Semantic Model For Describing The Perceived Environment**, National Swedish Building Research Summaries Document D12.
- 146• Kuller R, 1982, **Non Visual Effects Of Light And Colour**, Swedish Council for Building Research.
- 147• LaBar G, 1992, **Putting Indoor Air Quality In Its Place**, Occupational Hazards, October, p105-108.

- 148• Lam W.M.C (ed), 1977, **Perception And Lighting: As Formgivers For Architecture**, McGraw-Hill, New York.
- 149• Lam W.M.C, 1986, **Sunlighting: As Form Giver For Architecture**, Von Nostrand Reinhold, New York.
- 150• Lambropoulon E, 1992, **Relation Between Average Df On Horizontal Plane And Subjective Impression**, MSc Environmental Studies Thesis, Bartlett Graduate School, UCL.
- 151• Larson L, 1964, **Lighting And Its Design**, Whitney Library of Design, New York.
- 152• Lechner N, 1990, **Heating, Cooling And Lighting: Design Methods For Architects**, Wiley interscience Pub, London.
- 153• Lee T, 1976, **Psychology And The Environment**, Methuen, London.
- 154• Lerman S, 1980, **Radiation Energy And The Eye**, McMillan Publishing Co., New York.
- 155• Lewis A.L, 1994, **The Aging Visual System**, Lighting Design and Application, p 34 and 36, March.
- 156• Lewy A.J and Markey S.P, 1978, **Analysis Of Melatonin In Human Plasma By Gas Chromatography Negative Chemical Ionization Mass Spectrometry**, Science, vol 201p 741-743.
- 157• Lewy A.J and Markey S.P, 1980, **Analysis of Melatonin In Human Plasma By Gas Chromatography Negative Chemical Ionization Mass Spectrometry**, Science 201, pp 741-743.
- 158• Lewy A.J, Lern H.W, Rosenthal N.E and Wehr T.A, 1982, **Bright Artificial Light Treatment Of A Manic Depressive Patient With A Seasonal Mood Cycle**, American Journal of Psychiatry no139, p1496-1498.
- 159• Lewy A.J, Sack R.L, Frederickson R.H, Reaves M, Denny D and Zielski D.R, 1983, **The Use Of Bright Light In The Treatment Of Chronobiologic Sleep And Mood Disorders: The Phase Response Curve**, Psychopharmacology Bulletin, Vol 19, no 3, p523-525.
- 160• Lewy A.J, Socks R.L, Miller S and Hoban T.M, 1987, **Antidepressant And Circadian Phase Shifting Effects Of Light**, Footnote 17 Science 235 p 352-354.
- 161• Lighting Design and Application, 1982, **Offices**, Vol 12, No 4, pp 12-25, April.
- 162• Lighting Design and Application, 1983, **Offices**, Vol 13, No 3, pp 10-19, 24-36, March.
- 163• Lighting Design and Application, 1985, **Offices**, Vol 15, No 10, pp 27-30, October.
- 164• Lindner H and Kropf S, 1993, **Asthenopic Complaints Associated With Fluorescent Lamp Illumination: The Role Of Individual Disposition**, Lighting Research and Technology, Vol 25, no 2, pp 59-69.
- 165• Loe D, 1993, **Lighting For Museums And Art Galleries**, CIBSE Seminar, 14 December, London.
- 166• Loe D, 1993, **The Power Of Lighting ; research in the field**, LD+A, april, 52-65.
- 167• Loe D.L, Mansfield K.P and Rowland E, 1994, **Appearance Of Lit Environment And Its Relevance In Lighting Design: Experimental Study**, Lighting Res Technol, Vol 26 no 3.
- 168• Loe D.L, Rowland E and Watson N.F, 1982, **Preferred Lighting Conditions For The Display Of Oil And Watercolour Painting**, Ltg res and Tech, vol 14 no 4.

- 169• Loe, 1993, **Light And Lighting Msc Lecture**, Module L1: Lecture 1, 15th October.
- 170• London Hazards Centre, 1990, **Sick Building Syndrome: Causes, Effects And Control**, A London Hazards Centre Handbook, London.
- 171• Longmore J, 1966, **Lighting Of Work Places**, Ministry of Technology, Ergonomic for Industry, No 9, London.
- 172• Ludlow A.M, 1976, **The Function Of Windows In Buildings**, Lighting Research Technology, Volume 8(2), p57-68.
- 173• Lynes (ed), 1978, **Development In Lighting - 1** , Applied Science Publication Ltd, England.
- 174• Lythgoe R.J, 1932, **The Measurement Of Visual Acuity**, Medical Research Council Special Report, No173.
- 175• Mandler G,1984, **Mind And Body - Psychology Of Emotion And Stress**, W-W Norton And Co, New York - London.
- 176• Manning P (ed), 1965, **Office Design: A Study of Environment**, Pilkington Research Unit.
- 177• Mansfield K.P, 1994, **Light and Lighting MSc Lecture**, Module L3: Lecture 1, 11th January .
- 178• Mants D.C and Muir Gray J.A, 1986, **Building Regulation And Health**, Building Research Establishment Report.
- 179• Markus T.A, 1967, **The Function of Windows: A reappraisal**, Building Science, 2, p96-121.
- 180• Markus T.A, 1967, **The Significance Of Sunshine And View For Office Workers**, Edited By Hopkinson R.G, Sunshine Building, Bouwcentrum International, Rotterdam.
- 181• Marr D, 1982, **Vision: A Conceptual Investigation Into The Human Representation And Processing Of Visual Information**, Freeman, USA.
- 182• Marsden A.M, 1969, **Brightness: A Review Of Current Knowledge**, Lighting Res. Technol, Vol 1 no 3, p 171-181.
- 183• Marshall J, 1985, **Radiation And The Aging Eyes**, Ophthal. Physiol. Opt, vol 5(3), p241-263.
- 184• Matthews V, 1992, **Office Technology 2**, Daily Telegraph, 3 November: p11.
- 185• Mayron L.W, 1975, **Caries Reduction In School Children**, Applied Radiology July/August.
- 186• McCullough W, 1969, **Physical Working Conditions**, Gower P., London.
- 187• McDowall, M.E, 1987, **The Identification Of Man-Made Environmental Hazards To Health**, McMollan Press, London.
- 188• McKinlay A F and Whillock M J, 1987, **Measurements Of Ultraviolet Radiation From Fluorescent Lamps Used For General Lighting And Other Purposes In Uk In Passchiers W F And Bosnakovic B F M (Eds). Human Exposure To Ultraviolet Radiation: Risk And Regulations**, pp 253-258, Oxford: Excerpta Medica.
- 189• McKinlay A.G, Harlen F and Whillock M.J, 1988, **Hazards Of Optical Radiation**, Adam Hilger, Bristol.
- 190• McMullan R, 1992, **Environmental Science In Buildings**, 3rd(ed), MacMillan Press Ltd.

- 191• Melhuish A, 1978, **Executive Health**, Business Book Ltd, London.
- 192• Miller, 1979, **Symptoms**, 1st (ed), Sigmund Stephen (ed), McMillan London Ltd, London.
- 193• Moon P and Spencer D.E, 1944, **Visual Data Applied To Lighting Design**, J. Opt Soc Amer. 34(10)605.
- 194• Mostepanenko E.I, 1984, **Opportunities For The Artistic Use Of Light To Convey A Play Images**, ABTT News, November, p4.
- 195• Mougan H.W, 1958, **The Waking Brain**, Charles C.T, Springfield, Illinois.
- 196• Muel B, Whitman G.B, Armstrong R.B and Deleo V.A, 1985, **Photosensitivity Diseases Related To Interior Lighting**, Ann. NY Acad. Sci 453 :pp317-327.
- 197• Ne'man and Hopkinson, 1974, **Minimum Window Size**, Lighting Research Technology, Volume 6(2).
- 198• NRPB, **Protection Against Ultraviolet Radiation In The Workplace**, National Radiological Protection Board, H.M.S.O.
- 199• Nuckolls J.L, 1983, **Interior Lighting For Environmental Designers**, Wiley, New York.
- 200• O'Mahony T, 1985, **Light And Emotion: An Aesthetic-The World Is Really People And Emotion**, Lighting Design and Application, Vol 15, No 9, pp 25, September.
- 201• O'Muircheartaigh, 1976, **Statistical Aspects Of Subjective Measure Of Quality Of Life**, University College Of London, London.
- 202• O'Sullivan P, 1993, **Health Hazards in the Use of Buildings**, Water and Environmental Managements, Vol 7, no 2, pp122-124, April.
- 203• Olgyay V, 1992, **Designing with Climates**, Van Nostrand Reinhold.
- 204• Palmer R.H, 1985, **The Lighting Art: The Aesthetics Of Stage Lighting Design**, Prentice-Hall, California.
- 205• Passchier W.F and Bosnjakovic B.F.M (eds), 1987, **Human Exposure To Ultraviolet Radiation: Risk And Regulations**, Excerpta Medica, Amsterdam: Elsevier Science Publishers.
- 206• Pasternack B, Dubin N and Moseson M, 1983, **Malignant Melanoma And Exposure To Fluorescent Lighting**, Letter, Lancet 704.
- 207• Pearson D, 1991, **Making Sense Of Architecture**, Architectural Review, vol 139, no 1136, p68-70, October.
- 208• Perkin, 1992, **Investigation Into Effects Of Luminance Pattern On Subjective Impression**, MSc Environmental Studies Thesis, Bartlett Graduate School, UCL.
- 209• Perry M, Campbell F and Rothwell S, 1987, **A Physiological Phenomenon And Its Implications For Lighting Design**, Lighting Res Technol, 19(1)1-5.
- 210• Petterson, Swedish Newsletter, 1991, **Poor Lighting Causes Hormone Imbalance In School Children**, Newsletter of Swedish Building Research No 2.
- 211• Phillips D, 1964, **Lighting In Architectural Design**, McGraw-Hill, New York.
- 212• Phillips D, 1970, **Lighting**, 4th (ed), Design Centre Publication, McDonald and Co, London.
- 213• Phillips Lighting, 1994, **Visit/Seminar**, Phillips Headquater, Croydon.



- 214• Phillips, 1992, **The Visual Environment and Patients Health within Hospitals**, Thesis, UCL, London.
- 215• Pineger, 1994, **Towards A Green And Pleasant Office**, in Lighting Forum Seminar, CIBSE Seminar Proceeding, Lightshow, Earls Court.
- 216• Plummer H, 1987, **Poetic Of Light**, extra edition, Architecture and Urbanism, December.
- 217• Potter I.N, n.d, **The Sick Building Syndrome: Symptoms, Risk Factors And Practical Guidance**, BSRIA, Technical Notes 4/88.
- 218• Powell J.A (ed), Cooper I and Lera S, 1984, **Designing For Building Utilisation**, E.& F.N. Spon Ltd, New York.
- 219• Pritchard D.C (ed), 1982, **Development In Lighting - 2** , Applied Science Publication Ltd, England.
- 220• Pritchard D.C, 1986, **Interior Lighting Design**, 6th(ed), Published jointly by the Lighting Industry Federation and The Electricity Council, London.
- 221• Pritchard D.C, 1995, **Lighting**, 5th(ed), Longsman Scientific and Technical.
- 222• Raw G, Leinster P, Thomson N, Leaman A and Whitehead C, 1991, **A New Approach To The Investigation Of Sick Building Syndrome**, CIBSE National Conference 1991, University of Kent, Canterbury, 7-9 April, pp339-344.
- 223• Raw G.J, 1992, **Sick Building Syndrome: A Review Of The Evidence On Causes And Solution**, HSE Contract Research Report no 42/1992, London.
- 224• Raw G.J, Phil D and Psychol C, 1992, **Sick Building Syndrome: A Review Of The Evidence On Causes and Solution**, Building Research Establishment, London.
- 225• Rea M.S, 1982, **Calibration Of Subjective Scaling Responses**, Lighting Research Technology, Vol 14 no 3, p121-129.
- 226• Rea M.S, 1983, **Behavioral Responses To A Flexible Desk Luminaire**, JIES October.
- 227• Rea M.S, 1986, **Some Practical Implications Of A New Visual Performance Model**, Proc National lighting Conference, Nottingham, CIBSE, London.
- 228• Rea M.S, Ouellette M.J and Kennedy M.E, 1985, **Lighting And Task Parameters Affecting Posture, Performance And Subjective Rating**, JIES vol 15 no 1.
- 229• Reid C, 1988, **Architectural Light**, Architectural Journal, 13 April.
- 230• Rene Dubos, 1979, **Mirage Of Health**, in Black N. et al, Health and Diseases, Open University Press, Milton Keynes.
- 231• Rigel D.S, Friedman R.J, Levenstein M.J and Greenwald D.I, 1893, **Malignant Melanoma And Exposure To Fluorescent Lighting At Work**, letter, lancet 704.
- 232• Rigel D.S, Friedman R.J, Levenstein M.J and Greenwald D.I, 1983, **Relationship Of Fluorescent Lights To Malignant Melanoma; Another View**, J Dermatol. Surg. Oncol. pp836-838.
- 233• Robertson A and Burge S, 1986, **Building Sickness - All In The Mind?**, Occupational Health, March, pp 78-81.
- 234• Robertson A.S and Burge S, 1985, **Building Sickness**, The Practitioner No 229, pp 531-534.

- 235• Robertson A.S, Burge P.S, Hedge A., Sirs J, Gills F.S, Finegan M, Pickering C.A.C, and Dalton G, 1985, **Comparison Of Health Problems Related To Work And Environmental Measurements In Two Office Buildings With Different Ventilation System**, British Medical Journal, 291, pp373-376.
- 236• Robertson A.S, McInnes M, Glass D, Dalton G and Burge P.S, 1989, **Building Sickness, are Related to The Office Lighting?** Annals Of Occupational Hygienes No 33, pp 47-59.
- 237• Roessler G, 1980, **The Psychological Function Of The Windows For Visual Communication**, Lighting Research Technology, Volume 12 (8).
- 238• Ronch L.R and Bodmann H.W, 1973, **Fluorescent Lighting, Skin Cancer And Malignant Melanoma**, CIE Journal, December.
- 239• Rosenthal N.E, Sacks D.A, Carpenter C.J, Parry B.L, Mendelson W.B, and Wehr T.A, 1985, **Antidepressant Effect Of Light In Seasonal Affective Disorder**, American Journal of Psychiatry, Vol 142, no 2, pp 163-170.
- 240• Rosenthal N.E, Sacks D.A, Gillin C, Lewy A.J, Goodwin F.K, Davenport V, Muellin P.S, Newsome D.A and Wehr T.A, 1984, **Seasonal Affective Disorder: A Description Of The Syndrome And Preliminary Findings With Light Therapy**, Archives of General Psychiatry, No 41, pp72-80.
- 241• Rosenthal N.E, Sack D.A, Carpenter C.J, Parry B.L, Mendelson W.B and Wehr T.A, 1987, **Antidepressant Effects Of Light** Footnote 17 Science 235:pp 352-354.
- 242• Rowland A.J and Cooper P, 1983, **Environment And Health**, Edward Arnold, London.
- 243• Rowland E, Loe D.L, McIntosh R.M and Mansfield K.P, 1985, **Lighting Adequacy And Quality In Office Interiors By Consideration Of Subjective Assessment And Physioical Measurements**, CIE Journal 4.
- 244• Rubin A.I and Elder J, 1980, **Building For People: Behavioral Research Approaches And Direction**, National Bureau of Standards Special Publication 474, Washington.
- 245• Ruck N.C (ed), 1989, **Building Design And Human Performance**, Van Nostrand Reinhold, New York.
- 246• Rudolph P, 1978, **Light, Architecture And Aesthetic: Architecture And Lighting, That The Two Should Meet**, Lighting Design and Application, November.
- 247• Russell L.P, 1991, **Listening To Lighting's Music**, Ligting Design + Application, vol 21, no 3, p7-12.
- 248• Ruys, 1970, **Windowless Offices**, MA Thesis, University Of Washington, Seattle, Washington, USA.
- 249• SAD Association, n.d, **Seasonal Affective Disorder (S.A.D)**, SADA Information, PO Box 989, London SW7.
- 250• Sarafino E.P, 1990, **Health Psychology: Biopsychosocial Interaction**, 2nd Edition, John Wiley and Sons, New York.
- 251• Schiff W, 1980, **Perception: An Applied Approach**, Houghton Mifflin, New York.
- 252• Schlaefle E, 1995, **Light Is Life**, Design and Light, 1/95, vol 5, April, p12-14.
- 253• Schmits P, 1995, **Office Lighting**, Architecture and Light, No 7 July/August/September.
- 254• Shepherd A J, Julian W G, Purcell A T, 1992, **Measuring Appearance: Parameters Indicated from Gloom Studies**, LRT, 24(4)pp 203-214.

- 255• Shepherds, Julian and Purcell, 1989, **Gloom As A Psychophysical Phenomena**, Lighting Research Technology 21(3) pp 89-97.
- 256• Shorter E, 1994, **From The Mind Into The Body: The Cultural Origins Of Psychosomatic Symptoms**, Free Press, New York.
- 257• Shorter E, 1994, **From The Mind Into The Body: The Cultural Origins Of Psychosomatic Symptoms**, The Free Press. New York.
- 258• Shorter E, 1994, **From the Mind Into The Body - The Cultural Origins Of Psychosomatic Symptoms**, Free Press, New York.
- 259• Schultz J.H, 1965, **Lebensbilderbuch eines Nervenarztes: Jahrzehnte in Dankbarkeit** (Stuttgart: Thieme, 1964) p64-65.
- 260• Siemen Aktiengesellschaft, 1995, **Design And Light**, 1/95, vol 5, April, p6-7.
- 261• Simpson J, 1989, **Maintenance And Design Cure Sick Buildings**, Building Today, April 20, pp 38-39.
- 262• Simpson J.A. and Weiner E.S.C, 1989, **The Oxford English Dictionary**, 2nd(ed), vol 8, Clarendon Press, Oxford.
- 263• Slater A.I, 1989, **Illuminance Distribution: Prediction For Uniform And Non-Uniform Lighting**, Lighting Research Technology, 21(4) 133-158.
- 264• Smith R.D, 1986, **Light And Health - A Broad Overview**, Lighting Design and Application, February p32-40.
- 265• Sobel M, 1987, **Light**, University of Chicago Press, London.
- 266• Sorahan T and Grimley R.P, 1980, **The Aetiological Significance Of Sunlight And Fluorescent Lighting In Malignant Melanoma: A Case-Control Study**, Br. J Cancer 52: pp765-769.
- 267• Sorensen S and Brunnstrom G, 1995, **Quality Of Light And Quality Of Life: An Intervention Study Among Older People**, Lighting Research Technology, 27(2) 113-118.
- 268• Spillman L. and Werner J.S (ed), 1990, **Visual Perception: The Neurophysiological Foundation**, Academic Press, San Diego.
- 269• Squillace S, 1990, **Photobiological Effects Of The Visible Spectrum**, Lighting Design and Application, August.
- 270• Squillace, 1973, Lighting Design and Application.
- 271• Steck B, 1982, **Effect Of Optical Radiation On Man**, Lighting Research Technology, vol 14(3), p130-141.
- 272• Steffy G, 1986, **Lighting For Architecture And People: A Case Study**, Lighting Design and Application, July, p38-40.
- 273• Steffy G.R, 1990, **Architectural Lighting Design**, Van Nostrand Reinhold, New York.
- 274• Sterling E and Sterling T, 1983a, **The Impact Of Different Ventilation Levels And Fluorescent Lighting Types On Building Illness: An Experimental Study**, Canadian Journal Of Public Health, no 74, pp 385-392.
- 275• Steven S.S, 1976, **Psychophysic: Introduction To Its Perceptual, Neural And Social Prospects**, Wiley, New York.

- 276• Stolwijk J.A.J, 1984, **The Sick Building Syndrome**, in Berglund B. et al (ed), Indoor Air, Vol 1, Recent Advances in The Health Science and Technology, Swedish Council for Building Research, Stockholm, Sweden, p23-29.
- 277• Stone P.T, 1980, **Light And The Eyes At Work**, The Ophthalmic Optician, 5 January.
- 278• Stone P.T, 1993, **Light And Lighting Msc Lecture**, Module L1:Lecture 4, 26th October.
- 279• Stone, P.T, 1989, **A Review Of The Health Aspects Of Lighting**, Contract Report To The BRE.
- 280• Stones P.T, 1980, **Owen Aves Memorial Lecture: Light And The Eyes At Work**, The Ophthalmic Optician,5 January :pp8-13.
- 281• Stones P.T, 1992, **Fluorescent Lighting And Health**, Light Research Technology, vol 24, no 2, pp55-61.
- 282• Sucov E.W and Taylor L.H, 1975, **The Effect Of Non-Uniform Light Distribution On Behaviour**, Compte Rendu, 118e session, P- 75- 03, CIE Congress, London.
- 283• Sudjic D, 1993, **The Lighting Book**, Mitchell Beazley, London.
- 284• Sundstrom E and Sundstrom M.G, 1986, **The Psychology Of The Physical Environment In Offices And Factories**, Cambridge University Press, London.
- 285• Svaboda, 1985, **The Theatre Today - The Theatre Tomorrow**, ABTT News, February, p2-3.
- 286• Sykes J.M, 1988, **Sick Building Syndrome: A Review**, Specialist Inspector Reports, Health and Safety Executive Technology Division, Report no 10, June.
- 287• Taylor L.H and Sucov E.W, 1974 **The Movement Of People Towards Light**, JIES, April.
- 288• Teymur N, 1982, **Environmental Discourse: A Critical Analysis Of 'enviromentalism' In Architecture, Planning, Design, Ecology, Social Science And The Media**, Question Press, London.
- 289• Thorington L, 1973, **Light, Biology And People**, Lighting Design and Application, December.
- 290• Tiller D.K and Veitch J.A, 1995, **Perceived Room Brightness: Pilot Study On The Effect Of Luminance Distribution**, Lighting Research Technology, 27(2)93-101.
- 291• Tiller D.K, 1989, **Towards Better Office Design Standard**, Lighting, Vol 3, No 3, pp23-24, June.
- 292• Tong D and Tyler M, 1991, **Ec Directive On Vdu's: Safety In The Office**, Architecture Journal, 8 May, pp 61-63.
- 293• Trotter A.P, 1892, **The Distribution And Measurement Of Illumination**, Institute of Civil Engineers, London.
- 294• Turner H.J and Julian W.G, 1983, **Lighting: Basic Concept**, Department of Architectural Science, Australia.
- 295• Turner J, 1994, **Lighting: An Introduction To Light, Lighting And Light Use**, BT. Batsford Ltd, Hong Kong.
- 296• Ure J.W, 1980, **The Technical, Functional And Economic Viability Of Lighting Control Systems In Open Plan Offices**, Association in Building Services, Britain, September.

- 297• Vaughan N, 1993-1994, **Supervision Notes**, London.
- 298• Veitch J.A and McColl S.L, 1995, **Modulation Of Fluorescent Light: Flicker Rate And Light Source Effects On Visual Performance And Visual Comfort**, Lighting Research and Technology, Vol 27, no 4, pp 243-256.
- 299• Vernon M.D (ed), 1966, **Experiments In Visual Perception**, Penguin Modern Psychology, England.
- 300• Vernon M.D, 1963, **The Psychology Of Perception**, Penguin Books, England.
- 301• Visher J, 1989, **Environment Quality In Offices**, Dissertation, UCL, London.
- 302• Waldram J.M, 1923-1989, **Published Papers Relating To Lighting**, UCL, London.
- 303• Walker B, 1991, **Allergic Reaction To Building**, Building Services, January.
- 304• Watson L, 1990, **Lighting Design Handbook**, MacGraw-Hill, New York.
- 305• Weale R.A, 1960, **The Eye And Its Function**, Hatton Press, London.
- 306• Weale R.A, 1963, **The Aging Eye**, H.K Lewis, London.
- 307• Weale R.A, 1982, **A Biography Of The Eye: Development, Growth And Age**, Lewis, London.
- 308• Weale R.A, 1982, **Focus On Vision**, Hodder and Stoughton, London.
- 309• Weale R.A, 1983, **Light And Age**, C.I.E Journal, vol 2(2) p60-64.
- 310• Weston H.C, 1953, **The Relation Between Illumination And Visual Performance**, Illumination Research Committee, D.S.I.R, London, H.M.S.O.
- 311• Weston H.C, 1962, **Sight, Light And Work**, 2nd Ed, H.K Lewis & Co Ltd, London.
- 312• Whillock M, Clark I.E, McKinlay A.F, Todd C.D and Mundy S.I, 1986, **Ultraviolet Radiation Levels Associated With The Use Of Fluorescent General Lighting, UVA And UVB Lamps In The Workplace And Home**. National Radiological Protection Board Report NRPB-R221, London HMSO.
- 313• WHO, 1972, **Health Hazard Of The Human Environment**, Geneva.
- 314• WHO, 1987, **Psychological Factors At Work And Their Relation To Health**.
- 315• Wilkins A.J and Clark C, 1990, **Modulation Of Light From Fluorescent Lamps**, Lighting Research Technology, Vol 22, No 2, pp 103-109.
- 316• Wilkins A.J et al, 1987, **Fluorescent Lighting, Headaches And Eye Strain**, Proceedings Of The National Lighting Conference, Cambridge, p188-16, CIBSE, London.
- 317• Wilkins A.J, 1990, **Modulation Of Fluorescent Lighting**, Medical Research Council.
- 318• Wilkins A.J, 1993, **Health And Efficiency In Lighting Practise**, Energy Vol 18 no 2, pp123-129.
- 319• Wilkins A.J, 1993, **Health And Efficiency In Lighting Practise**, Medical Research Council.
- 320• Wilkins A.J, Nimmo-Smith E, Slater A.I and Bedocs L, 1989, **Fluorescent Lighting, Headaches And Eye Strain**, Lighting Research Technology 21(1): pp 11-18.
- 321• Wilman C.W, 1966, **Seeing And Perceiving**, Pergamon Press, London.

- 322• Wilson S and Hedge A, 1987, **The Office Environment Survey: A Study Of Building Sickness**, Building Use Studies.
- 323• Wilson, O'Sullivan, Hedge and Jones, 1987, **Sick Building Syndrome And Environmental Conditions: Case Studies In Nine Buildings**, BUS, London.
- 324• Wood J.E, Jansen J.E, Morey P.R, Rask D.R, 1987, **Resolution Of The Sick Building Syndrome**, IAQ87, Practical Control of Indoor Air Problems, Proceeding of The ASHRAE Conference, Arlington, Virginia, May 18-20, pp338-348.
- 325• **Workplace Comfort Forum**, 1995, Conference Proceeding, RIBA, March.
- 326• Wotton E, 1986, **Daylight And Window In Hospital Wards**, Lighting Design and Application, p55-86, June.
- 327• Wurtman R.J, Baum M.H and Potts J.T (eds), 1985, **The Medical And Biological Effects Of Light**, Annals Of The New York Academy Of Sciences, vol 453.
- 328• Wurtman R.J, Baum M.J, and Potts J.T., Jr (ed), 1985, **The Medical And Biological Effects Of Light**, New York, Annals of the New York Academy of Science, Vol 453.
- 329• Yonemura, G.T, 1978, **Light And Vision**, in Lynes (ed), Development in Lighting 1, Applied Science Publication Ltd, London, pp25-46.
- 330• Youngson R, 1985, **Everything You Need To Know About Your Eyes**, Sheldon Press, London.
- 331• Zackrison H.B, 1983, **Light Distribution Controlling Mediums For Use In Facilities Utilizing CRT's**, Lighting design and Application, p24-36, March.
- 332• Zajonc A, 1993, **Catching the Light: The Entwined History Of Light And Mind**, Bantam Press, London.
- 333• Zeki S, 1993, **A Vision Of The Brain**, Blackwell Scientific Publication, London.
- 334• Zwicker C (ed), 1952, **Fluorescent Lighting: A Review Of The Scientific And Technical Fundamentals And Of The Applications Of The Fluorescent Lamp And its Accessories**, Phillips Technical Library.

## STATISTIC BIBLIOGRAPHY

- 1• Babbie E.R, 1973, **Survey Research Method**, Wadsworth Publishing Company, California.
- 2• Blalock H.M, 1979, **Social Statistics**, Revised 2nd Edition, McGraw-Hill, Singapore.
- 3• De Vaus D.A, 1994, **Survey in Social Research**, 3rd Edition, UCL Press, England.
- 4• Leach C, 1979 **Introduction to Statistics: Nonparametric Approach for the Social Sciences**, John Wiley and Sons, Chicester.
- 5• Noether G, 1971, **Introduction to Statistics: A Fresh Approach**, Houghton Mifflin, Boston.
- 6• Siegel S and Castellan N.J, 1988, **Nonparametric Statistics for Behavioral Sciences**, 2nd Edition, McGraw-Hill, New York.
- 7• Yin R.K, 1993, **Application of Case Study Research**, Applied Social Research Method, Vol 34, Sage, London.
- 8• Yin R.K, 1993, **Case Study Research: Design and Methods**, 2nd Edition, Applied Social Research Method, Vol 5, Sage, London.
- 9• ITM Research Workshop Proceedings, 1991

# **APPENDIX 1: Effects Of Daylight On Health**

## **Introduction**

This section is a review of literature. It is essentially the background of the subject studied in the thesis, of which the thesis is a specific part. It gives only the effect of natural light on health. The effect of artificial light is covered in the thesis. The references to this section are pooled together with that of the thesis.

## **Effect of Natural Light On Human Health**

Natural daylight is variable in spectral output and intensity. This variation depends on the time of year and is determined by the position of the sun and atmospheric conditions. There also exists temporal changes in lighting due to the diurnal variation: dawn to dusk.

Health effect of natural light varies with the electro spectrum. The electro magnetic spectrum of sunlight is broad, extending from beyond the radio waves at one end to cosmic rays at the other. However, this research is limited from 290 to 1400 nm, light above ultra violet or beyond infra red is excluded.

The photobiological reaction in humans with regards to light is basically categorised as:

- skin responses
- internal glandular reactions

### **i) Skin Responses**

There are two type of skin response:

- Invisible
- Visible.



### The Invisible Skin Response

One major benefit of daylight is the role it plays in the production of vitamin D3 in the skin which is used to synthesize calciferol and other hormones. Medically, although not conclusive, it has been shown that without this vitamin, the intestine cannot absorb sufficient calcium and phosphorus, essential for bone growth, repair and maintenance (Thorington, 1973). This is effectively a mechanism to offset rickets, a bone malformation condition occurring mainly in children. Whereas in older people, this problem manifests itself as osteomalacia (softening of the bone). Vitamin D3 is also vital as it acts as the precursor to the absorption of other minerals in the human body.

D3 can rarely be obtained from ordinary food and is normally synthesized as a result of exposure to natural light. However, one does not need huge amounts of D3. An average daily exposure of a person to ordinary daylight for a quarter of an hour in the open air in the UK is sufficient to give a number of units of D3 to sustain good health. This only becomes critical for people who are confined to the indoor environment. Consequently, it has been suggested that sunbathing has no health advantages.

### The Visible Skin Response

The visible response is the skin pigmentation. Skin produces a protective response by pigmentation and this can occur in two ways.

- Immediate pigmentation.
- Secondary pigmentation.

The immediate pigmentation phase tends to occur within minutes of the exposure, largely to UVA. It can be stimulated to a certain degree by visible light. Peak sensitivity of the skin to the wavelength is 340nm (The band extends from 300-430nm). This creates the oxidation of the melanin pigment (not to be confused with melatonin). For this particular process the effect disappears relatively fast after exposure and one gets a residual amount that remains for a short while. It declines from its peak intensity in approximately 24hrs and has a flattening effect over a period of weeks. Besides the skin pigmentation, the health benefit of UVA is not known. However, UVA has no potent effect, it takes approximately a thousand times the amount of radiation from UVA to obtain equivalent response to that of UVB (Glass does not transmit UVA, therefore no amount of sitting by a window will induce skin pigmentation. Therefore, people who work indoors with low UV generating electric light, are shielded from direct sun and travel early or late in the day when UVA radiation is very low, will have minimal UVA exposure).

Secondary pigmentation is caused by prolonged exposure to UVB radiation. The skin suffers a burning reaction called erythema. After a few days the secondary pigmentation appears. Providing there is no continuous exposure to UVB this pigmentation will gradually disappear with normal cell replacement. Peak sensitivity of the skin to the wavelength is 297nm (This extends from 280-315nm). UVB is potent to the skin. Intermittent over-exposure to UVB causes the skin to become coarse and wrinkle. Where there is constant over-exposure, skin cancer can be induced. There are 3 types of skin cancer:

- squamous cell carcinoma
- Basal cell carcinoma
- melanoma

The first two types are not very critical and commonly found in farmers or people that work outdoors. On the other hand, malignant-melanoma has only recently been discovered and is dangerous. It is rare but there is a noticeable growing number of cases. In the UK, positive correlations were shown between incidents of skin cancer and sunshine hours for different regions (Rowland and Cooper, 1983). The occurrence of these malignant skin cancers may also be partly caused by the ozone depletion and the increase in UVC levels, as well as a result of skin sensitisation due to an indoor lifestyle.

The category of people that would succumb to this condition is not known. But, it is thought that light haired, white skinned, celtic people particularly are more vulnerable to UV light, especially on long exposure. This is very common among indoor workers, especially young white females in equatorial zones. Causes are not understood and correlation with ultra violet radiation is not conclusive (Ronch and Bodmann, 1973).

UVC has the shortest wavelength. It is most hazardous and is fortunately filtered out by the earth's stratosphere. But, with ozone depletion due to release of aerosols and CFC's in the atmosphere, there is a growing concern as it becomes possible for UVC to reach the earth's surface. Moderate exposure of UVC has been shown medically to cause erythema (reddening of the skin, or sun burn) conjunctivitis and keratitis (inflammation of the eye).

At the other end of the visible spectrum, infra red has no known biological effects other than heating. This heat penetrates into the skin and muscles and result in increased blood circulation. Infra red lamps are used for this reason in muscle therapy. This wavelength can penetrate glass and in fact, heating is a feature of any window under direct radiation, whether beneficial or unwanted, as in summer.

## ii) Internal Glandular Reactions

The internal glandular reactions is the reaction of the glands inside the human body whereby hormones are produced. The internal glandular reaction is mediated by the pineal gland<sup>86</sup>. Visible lights effects the Light-Eye-Brain interaction through the second path (an optical tract that "sees" without vision (Guth, 1973). The following sections deals with responses due to these pathway reactions.

The pineal gland does not sense light, but it receives nerve signals that originate in the retinas of the eyes. Melatonin is produced in the pineal gland during the dark. Lewy showed that it rises during the dark period and declines during the light period of the day (Lewy, 1978). This is a continuous diurnal process. This synthesis and inhibition follows the circadian cycle. It has been shown that for birds and mammals it regulates over the season.

The melatonin affects the production of several other hormones by affecting the thyroid gland and metabolic process. As such, the pineal has a relationship with other organs especially with the pituitary, thyroid, adrenal and the gonads. The light reaching the retina has an effect on the entire endocrine system - pineal, pituitary, hypothalamus and thyroid, thereby influencing certain body functions. The secretion of melatonin, enables the pineal to regulate the human body, it acts as a biological clock and an endocrine gland. It coordinates with the neural (nervous) input before resulting with a chemical output. This makes light response in human such that it has a direct influence through a complex change.

The following section aims to illustrate this complex interrelation of the pineal and other glands. To begin with, light has been shown to be helpful in treatment of psoriasis when used together with sensitising drugs (Squillace, 1973). Medical research has also shown that water balance, glucose balance, certain body cell rhythm, plasma - cortisol and human growth hormone levels are biologically effected by the light absorbed through the eye (Thorington, 1973). This report also showed that bilirubin level was also low for people with eye sight. Another experiment showed that light helps to convert bilirubin in premature infants into the necessary excretable waste, and therefore avoid hyperbilirubinemia which could cause mental disorder and cure the consequent case of jaundice (Guth, 1973).

---

<sup>86</sup> It used to be referred to as the "third eye". It has been known to exist in the human body for a very long time but has always been thought as a residual organ much like the appendix. Only over the last 50 years it has been shown to respond to light.

Light incident on the eyes stimulates the rate and chemical composition of saliva, which is reduced in quantity to about 25% after dark. It has also been found that light entering the eye of sighted subjects directly after the urinary chemical composition as compared to darkness and that the effects are different for red and blue radiations (Thorington, 1973). Effect of spectral quality has not been verified and no correlation has been found with respect to humans ( Guth, 1973).

### **iii) Daylight and Seasonal Rhythm**

Exposure to the natural light has adaptive effects. The spectrum, intensity and periodicity of light are relied upon by most organisms as a cue to the physical and temporal state of the environment. Induced hormonal secretion in these organs by the melatonin, affect biological rhythms such as menstrual cycle and the sex organs. In humans its function is still not clear besides regulating sleep and waking corresponding to the daylight condition which varies over the day and year. The general notion is that it serves the function of regulating bodily rhythms that are on 24hrs or a longer seasonal basis. One aspect that has been focused upon recently is depression disorders which involves swing of moods corresponding to lighting environment (this is discussed further under sub-topic SAD). This is a condition which effects many people in higher latitudes.

### **iv) Seasonal Affective Disorder**

This is an illness connected with daylight deprivation. It has been found that in these patients depression occurs during the autumn and winter months. In Britain this takes effect between September and April each year. It is said to be caused by a chemical imbalance in the hypothalamus - a photo sensitive gland in the brain which controls the pituitary gland, due to the shortening in daylight hours and the lack of sunlight in winter. Therefore, when autumn approaches depression begins, with no remission until the better light conditions in spring time (Lewy, 1978). This depression is recognised as Seasonal Affective Disorder (SAD). Rosenthal has shown that this depression is accompanied by physiological activities (Rosenthal, 1985):

1. sleep problems - a desire to sleep and difficulty to stay awake or disturbed sleep and early morning wakening.
2. lethargy - feeling of fatigue and inability to carry out normal routine.
3. overeating - a craving for carbohydrates and sweet foods, with resultant weight gain.
4. depression - feeling of misery and loss of self esteem.

5. social problems - irritable and desire to avoid social contact.
6. anxiety - tense and unable to tolerate stress.
7. loss of libido - decrease in sex and physical contact
8. mood changes - extreme of moods and over-activity (hypomania) in spring and autumn.

Some sufferers are vulnerable to infections, especially musculoskeletal and gastrointestinal problems. SAD symptoms tends to disappear in spring, either suddenly or gradually and these patients are become active, energetic and function normally. This condition also effects children but to a lesser extent. Rosenthal et al also discovered that these patients can be cured with phototherapy which has proved effective in up to 85% of diagnosed cases<sup>87</sup>. For many people it is a seriously disabling illness, for others, a mild but irritating condition. Therefore to a certain extent it effects everyone of us (SAD assoc, 1993).

#### v) Circadian Rhythm

Humans have various daily rhythms. Some of these are generated by light while some are generated internally. Studies have shown that both light and social cues are needed for the maintenance of these rhythms. In addition to these, temperature, diet, meal distribution and posture all play a part in the synchronisation or induction. The effect on human rhythms of displacement of the day-night cycle by air travel is well studied.

Experiment on both sighted and blind people can provide some information as to how much control light may exert. A variety of physiological functions were monitored during a midsummer voyage to the arctic (Weale, 1982). In spite of significant changes, adaptation to 21hr and 27hr days were not complete even after six weeks. At latitudes where daylight becomes continuous, some body functions became desynchronized at first. After two weeks some functions such as excretion re-established a 24hrs rhythm, however the cause is unknown. The pattern for blind persons differed significantly. A 24hr rhythm was maintained during the start of the experiment and only after isolation from sighted people did a change set in, the subjects eventually settled down to a 25hr rhythm. This was considered to be an indication of the power of social cues in maintaining a circadian rhythm.

---

<sup>87</sup> The important parameter for this effect seems to be illuminance i.e below 1000 lux is not effective. At this point a number of issues remain to be clarified. For a start, light treatment may be affective for other reasons. Secondly, the role played by and the importance of spectral distribution in phototherapy. Lewy showed that there were no differences between cool-white and Vita-lite operating at 2500lux. Thirdly, the question of optimum illuminance.

Positive evidence that light does play a role in human endocrine activity was obtained through experiments with subjects on strict sleep-wake, light-dark cycles (Weale,1982). It has been shown that glandular and metabolic functions in humans vary according to the time of day or night, but there is very little information about the extent to which the normally encountered light-dark cycle affect them. The highly controlled laboratory conditions employed in animal studies generally have little counterpart in the variety in man's environment. Again there are gaps between detailed biochemical findings and their effects in everyday life. In human species there are people that are most energetic at dawn while others are most energetic at night. Night activity involves strenuous physical effort and is quite possibly restricted to the young and energetic.

There is a psychological circadian relationship observed in most people. In a study carried out in an office landscape, the preference for fluorescent daylight tubes decreases in the evening. When there was no natural daylight outside, the electric light indoors became unpleasant, unnatural, cold and harsh (Kuller, 1982).

The necessity of circadian rhythm was best put forward by Kalff (1970) of Phillips lighting:

*" In the morning we wake up after a night of rest and sleep. People start the day full of energy. The sun is also up and full of colours and the lighting is light and cool. As the sun rises higher the light becomes more profused and warm in colour. During the second half of the day, when energy was already spent and a person begin to feel tired, we long for rest. This longing is accompanied by the gradual decline of the sun assuming a warmer glow and the consequent reduction of light. Therefore with the modern society, where the later part of the day is spent at home, hence the reason for less light and warmer colours in the domestic front. Our intellectual activity will generally diminish and our emotional lifes assumes a bigger role."*

**APPENDIX 2a: The Sample Of The Link Questionnaire**

# HEALTHY OFFICE ENVIRONMENT STUDY

For The Science & Engineering Research Council and the DTI

94 Victoria Street, London

## OCCUPANT'S QUESTIONNAIRE

March 1993

### Introduction

Interest in people's health in offices has been growing over recent years as you may have noticed from articles in newspapers and magazines. This study was set up to understand better the factors affecting health and comfort in office environments and to derive some lessons that can be used in the design of future buildings.

As part of our investigations we are carrying out detailed research in a number of buildings, including the one you work in, and it would help us considerably if you would take the time to complete this questionnaire, which is intended to draw upon and make use of your experience as a building user. The wide ranging nature of the questions asked reflects current theory concerning the determinants of people's health at work.

All the answers that you provide will be treated in confidence and used only for the purposes of our research. They will be stored on a computer and their use is governed by the terms of the Data Protection Act 1984.

Your employers or their representative will not have access to the questionnaires but only to the general conclusions conveyed in technical reports on the environmental performance of the building. Individuals will not be identified in these reports.

In answering the questions please do so from your own point of view, without consultation with your colleagues. It is important that the answers you give represent your viewpoint rather than that of somebody else.

When you have completed the questionnaire please hold on to it for collection by ourselves tomorrow.

Nigel Vaughan

The Welsh School of Architecture, UWCC, Cardiff  
Telephone: 0222 388348

Tadeusz Grajewski

The Bartlett School of Architecture, UCL, London  
Telephone : 071 387 7050 x 5908

### Please read this before you start

1. Please answer every question, or put a question mark against any that you can not answer.
2. Most questions refer to your WORKSPACE. This is the place where you spend most of your time at work. Typically this is where your desk is situated.
3. Most questions can be completed by ticking shaded areas in a table (see the examples below), or one box in a set of boxes.

#### Example 1

Q. How good is the food in the canteen?

A. If you thought the food was good but that there was room for improvement you might tick :-

Very Poor	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	Very Good
--------------	-----------------------	-----------------------	-----------------------	----------------------------------	-----------------------	--------------

#### Example 2

Q. How frequently have you commented to the following people about the building you work in?

		Never	1	2	3	4	5	Very Often
A colleague								<input checked="" type="checkbox"/>
A friend outside of work			<input checked="" type="checkbox"/>					
The people you live with						<input checked="" type="checkbox"/>		

#### Example 3

Q. By ticking one of the seven boxes in between each word pair, please indicate the extent to which a particular word, in each pair, most describes your WORKSPACE.

A. If you find your workspace (see the instructions for what is meant by this term) reasonably "pleasant", fairly "likeable" but very "cramped" you might tick the boxes as shown :-

		I feel my WORKSPACE is :-								
		3	2	1	0	1	2	3		
		←-----→								
Pleasant	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Unpleasant	<input type="checkbox"/>
Unlikeable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Likeable	<input type="checkbox"/>
Spacious	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Cramped	<input type="checkbox"/>



Q. Please answer the following questions about yourself :-

- Name
- Job title, band or grade
- Which of the following terms most describe your work/job ?
 

Managerial	<input type="checkbox"/>	Technical	<input type="checkbox"/>
Clerical	<input type="checkbox"/>	Administrative	<input type="checkbox"/>
Professional / Executive	<input type="checkbox"/>	Other	<input type="checkbox"/>
- Department
- How long have you worked in this building ?      years  months
- How many hours a week do you work in this building ?      hours
- How many hours a week do you work, including overtime?      hours
- When did you move to your current desk/workspace ?      Month, year
- Age      years
- Sex      male  female
- Do you smoke ?      yes  no
- Have you ever been diagnosed by a doctor as having an allergy ?      yes  no
- How many days have you had off work due to illness in the past 12 months ?      days
- How often do you engage in the following activities ?
 

	Daily	Weekly	Monthly	Less often	Never
Vigorous sports i.e. football, squash	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Less vigorous sports i.e. golf, sailing, walking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Passive relaxation i.e. meditation, yoga	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Gardening, D.I.Y.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Some other activity for relaxation. Please specify	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- Please describe your journey to work. (hours / miles)
 

	Journey time	<input type="text"/>	Journey distance	<input type="text"/>
Method of travel	Car	<input type="checkbox"/>	Bus	<input type="checkbox"/>
	Train	<input type="checkbox"/>	Motorbike	<input type="checkbox"/>
	Cycle	<input type="checkbox"/>	Walk	<input type="checkbox"/>
- How long have you been in continuous full-time paid employment since last having a break of a year or more ?      years

C. Please indicate whether you have experienced any of the following in the past 24 months.

- |  |                          |  |                          |
|--|--------------------------|--|--------------------------|
| Death of a spouse                      | <input type="checkbox"/> | Prosecuted for a violation of the law                    | <input type="checkbox"/> |
| Death of a close family member         | <input type="checkbox"/> | Time off work due to a major illness                     | <input type="checkbox"/> |
| Divorce                                | <input type="checkbox"/> | Time off work due to a major injury                      | <input type="checkbox"/> |
| Marital separation                     | <input type="checkbox"/> | Got married  | <input type="checkbox"/> |
| Break-up of long standing relationship | <input type="checkbox"/> | Trouble with a close relative                            | <input type="checkbox"/> |
| Marital or partnership reconciliation  | <input type="checkbox"/> | Trouble with neighbours                                  | <input type="checkbox"/> |
| Close family member been very ill      | <input type="checkbox"/> | Changed jobs   | <input type="checkbox"/> |
| Big change in financial circumstances  | <input type="checkbox"/> | Took out a new mortgage or loan                          | <input type="checkbox"/> |
| Pregnancy                              | <input type="checkbox"/> | Big change in responsibilities at work                   | <input type="checkbox"/> |
| A major problem at work                | <input type="checkbox"/> | Had a big change in living conditions                    | <input type="checkbox"/> |
| Moved homes                            | <input type="checkbox"/> | Gained a new family member                               | <input type="checkbox"/> |
| Partner started or stopped work        | <input type="checkbox"/> | Studied for or sat exams                                 | <input type="checkbox"/> |
| Child left home                        | <input type="checkbox"/> | Changed the type of work carried out                     | <input type="checkbox"/> |
| Major change in eating habits          | <input type="checkbox"/> | Major problems with a colleague/boss                     | <input type="checkbox"/> |
| Journey time to work increased greatly | <input type="checkbox"/> | Threat of relocation                                     | <input type="checkbox"/> |
| Changed recreational activities        | <input type="checkbox"/> | Some other major incident or change please specify :-    | <input type="checkbox"/> |
| A violent criminal act i.e. mugging    | <input type="checkbox"/> | <input style="width: 100px; height: 20px;" type="text"/> |                          |
| Your car stolen                        | <input type="checkbox"/> |  |                          |
| Your home burgled                      | <input type="checkbox"/> |  |                          |
| Threat of redundancy                   | <input type="checkbox"/> |  |                          |

Q. How frequently is the air in your WORKSPACE :-

Air Quality	Frequency				
	1	2	3	4	5
Stuffy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fresh	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Stale	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smelly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Draughty	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Satisfactory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Humid	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dry	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q. Please tick just one of the terms to describe the odour in your WORKSPACE today :-

Odour Level Today
No odour <input type="checkbox"/>
Slight odour <input type="checkbox"/>
Moderate odour <input type="checkbox"/>
Strong odour <input type="checkbox"/>
Very strong odour <input type="checkbox"/>
Overpowering odour <input type="checkbox"/>

Approximately how long is it since you last entered the building today .....

Hours  Minutes

Q. How often have you experienced the following in your WORKSPACE :-

● For each question, if you ticked to the right of the dark line please answer the other question.

● What did you do about the situation?

Never  
1 2 3 4 5  
Very Often

Asked the Facilities Dept. to do something  
Did nothing but accepted the situation  
Altered a control myself  
Complained to somebody in authority  
Complained to a colleague  
Did some other action

Your feet being cold when your upper body is comfortable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
One side of your face being warmer or cooler than the other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Draughts on a localised part of your body	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Stiff neck or shoulders	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Backache	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Overheating in summer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Overheating in winter	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Underheating in summer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Underheating in winter	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Difficulty in controlling temperatures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dry, stuffy, damp or smelly air	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inadequate daylight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Too much daylight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Some other event or problem : please specify :-	<div style="border: 1px solid black; height: 20px; width: 100%;"></div>									

Q. By ticking one of the seven boxes in between each word pair, please indicate the extent to which a particular word, in each pair, most describes (A) your WORKSPACE and (B) YOURSELF at work.

A. I feel my WORKSPACE is :-

3 2 1 0 1 2 3

Pleasant	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Unpleasant
Unlikeable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Likeable
Peaceful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Not peaceful
Ugly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Beautiful
Interesting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Uninteresting
Sociable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Unsociable
Hostile	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Friendly
Relaxing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Stressful
Unsatisfying	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Satisfying
Inviting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Uninviting
Emotionally cold	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Emotionally warm
Unusual	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Ordinary
Formal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Home-like
Spacious	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Cramped
Public	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Private
Airless	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Airy
Functional	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Non-functional
Dim	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Light
Cheerful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Sombre
Subduing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Stimulating
Visually warm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Visually cool
Non-glaring	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Glaring
Colourful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Colourless
Noisy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Quiet
Hot	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Cold
Clean	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Dirty
Uncluttered	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Cluttered
Natural	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Un-natural

B. At work I (am) ..... :-

3 2 1 0 1 2 3

Sociable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Keep to myself
Unhappy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Happy
Tense	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Relaxed
Mainly sat down	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Mainly stood up
On the phone a lot	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	On the phone very little
Talk a lot	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Talk very little
Do computer work	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Do no computer work
On my own	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Part of a team

Q. By scoring out of 5, please rate your satisfaction with your WORKSPACE on the items listed below :-

Very Dissatisfied  
Very Satisfied

1 2 3 4 5

Its thermal comfort in winter					
Its thermal comfort in summer					
The ease with which temperatures can be varied					
The amount of daylight entering in winter					
The amount of daylight entering in summer					
The electric lighting					
The ease with which you can control the electric lighting					
Its visual appearance inside					
Its privacy					
Its suitability for the work you do					
Its layout and design					
Its character and 'atmosphere'					
The level of background noise					
The feeling of contact with the external physical environment					
The extent of the view through windows					
Its spaciousness					
Its decoration					
The quality of the air					
The design and layout of the computer workstation you use (if any)					
The degree that the workspace is enclosed					
The ease with which you can communicate					
The layout of the building					
The WORKSPACE overall					
The BUILDING overall					

Q. To what extent do you agree or disagree with the following statements :-

Strongly Agree  
Strongly disagree

1 2 3 4 5

My work is of value and worth doing					
I largely control and organise my own work					
My work is challenging and stimulating					
My work is innovative and creative					
My work is very predictable					
My work involves a lot of contact with other people and is very sociable					
I feel very fulfilled by the work that I do					
My work is made up of mainly repetitive tasks					
I am very satisfied with my job					
My job involves me in having a lot of responsibility					
My workload is so great that I frequently have to work overtime or at home					
I feel I belong in this organisation and would be very sorry to leave it					
I am valued by my colleagues					
I am valued by my immediate boss					
I am valued by the organisation that I work for					
The work I do makes me bored and leaves me feeling sleepy					
My job is reasonably secure for at least the next year or so					
My work situation is relatively stable and has not involved a lot of change					
I am working as efficiently as I can					
My department could be organised to work more efficiently than it does					
I am given all the information I need to do my job effectively					
My work is self-contained and independent of other groups in the building					
My working environment is lively and stimulating					
My work makes me frustrated and irritable					
My work leaves me exhausted					

Q. For each of the opposing statements below, please tick one of the numbered boxes to best reflect the way you are in your everyday life.

Example If you are generally on time for appointments, you would tick a numbered box between 7 and 11 on the first question. If you are usually casual about appointments, you would tick one of the lower numbers between 1 and 5.

Casual about appointments	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Never late
Not competitive	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Very competitive
Good listener	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Anticipates what others are going to say (nods, attempts to finish for them).
Never feel rushed (even under pressure)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Always rushed
Can wait patiently	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Impatient while waiting
Takes things one at a time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Tries to do many things at once, whilst thinking what to do next
Slow, deliberate talker	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Emphatic in speech, fast and forceful
Cares about satisfying themselves no matter what others may think	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Wants a good job to be recognised by others
Slow doing things	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Fast (in things like eating and walking)
Easy going	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Hard driving (pushes themselves and others)
Expresses feelings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Hides feelings
Many outside interests	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Few interests outside work and home
Unambitious	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Ambitious
Casual	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Eager to get things done

Q. To what extent do you agree or disagree with the following statements :-

	1	2	3	4	5
I frequently wake-up during the night or prematurely in the morning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I find it easy to go to sleep at night	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I find it easy to say "no" when asked to do work that is not strictly mine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
In the evening I find it hard to stop thinking about the day's events	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Relaxation after work is no problem for me	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I am not easily upset by what people say to me	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Considering my experience and qualifications I am happy with my salary	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I am generally able to cope with the problems life presents me with	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I find it hard to make decisions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I seldom laugh	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I enjoy a close working relationship with most of the people I work with	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
When people upset me I feel unable to argue with them	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
These days I have lost my interest in other people	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
After eating meals I tend to feel sleepy and a little vague	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I have little appetite for food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I seldom experience indigestion	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q. Please tick those boxes that describe the home you live in:-

Type of dwelling	Age of dwelling	Characteristics
Flat <input type="checkbox"/>	Before 1870 <input type="checkbox"/>	Centrally heated <input type="checkbox"/>
Terraced house <input type="checkbox"/>	Between 1870 and 1919 <input type="checkbox"/>	Fully double or secondary glazed <input type="checkbox"/>
Semi-detached house <input type="checkbox"/>	Between 1920 and 1945 <input type="checkbox"/>	Treated recently for worm or rot <input type="checkbox"/>
Detached house <input type="checkbox"/>	Between 1945 and 1960 <input type="checkbox"/>	Has a garden <input type="checkbox"/>
Semi-detached bungalow <input type="checkbox"/>	Between 1961 and 1980 <input type="checkbox"/>	Has been renovated <input type="checkbox"/>
Detached bungalow <input type="checkbox"/>	After 1980 <input type="checkbox"/>	Chimney sealed or no chimney <input type="checkbox"/>
Other type <input type="checkbox"/>		Additional insulation added <input type="checkbox"/>

Q. The following question aims to ascertain how the building affects communication patterns. Given below is a random list of some of the people who work in this building.

Please could you identify the people you know by placing a tick against their name; indicate whether you find that person useful to you in your work by placing a second tick in the next column (if you do not find the person useful leave this column blank); and identify the main means by which you communicate with that person by placing an 'F' for face to face interaction, or a 'P' for the phone, or an 'M' for E-mail in the last column.

Leave blank the rows of any people that you do not know.

Example If you know Joe Bloggs, normally interact with him by means of E-mail, and find him useful in your work, you would tick as shown in the first row :-

	Know this person	Useful to you in your work	Main form of communication				
Joe Bloggs	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	M				
Afful, David				Foster, Mick		Orion, Jeremy	
Aiken, James				Fuller, Julie		Patten, Jessica	
Alozie, Connie				Guha, Ananda		Pennycuik, David	
Archbold, Alexandra				Hallinan, Amanda		Perris, Roy	
Armstrong, Julie				Hammond, Brian		Rees, Rhianon	
Arnold, Irene				Harmer, Elizabeth		Robbins, Simon	
Barrell, Jackie				Harpley, Beryl		Round, Shila	
Barrell, Paula				Harrison, Karen		Scott, Michael	
Bastable, Gerald				Harrison, Irish		Seaton, Andrew	
Beales, Richard				Hollingsworth, Barbara		Seear, Joan	
Bearpark, Andy				Howard, Bill		Simpson, Jeanelle	
Bickersteth, Sam				Hudson, Barrie		Skinner, Peter	
Bonner, Jatinder				Hughes, Mike		Smea, Mike	
Braint, Dianna				Ireton, Helen		Smith, Martin	
Bright, Amanda				Janowski, Monica		Slaepper, Joan	
Brookes, Diana				Jenkins, Dick		Stevens, Isobel	
Brown, Pauline				Jones, Julie		Stuppel, John	
Bullock, Ken				Lamond, Alex		Tarbit, John	
Burton, Peter				Langan, Martin		Taylor, Ian	
Chambers, Ivy				Langlais, Natalia		Tranler, Nick	
Chan-Lok, John				Leitch, Rob		Troy, Peter	
Clarke, Owen				Locke, Marian		Turner, David	
Clothier, Charlotte				Longstaff, Dick		Vowles, Margaret	
Coffey, Niall				Machin, John		Waddington, Susan	
Davies, Deirdre				Maguire, Pat		Ware, Victoria	
Davies, Tall				Marshall, Kathy		White, Denise	
de Souza, Carol				McCallerty, Theresa		Wilmshurst, Jon	
Dinsdale, John				McCausland, Martin		Wood, Peter	
Dolg, Isobel				Medhurst, James		Wray, Alistair	
Dorrell, Doreen				Morley, Thea		Wright, David	
Firmanger, Lyn				Mullins, Clifford		Wright, Gill	

Q. Please answer the following questions about the lighting conditions in your WORKSPACE :-

	Never	1	2	3	4	5	Very Often
When writing or reading at your desk can you see the writing clearly ?							
Do people's faces appear clear when you look at them ?							
Do you experience any problems with reflections on computer screens ?							
Do the electric lights make any noise ?							
Do the electric lights flicker ?							
Are the electric lights on when you would prefer them to be off ?							
Are the electric lights off when you would prefer them to be on ?							
Is your attention distracted by bright areas outside your main field of view ?							
Do you experience any problems with shadows ?							

Q. If an object or surface is too bright it may cause you some discomfort even though you may not be looking directly at it. This is called glare.

Do you experience glare in your WORKSPACE ?

If so please specify where the glare comes from and how frequently it occurs ?

	Never	1	2	3	4	5	Very often
From a direct view of the sun							
From the sky outside							
From the scene (ground, buildings) outside the window							
From desk tops or other horizontal surfaces in the workspace							
From walls or other vertical surfaces in the workspace							
From electric lights							
From something else (please specify what in the box below)							

Q. In the past 12 months, how often have you experienced the following whilst in your WORKSPACE ?

Before answering ... please read the additional 2 questions on the side.

- For each symptom
- For each symptom

If you ticked to the right of the dark line  
Was the symptom better on days away from work ?

If you had the symptom more than 6 times  
Approximately how many times did you have it during the year ?

	Number of Times						No Yes		Times (Please state as a number not words)
	0	1	2	3	4	5	6+		
Tightness of the chest									
Dryness of the eyes									
Itching eyes									
A runny nose									
Lethargy and/or tiredness									
Watery eyes									
A dry throat									
Blocked or stuffy nose									
Headaches									
Flu-like symptoms but not flu									
A difficulty in breathing									
Hay fever									
Asthma									
Dry skin									
Aching limbs									
Fever									
Contact lens problems									
Backache									
Nausea									
Skin rash									
Noises in your head (tinnitus)									
Other, please specify									

Q. If, in the past 12 months, you experienced any of the following occurrences whilst in your WORKSPACE please indicate, if you can remember, when.

Tick as many boxes as appropriate.

- Occurrences
- No fixed occasion
  - Sunny weather
  - Hot weather
  - Cold weather
  - Fog or mist
  - Strong winds
  - Cloudy weather
  - Calm weather
  - Monday mornings
  - As the weather changes
  - Friday afternoons
  - Other mornings
  - Other afternoons
  - Some other time

Occurrences	Occurrences												
	No fixed occasion	Sunny weather	Hot weather	Cold weather	Fog or mist	Strong winds	Cloudy weather	Calm weather	Monday mornings	As the weather changes	Friday afternoons	Other mornings	Other afternoons
Tightness of the chest													
Dryness of the eyes													
Itching eyes													
A runny nose													
Lethargy and/or tiredness													
Watery eyes													
A dry throat													
Blocked or stuffy nose													
Headaches													
Flu-like illness (aching limbs, fever)													
A difficulty in breathing													
Workspace : unsatisfactory lighting													
Workspace : poor air quality													
Workspace : too noisy													
Workspace : too hot													
Workspace : too cold													

Q. This questionnaire has sought to build up a picture of your feelings about your workspace. To develop this into a more comprehensive understanding we would need to ask you some further questions, either in the form of an interview or additional questionnaire. Please indicate by ticking any of the boxes below whether you would be willing to take part in such further investigations.

Questionnaire  Interview

Thank you for completing this questionnaire. If you have any additional comments that you feel are relevant to the study please write them down on the reverse of this last sheet.

## **APPENDIX 2b: The Eye Health Questionnaire Sample**

**HEALTHY OFFICE ENVIRONMENT STUDY**  
**Occupant Eye Health Questionnaire**  
Ph.D study - Associated Investigation

**Introduction**

To enable us to better understand the results of the first questionnaire survey, would you please answer the following questions concerning your eye health. All the answers that you have provided will be treated in confidence and used only for the purpose of our research. They will be stored on a computer and their used is governed by the terms of the Data Protection Act 1984.

**When you have completed the questionnaire please hold on to it for collection by ourselves tomorrow.**

Please answer every question by ticking the circle alongside if agree, otherwise ignore. Put a question mark against any that you cannot answer.

- Q. Do you experience any of the following eye conditions?
- Shortsighted - cannot see distant object
  - Longsighted - difficult to see close object
  - Irregularities in the cornea and lens (Astigmatism)
  - Squint
  - Had an accidents involving your eyes in your lifetime
  - Had an ocular surgery.
  - Developing Cataracts
  - Partial loss of vision - having central, patchy or half vision
  - Double vision
  - Flashing lights and / or dense opaque spots blotting your vision which are difficult to ignore
  - Superficial pain on the eye
  - Deep pain in the eye
  - Find blinking hard and painful with effort and spasmodically
  - Feel pain and/or pressure around your cheek, temple, brow or areas near the eyes
  - Heavy eye discharges in the morning, which have the effect of 'gluing' your eyes shut
  - If you are longsighted, you feel this is gradually changing to being short sighted
  - When no glare is present, find reading easier under bright light.
  - Especially sensitive to light
  - Annoyed by light scatter
  - Often your eyes involuntarily become fixed on a single point in space for long periods of time.
  - Rubbed your eyes often
  - There are growth on the eye

Q. How often do you have your eyes checked?  
.....yrs

- Q. When your eyes are tired, you
- Take a break and close your eyes
  - Take a break but do not rest your eye (eg look in the distance or take a walk)
  - Carry on working

- Q. If you wear glasses at the office, please answer the following:
- Always have glasses on in the office
  - What is the lens material? Glass/Plastic
  - It is tinted
  - It is coated (eg anti reflection film)
  - There are scratches and/or flaws on the glasses
  - There are breaks, cracks or corrosion on the frame
  - There is a big differences in the lens specification between left and right eye

- Q. If you wear contact lenses at the office, please tick appropriate circles:
- Hard
  - Soft
  - Soft gas permeable
  - Have contact lenses problems

- Q. If you are a female, do you wear
- mascara
  - eyeliner on the rim of eye lids
  - metallic colour eye shadow

- Q. Do you experience any of the following conditions:
- Read much tiny print at work
  - Vision gets better when you are away from the office
  - Often feel tense around your neck
  - Do regular eye and neck exercise
  - Often have massages or spinal stimulation
  - Currently taking prescribed medication
  - Migraine
  - Sinusitis
  - Diabetic
  - Glaucoma
  - High blood pressure
  - Stroke
  - Thyroid Disorder
  - Gout

- Q. Does any member of your immediate family have
- Cataract
  - Glaucoma
  - Other chronic eye problems (more than wearing glasses or contact lenses)

Q. How long do you work before your eyes tire?  
.....min

Q. How many hours a day do you generally spend working with a VDU ?  
.....hrs

**Your cooperation is very much appreciated and we thank you in advance.**



## **Appendix 3: FACTORS AFFECTING EYE HEALTH**

Besides thermal environment, pollution level, glare, flickers, inadequate illuminance level established in the literature review that correlate with health hazard in building which also contribute to the occurrence of eye symptom, there are a few other causes of eye symptom. These are psychological stress and eye health.

### **Psychological Stress**

Eye symptom may be associated with psychosomatic disorder and can be rooted in emotion. When an individual has an emotional problem they often evidence itself in eye symptom. Where there is an emotional or physiological disturbance to begin with, lighting may accentuate the condition. This is demonstrated in a simple headache which is a systemic symptom. A person who experience distress, depression and irritability of temper also experience headache. Psychological factor of confinement and mild claustrophobia could also contribute to the occurrence of SBS.

**Headache** is caused by personal health or condition, environmental factors and diseases (Miller, 1979). It could also happen due to personal conditions or health such as fatigue, hunger, dietary factor, menstruation and premenstruation, postcoital and, mental or emotional stress. Fatigue and stress, may be due to environmental factors. Deficiency in iron or B12 or excesses in vitamin A or D, cheese, eggs and fats may also cause headache. The environmental factors are indoor toxicity, muscular tension at the back of the head, raised blood pressure and visual problem (Andrew, 1978). The toxicity may be due to stale air from inadequate ventilation, fumes of any kind, alcohol, ammonia, barbiturates, benzene and other volatile organic compound. Headache may also be related to eye, nose or throat diseases, metabolic disease and endocrine ailment, anaemia, disease of brain and nervous system, sinusitis, polyaemia, brain tumour and erysipelas.

A vast number of people express their mental and emotional distress in a headache. Acute temporary headache could be caused by diseases, acute infection or injury of the eye, ear, nose and/or throat. Chronic headache are significantly related to emotional and mental distress, neurotic factors, metabolic diseases and endocrine ailment. Headache comes from the nerves and arteries in the lining of the brain rather than the

brain tissue. In some people the vessels occasionally dilate usually located over one or both eyes. Thus reason for its link to visual disturbance.

## **Ocular Stress**

When an occupant is involved in many visual tasks often it is required of the occupant to look away intermittently and preferably at infinity to rest the eye. Eye strain can also be caused by the inability to rest the eyes (Weston). Eye strain is not caused by the light receptors but the overworked ocular muscles. Therefore, the bigger the visual field the more likely this situation could be achieved.

## **Lighting Condition**

Eye symptom may also be incurred by normal sighted persons when they are trying to see and work under unfavourable lighting conditions. This unfavourable conditions are namely minuteness (size) of task and poor contrast in task. The general belief is that as contrast gets bigger between the print and the background the better the visual impression and easier it is to see. Normally 75-80% is strived for. 50% is reasonable, but vision begins to deteriorate as contrast drop below 30% onwards. There are anecdotal evidences which suggest that there is an optimum to the contrast level, once this limit is exceeded than there will be a turn over in performance. Blackwell showed that greater contrast is required for lower adaptation luminance.

However, in the office both this issues are not pressing as they are normally well taken into account. The font size with written work are of 9 or 10. The text rarely involve reading small print. Contrast were within the 80% range, that is black characters on white papers.

## **Eye Health**

Eye symptoms could also result due to the state of eye health. This in turn is related to eye defect which is inborn or it could be a result of hereditary, aging or accident.

## Eye Defect

Visual perception is also governed by the primary factors; stereoscopic vision, ocular convergence, accommodation (Hesselgren, 1975). This basically describes the eye's mechanism. Where any part of this is defect it would slacken the performance and induce stress on the visual processing or an affront. This stress or affront could manifest itself as one of the symptoms.

Eye problem with regard to accommodation arises due to the muscle imbalances. Under normal condition the human eye relies on binocular vision. Binocular vision is the coordination of the two eyes to produce a single mental visual impression. The eye muscles converge the eye balls with the aim of obtaining one image. Inside the eye ball lies the lenses which collapse or expand accordingly which enable it to have a focusing property. Both these actions occur simultaneously and automatically. This process results with an image on the retina (at the back of the eye). Under normal conditions, lack of accommodation is accompanied by lack of fusion. For fusion of images to take place, the images from both eyes should rest on the "Panum Fusional" areas and brought within reasonable tolerance. An elementary phenomenon and is very common is that a muscle might be weak on one side of an eye than another. Thus, turning the eye out or in of the proper conjugated focus. This disables fusion and a person gets double vision (ephorbia). Consequently, with serious squint, the eye would go right off. As the brain normally would not be able to sustain double vision for long, it disacknowledges the deviating eye. This is commonly referred to as "lazy eyes" or medically as "dephobia". To avoid dephobia, an image is suppressed. Sometime this suppression works well and people are able to put up with it. This defect under continuous work creates a certain strenuous impact and tends to give visual fatigue and possibility of headaches. Due to some "fusional reserve" some people are not disturbed by it whilst others are. Proper refraction brings the image on to the proper focussing area although the eye is still permitted to deviate and the deformity can be overcome. It has also been shown that if a person has a marked problem with fusion the person would also have failure in depth perception.

This defect could also be caused by biological changes due to aging. The changes in visual performance are:

- reduction in the range of accommodation of the eye
- a considerable increase in the absorption and scattering of light in the eye.
- a reduction in pupil diameter for a given adaptation luminance.

The depreciation in eye visual performance is not linear, it worsen with age. As one gets older the physical form also alter. The size of the eyeball reduces and the lens

starts to go yellow towards opacity, with the result that between the age of 20-60, there is a 30% loss in light energy absorbed by the retina (Weale, 1978) and the eye becomes less sensitive (Boyce, 1981). Normally at the age between 40-45 years onwards individuals would at least require reading glasses and eye sight changes after this age. With age, individuals are also more sensitive to glare thus more chances of eye symptom occurrence. There is also the possibility of developing cataract, which might not be bad enough to impair vision but significant to glare effect. These are associated with rise in dissatisfaction and create stress on vision. As a person ages there is also a distinct preference for warm incandescent light to cold fluorescent.

### **Correct Refraction**

Research has shown that 25% of people in general do not have glasses when they should (Weale,). Eye defects such as short sighted, logsighted and astigmatism are common and could be corrected with proper refraction. For these bespectacled occupants, where the prescription was ignored, symptoms could occur due to this deliberate action. This prescription is not fix, it varies with time lapse. Therefore, it is also important to determine whether these occupants have their eyes checked on regular basis (recommended interval: 3 years). This is because where the refraction is no longer suitable symptoms will also occur.

The weight of the glasses and its condition (scratches or flaws on the glasses) could also contribute to eyes symptom occurrences. Another factor though not common but related to refraction specification that would contribute as a possible cause to eye strain that potentially lead to eye symptom occurrence is where a big differences in lens specification between the right and left eye exist.

### **Other Factors**

Some occupants that suffer from migraine are not treatable and sufferers are much more sensitive to light. People with larger pupils have more light entering the eyes as opposed to people with small pupils. Thus they are more sensitive to light. Having larger pupil is not a defect, nevertheless it effects the state of tolerance towards the lighting environment. However, it is rather cumbersome to go about the office measuring the occupant's pupil. This is best left to laboratory experiments. From appraisal of eye health it was also noted that eyes that are healthy do not stay fixed for long. The eyes are constantly scanning the environment. When the eyes are found to

stare into mid-air often this indicates an association with eye problem. people who are more sensitive to light or have eyes that tire easily under prolong activity and exposure could lead to eye symptoms. Working with computer has also been known to cause eye symptoms and that people with sensitive eyes and eyes that easily tire suffer most.

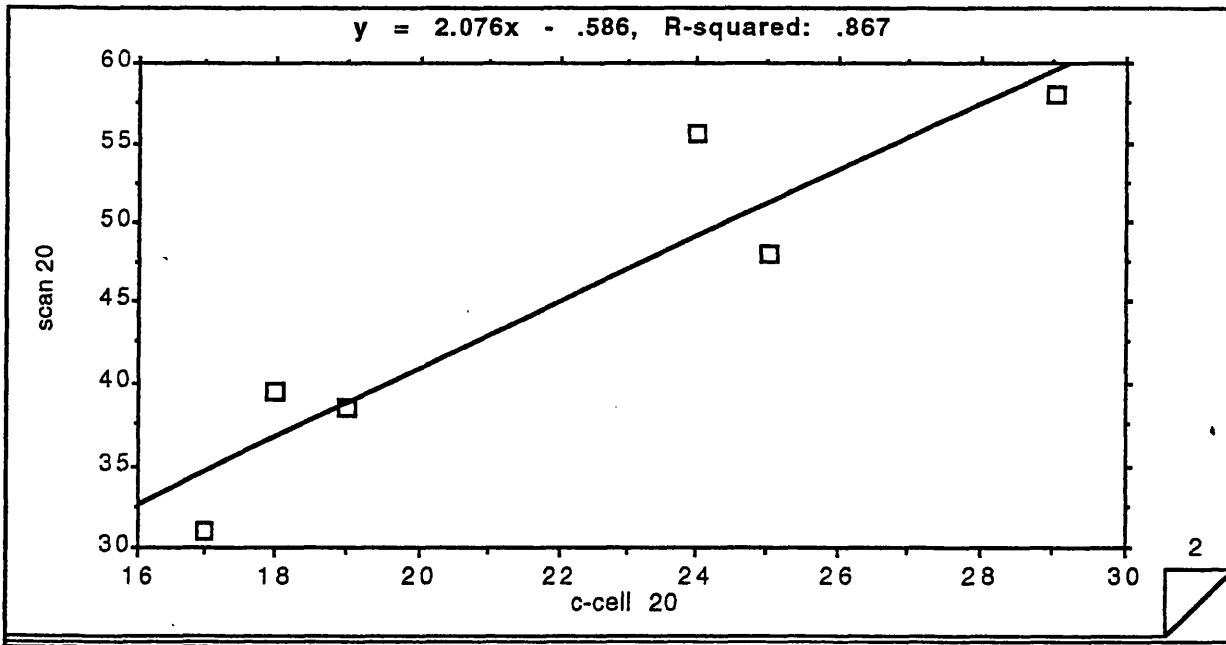
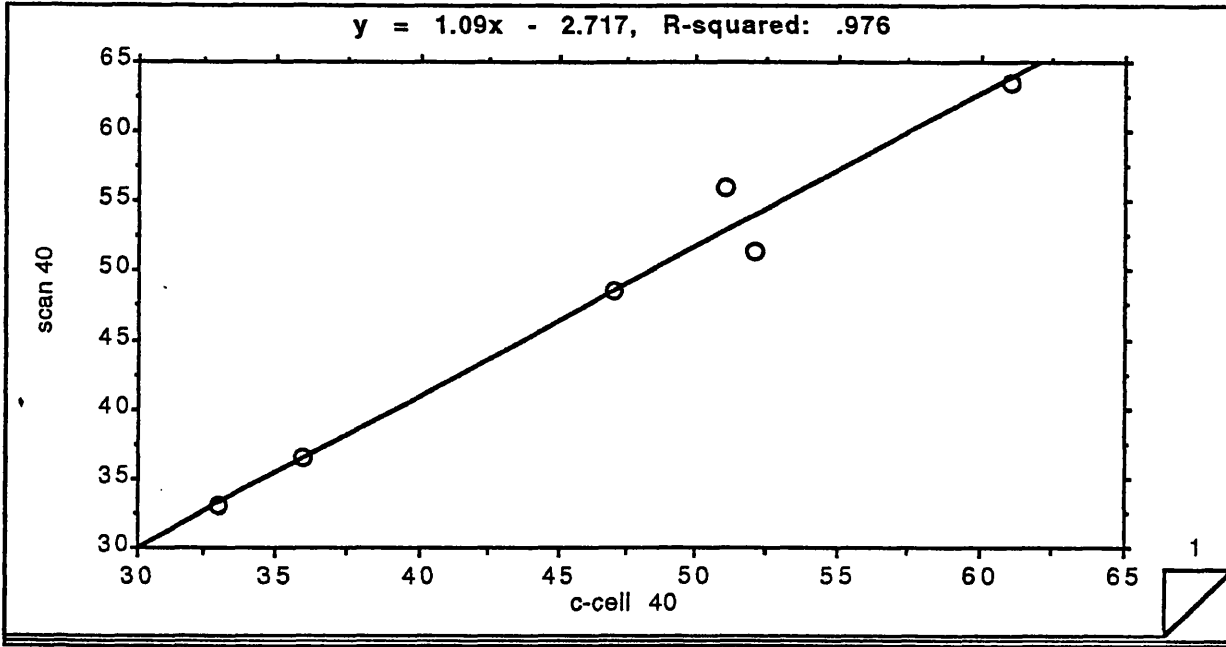
How the occupants treat their eyes would also provide clues on the eye health. If the eyes is well exercised and well taken care of they will be healthier and they run less chances of experiencing eye symptoms. Eye health can also be related to chemical or makeup used on the eyes. This particularly applies to the female individual.

Unhealthy eyes were identified referring to ophthalmological work by Weale, Benjamin, Cronly-Dillon et al, Allen et al, Glaspool and Youngson, and can be detected by indication of the following:

- often rubbing the eyes
- experiencing eye irritation, pain in the eyes similar sensation as having sand in the eyes, superficial on the eye, deep pain in the eyes, spreading pain
- experience eye discharge - discharge gluing eye lashes in the morning
- inflammation of iris
- corneal ulceration
- growth on the eye
- sight disturbance loss of vision, general blurring, central loss, patchy loss, half loss of sight, experiencing double or flashing light and spot in the eyes
- whether the occupant squint their eyes to look at distant objects - pain around the cheek, temple, brow or area near the eye (symptoms related to glaucoma)
- personal background as to whether they had ocular surgery, injury involving their eyes or relatives with eye problems that are potentially hereditary like cataract or glaucoma. Where individual had previously had problem with their eye sight there is a higher potential that these problems are reoccurring. People who suffer cataract gets annoyed by scatter of light in their vision.
- experiencing difficulty whilst reading and images not sharp
- often stare in midair (when under strain eyes are rigid and fix. Healthy eyes move constantly)
- seldom blink. Achieve with effort and spasmodically and find it painful.
- feel tense around the neck, constant massage stimulate good blood circulation to the brain which facilitate vision
- other health that causes eye symptoms are sinuses, nausea, high blood pressure, stroke, thyroid disorder, diabetic and gout

## **APPENDIX 4: Testing Of The Semi-Cylindrical Cell**

c-cell to scanner comparison



c-cell to scanner comparison

Simple Regression X<sub>2</sub>: c-cell 20 Y<sub>2</sub>: scan 20

DF:	R:	R-squared:	Adj. R-squared:	Std. Error:
5	.931	.867	.834	4.303

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
REGRESSION	1	482.645	482.645	26.067
RESIDUAL	4	74.063	18.516	p = .007
TOTAL	5	556.708		

No Residual Statistics Computed

3

Simple Regression X<sub>2</sub>: c-cell 20 Y<sub>2</sub>: scan 20

Beta Coefficient Table

Parameter:	Value:	Std. Err.:	Std. Value:	t-Value:	Probability:
INTERCEPT	-.586				
SLOPE	2.076	.407	.931	5.106	.007

Confidence Intervals Table

Parameter:	95% Lower:	95% Upper:	90% Lower:	90% Upper:
MEAN (X,Y)	40.205	49.961	41.338	48.829
SLOPE	.947	3.205	1.209	2.943

4



c-cell to scanner comparison

Simple Regression X<sub>1</sub>: c-cell 40 Y<sub>1</sub>: scan 40

DF:	R:	R-squared:	Adj. R-squared:	Std. Error:
5	.988	.976	.97	1.999

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
REGRESSION	1	657.851	657.851	164.649
RESIDUAL	4	15.982	3.995	p = .0002
TOTAL	5	673.833		

No Residual Statistics Computed

1

Simple Regression X<sub>1</sub>: c-cell 40 Y<sub>1</sub>: scan 40

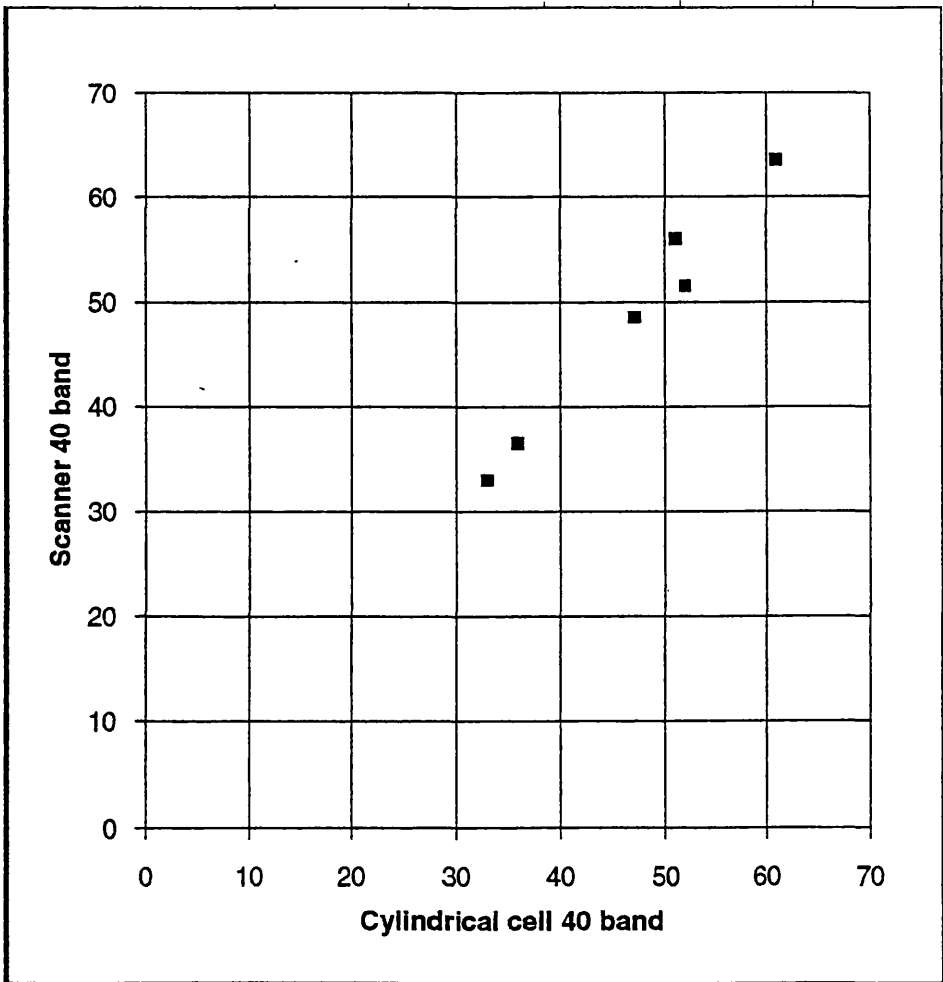
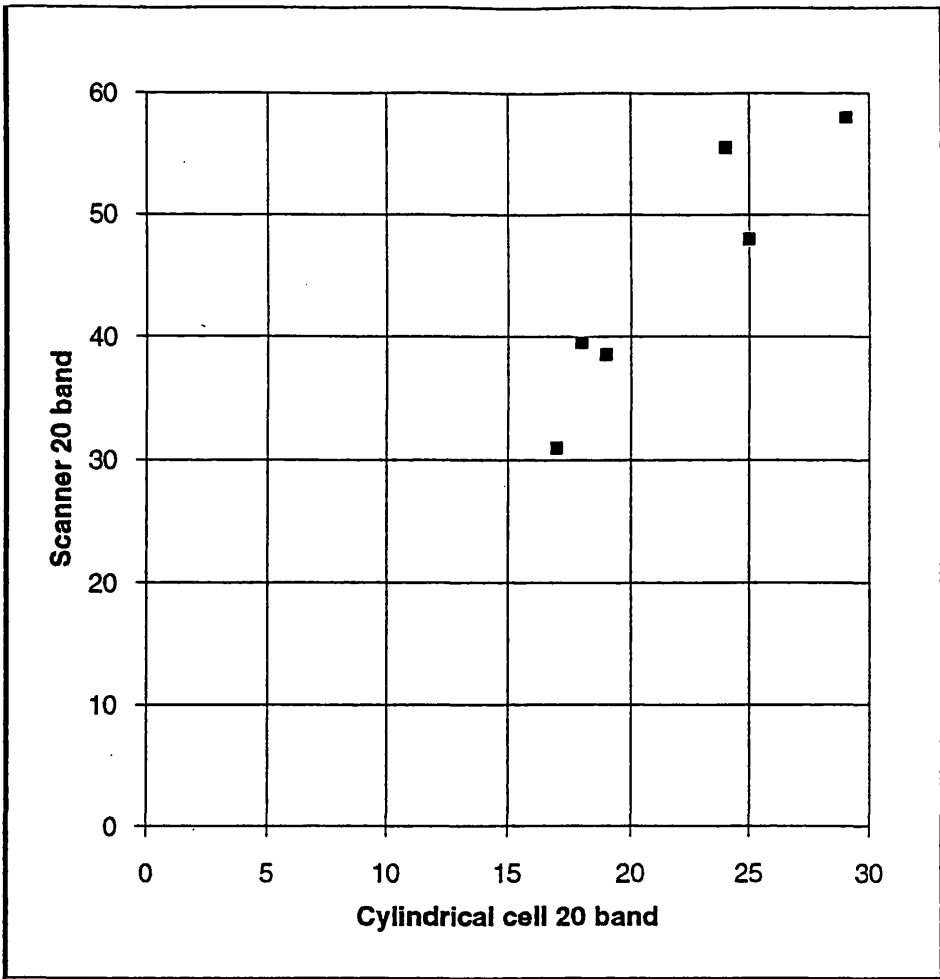
Beta Coefficient Table

Parameter:	Value:	Std. Err.:	Std. Value:	t-Value:	Probability:
INTERCEPT	-2.717				
SLOPE	1.09	.085	.988	12.832	.0002

Confidence Intervals Table

Parameter:	95% Lower:	95% Upper:	90% Lower:	90% Upper:
MEAN (X,Y)	45.901	50.433	46.427	49.907
SLOPE	.854	1.326	.909	1.272

2



### Comparison of readings for Scanner and Cylindrical Cell

case	Installation	Cylindrical cell (lux)			Scanner (cd/m <sup>2</sup> )					
		50	40	20	50	40	20			
1	Recess fitting only (full power)	58	52	29		51.5	58			
2	Curtain wall washer + half power recess	39	33	17		33	31			
3	Wall wash both sides + half power recess	59	51	24		56	55.5			
4	Wall wash + spot light on curtain (recess off)	41	36	18		36.5	39.5			
5	Curtain Wash + Up lighters	72	61	25		63.5	48			
6	Uplighters only (care to avoid glare)	57	47	19		48.5	38.5			
<p>N.B: Cylindrical cell was placed at 1.2m from floor level to represent average eye height at seated position.            Caution was taken to level the mount of the cylindrical cell using spirit level and allowance were made for the flourescent light to stabllize upon switching on.</p>										

## **APPENDIX 5: Explanation For The Figures In Volume 2**

For all the figures, the first column down the page refers to the group facing the windows, the second column refers to the group with the windows to the side of the work positions and the third column refers to the group with the windows to the back of the work position.

### **Figures 5.5.1a (Eye symptom distribution in each group)**

Refer to page 7 of the LINK questionnaire. This survey was conducted prior to the column for actually number of symptoms experienced over the last 12 months being inserted. Thus it refers only to the first 6 column on the left hand side. The x-axis thus refer to the 6 columns in the questionnaire and the y-axis refers to the number of occupants that ticked that particular column.

In the assessment of the health symptoms 21 symptoms were listed on a scale of 0 (no occurrence) to 6 (i.e symptoms occurred more than 5 times over the last 12 months). Where symptoms occurred more than twice, the occupant was required to indicate if the symptoms goes away when the individual was away from the building, where zero (No) and 1 (Yes). At the end, the occupant was also to indicate if they suffered any other symptoms not specified in the list. The Personal Symptom Index was then derived based on the first 10 symptoms that occurred more than 2. If individuals ticked more than 10, they are listed as paranoid and hypochondriac, and thus omitted from the list of people suffering from sick building syndrome. Next, the occupant was to indicate when these symptoms occurred on a scale 1-14 in the order left to right, as listed in the questionnaire.

Figure 6.4.1a, 7.4.1a and 8.4.1a

Gives actually number of symptoms occupants experienced over the last 12 months (Refer to page 7 of the LINK questionnaire. The last column on the left modules of questions). The x-axis has a scale interval of 50. This mean that the first bar gives all the occupant that have score of 0-50.

Figure 6.4.1b, 7.4.1b and 8.4.1b:

Gives all the occupants that has between 0-50 accounts of eye symptoms. The x-axis thus refer to the 6 columns in the questionnaire (refers only to the first 6 column on the left hand side of the LINK questionnaire). The bar between 0-1 gives those

occupants that do not experienced any eye symptom, the bar between 6-7 gives occupants that had experienced eye symptom more that 6 times. The interval between 7-8 is not assigned to any score.

**FIGURES 5.5.3a-d, 6.4.3a and b, 7.4.3a and b, and 8.4.3a and b  
(Distribution of occupants assessments of appearance of work position)**

The occupant was to appraise the interior of the work position, this include different aspects of subjective feeling regarding the space (refers to page 3 of the LINK questionnaire). In this part of the survey, the occupant rated the qualitative environment with descriptive words on a semantic rating scales to give an overall character of the perception. The scales are flipped over occasionally to avoid the occupant from adapting a pattern of ticking a particular column in the respective sections and to ensure that they were aware of their appraisals. It was rated from 1(negative perception) to 7(positive perception).

<b>Scale 1</b>	<b>Scale 7</b>
unpleasant	pleasant
unlikeable	likeable
not peaceful	peaceful
ugly	beautiful
uninteresting	interesting
unsociable	sociable
hostile	frienfly
stressful	relaxing
unsatisfying	satisfying
uninviting	inviting
emotionally cool	emotionally warm
ordinary	unusual
formal	homelike
cramped	spacious
public	private
airless	airy
non-functional	functional
dim	light
sombre	cheerful
subduing	stimulating
visually cool	visually warm
glaring	non-glaring
colourless	colourful
noisy	quiet
cold	hot
dirty	clean
cluttered	uncluttered
un-natural	natural

The x-axis on the figures refers to the assessment of the 1-7 scale on the questionnaire. The bar between 0-1 on the x-axis refers to the scale 1, between 1-2 on the x-axis refers to scale 2 and so on. Bar between 8-9 does not refer to any scale. The y-axis that is indicated as counts refers to the number of occupants that tick that particular scale.

**FIGURES 5.5.4a, 5.5.4b (Distribution of the measured physical light attributes for the group).**

The general concept of the explanations that follows also apply to figure 6.4.4a and b, figure 7.4.4a and b, and figure 8.4.4 a and b. The x-axis however is adjusted to the ranges of readings obtained.

**Window area**

This measured physical attribute on the x-axis is divided into ranges with an interval of 2. For example bar 1 which is between 0-2 refers to the window area that read 0-2m<sup>2</sup>. Counts on the y-axis refers to the number of occupants that have that particular range of window area. Counts on all the figure refers to the same thing.

**Ratio of Window area to isoperimeter area**

The x-axis refers to the ratio of window area to isoperimeter area. Again 0-0.1 gives all the occupants that have the ratio within this range.

**Average Luminance during the daytime.**

The x-axis gives the average luminance reading. The scale is of 12.5 interval. For example the first bar (on the left) in the first column gives all the occupants that have an average luminance between 27.5-50 cd/m<sup>2</sup>.

**Isoarea (isovist area-m<sup>2</sup>)**

The x-axis has a scale interval of 5. The first bar (on the left) gives all the occupants that have an isoarea between 5-10m<sup>2</sup>.

**Isoperimeter (m)**

The scale has an interval of 5. The first bar gives the occupants that have isoperimeter between 10-15m.

**Isoperimeterarea (m<sup>2</sup>)**

Isoperimeterarea gives the circumference area of the perimeter multiply with the height of the walls. This x-axis has a scale interval of 10. The first bar (on the left) gives the occupants that has isoperimeterarea between 30-40m<sup>2</sup>.

**Worktop illuminance (lux)**

The x-axis has a scale interval of 50. However, each bar has a range of a 100. The first bar than gives all the occupants that have the work top illuminance between 400-500lux.

## **Eye Illuminance**

Gives the amount of light that arrives at eyes. The x-axis has a scale interval of 50. The first bar gives all occupants that have an eye illuminance between 200-250lux.

**THE INFLUENCE OF THE APPEARANCE OF WORK  
POSITIONS ON THE OCCURRENCE OF EYE  
SYMPTOMS IN OFFICE BUILDINGS**

by

**NOR HALIZA BTE MADROS**

**This thesis is submitted in fulfilment of the requirements for the  
Degree of Doctor of Philosophy from the University of London**

**VOLUME 2  
(TABLES & FIGURES)**

**BARTLETT SCHOOL OF GRADUATE STUDIES  
UNIVERSITY COLLEGE OF LONDON  
1998**



## LIST OF PLATES

- Plate 4.5.2-IIa : Minolta luminance meter  
Plate 4.5.2-IIb : Hagner ECI-S lux meter
- Plate 5.1-1 : Photographs of South Lakeland District Council and the buildings surrounding it.  
Plate 5.1-2 : Photographs of South Lakeland District Council and the buildings surrounding it.  
Plate 5.1-3 : Photographs of South Lakeland District Council and the buildings surrounding it.  
Plate 5.4a : Photographs of work positions  
Plate 5.4b : Photographs of work positions  
Plate 5.9.2a : Hagner lux meter and semi cylindrical cell  
Plate 5.9.2b : Solid angle slide ruler
- Plate 6.0-1 : Photographs of Pearl Assurance Building and the buildings surrounding it.  
Plate 6.3a : Photographs of work positions  
Plate 6.3b : Photographs of work positions  
Plate 6.3c : Photographs of work positions  
Plate 6.3d : Photographs of work positions  
Plate 6.3e : Photographs of work positions  
Plate 6.3f : Photographs of work positions
- Plate 7.0-1 : Photographs of Sapphire Building and the buildings surrounding it.  
Plate 7.0-2 : Photographs of Sapphire Building and the buildings surrounding it.  
Plate 7.3(a) : Photographs of work positions  
Plate 7.3(b) : Photographs of work positions  
Plate 7.3(c) : Photographs of work positions  
Plate 7.3(d) : Photographs of work positions  
Plate 7.3(e) : Photographs of work positions  
Plate 7.3(f) : Photographs of work positions  
Plate 7.3(g) : Photographs of work positions  
Plate 7.3(h) : Photographs of work positions
- Plate 8.0-1 : Photographs of Pearl assurance Building and the buildings surrounding it.  
Plate 8.0-2 : Photographs of Pearl assurance Building and the buildings surrounding it.  
Plate 8.0-3 : Photographs of Pearl assurance Building and the buildings surrounding it.  
Plate 8.3a : Photographs of work positions  
Plate 8.3b : Photographs of work positions  
Plate 8.3c : Photographs of work positions  
Plate 8.3d : Photographs of work positions

## LIST OF TABLES

Table 5.4a	:	Sample job classification
Table 5.4b	:	Age and gender of sample
Table 5.4c	:	Distribution of sample over the floors
Table 5.5.2	:	Measured thermal, relative humidity and pollutant levels
Table 5.5.4a	:	Work Position Physical Attributes
Table 5.5.4b	:	The range of the measured physical light attributes for the group
Table 5.8a	:	Difference of symptom occurrence with respect to occupants Location
Table 5.8b	:	Comparison of Occupants Perception of Work Position Appearance between Seat Orientation
Table 5.8c	:	Comparison of Measured Lighting Variables between Cluster and Seat Orientation
Table 6.3a	:	Sample job classification
Table 6.3b	:	Age and gender of sample
Table 6.3c	:	Distribution of sample over the floors
Table 6.4.2	:	Measured thermal, relative humidity and pollutant levels
Table 6.4.4	:	The range of the measured physical light attributes for the group
Table 6.6a	:	Difference of symptom occurrence with respect to occupants Location
Table 6.6b	:	Comparison of Occupants Perception of Work Position Appearance between Seat Orientation
Table 6.6c	:	Comparison of Measured Lighting Variables between Seat Orientation
Table 7.3a	:	Sample job classification
Table 7.3b	:	Age and gender of sample
Table 7.3c	:	Distribution of sample over the floors
Table 7.4.2	:	Measured thermal, relative humidity and pollutant levels
Table 7.4.4	:	The range of the measured physical light attributes for the group
Table 7.6a	:	Difference of symptom occurrence with respect to occupants Location
Table 7.6b	:	Comparison of Occupants Perception of Work Position Appearance between Seat Orientation
Table 7.6c	:	Comparison of Measured Lighting Variables between Seat Orientation
Table 8.3a	:	Sample job classification
Table 8.3b	:	Age and gender of sample
Table 8.3c	:	Distribution of sample over the floors
Table 8.4.2	:	Measured thermal, relative humidity and pollutant levels
Table 8.4.4	:	Range of physical measurements
Table 8.6a	:	Difference of symptom occurrence with respect to occupants Location
Table 8.6b	:	Comparison of Workspace Appearance between Seat Orientation
Table 8.6c	:	Comparison of Measured Lighting Variables between Seat Orientation

## LIST OF FIGURES

- Figure 5.1-1 : Location plan  
Figure 5.1-2 : Site plan and juxtaposition of adjacent buildings  
Figure 5.4 : Floor layout of South Lakeland House, Kendal indicating the cluster and the work position for the lighting study  
Figure 5.5.1a : Eyes Symptom Distribution in each group  
Figure 5.5.1b : Distribution of the occurrence of Dry eyes  
Figure 5.5.1c : Distribution of the occurrence of Itching Eyes  
Figure 5.5.1d : Distribution of the occurrence of Watering eyes  
Figure 5.5.1e : Distribution of the occurrence of Headaches  
Figure 5.5.1f : Distribution of the occurrence of problem wearing Contact Lenses  
Figure 5.5.3a : Distribution of occupants assessments of Appearance of Work position  
Figure 5.5.3b : Distribution of occupants assessments of Appearance of Work position  
Figure 5.5.3c : Distribution of occupants assessments of Appearance of Work position  
Figure 5.5.3d : Distribution of occupants assessments of Appearance of Work position  
Figure 5.5.4a : The distribution of the measured physical light attributes for the group  
Figure 5.5.4b : The distribution of the measured physical light attributes for the group
- Figure 6.0-1 : Location plan  
Figure 6.0-2 : Site plan and juxtaposition of adjacent buildings  
Figure 6.3 : The location of the 122 work positions used in the lighting study  
Figure 6.4.1a : Distribution of occurrence of eye symptom in the sample (as experienced by occupants)  
Figure 6.4.1b : Distribution of occurrence of eye symptom in the sample (range 0-50)  
Figure 6.4.1c : Dry eyes occurrence distribution  
Figure 6.4.1d : Watering eyes occurrence distribution  
Figure 6.4.1e : Itching Eyes occurrence distribution  
Figure 6.4.1f : Headaches occurrence distribution  
Figure 6.4.1g : occurrence of problem with wearing contact lenses distribution  
Figure 6.4.2 : LINK environmental monitoring location  
Figure 6.4.3a : Distribution of Occupants assessments of Appearance of Work position  
Figure 6.4.3b : Distribution of Occupants assessments of Appearance of Work position  
Figure 6.4.3c : Distribution of Occupants assessments of Appearance of Work position  
Figure 6.4.4a : The distribution of the measured physical light attributes for the group  
Figure 6.4.4b : The distribution of the measured physical light attributes for the group
- Figure 7.0-1 : Location plan  
Figure 7.0-2 : Site plan and juxtaposition of adjacent buildings  
Figure 7.3 : The location of the 132 work positions used in the lighting study and positions surveyed by LINK  
Figure 7.4.1a : Distribution of occurrence of eye symptom in the sample (as experienced by occupants)  
Figure 7.4.1b : Distribution of occurrence of eye symptom in the sample (range 0-50)  
Figure 7.4.1c : Dry eyes occurrence distribution  
Figure 7.4.1d : Watering eyes occurrence distribution  
Figure 7.4.1e : Itching Eyes occurrence distribution

Figure 7.4.1f : Headaches occurrence distribution  
 Figure 7.4.1g : occurrence of problem with wearing contact lenses distribution  
 Figure 7.4.2 : LINK environmental monitoring location  
 Figure 7.4.3a : Distribution of Occupants assessments of Appearance of Work position  
 Figure 7.4.3b : Distribution of Occupants assessments of Appearance of Work position  
 Figure 7.4.3c : Distribution of Occupants assessments of Appearance of Work position  
 Figure 7.4.4a : The distribution of the measured physical light attributes for the group  
 Figure 7.4.4b : The distribution of the measured physical light attributes for the group

Figure 8.0-1 : Location plan  
 Figure 8.0-2 : Site plan and juxtaposition of adjacent buildings  
 Figure 8.3 : The location of the 44 work positions used in the lighting study and the location LINK surveyed  
 Figure 8.4.1a : Distribution of occurrence of eye symptom in the sample (as experienced by occupants)  
 Figure 8.4.1b : Distribution of occurrence of eye symptom in the sample (range 0-50)  
 Figure 8.4.1c : Dry eyes occurrence distribution  
 Figure 8.4.1d : Watering eyes occurrence distribution  
 Figure 8.4.1e : Itching Eyes occurrence distribution  
 Figure 8.4.1f : Headaches occurrence distribution  
 Figure 8.4.1g : occurrence of problem with wearing contact lenses distribution  
 Figure 8.4.2 : LINK environmental monitoring location  
 Figure 8.4.3a : Distribution of Occupants assessments of Appearance of Work position  
 Figure 8.4.3b : Distribution of Occupants assessments of Appearance of Work position  
 Figure 8.4.3c : Distribution of Occupants assessments of Appearance of Work position  
 Figure 8.4.4a : The distribution of the measured physical light attributes for the group  
 Figure 8.4.4b : The distribution of the measured physical light attributes for the group



Plate 4.5.2-IIa : Minolta luminance meter



Plate 4.5.2-IIb : Hagner ECI-S lux meter

## **Chapter 5: Pilot Study**

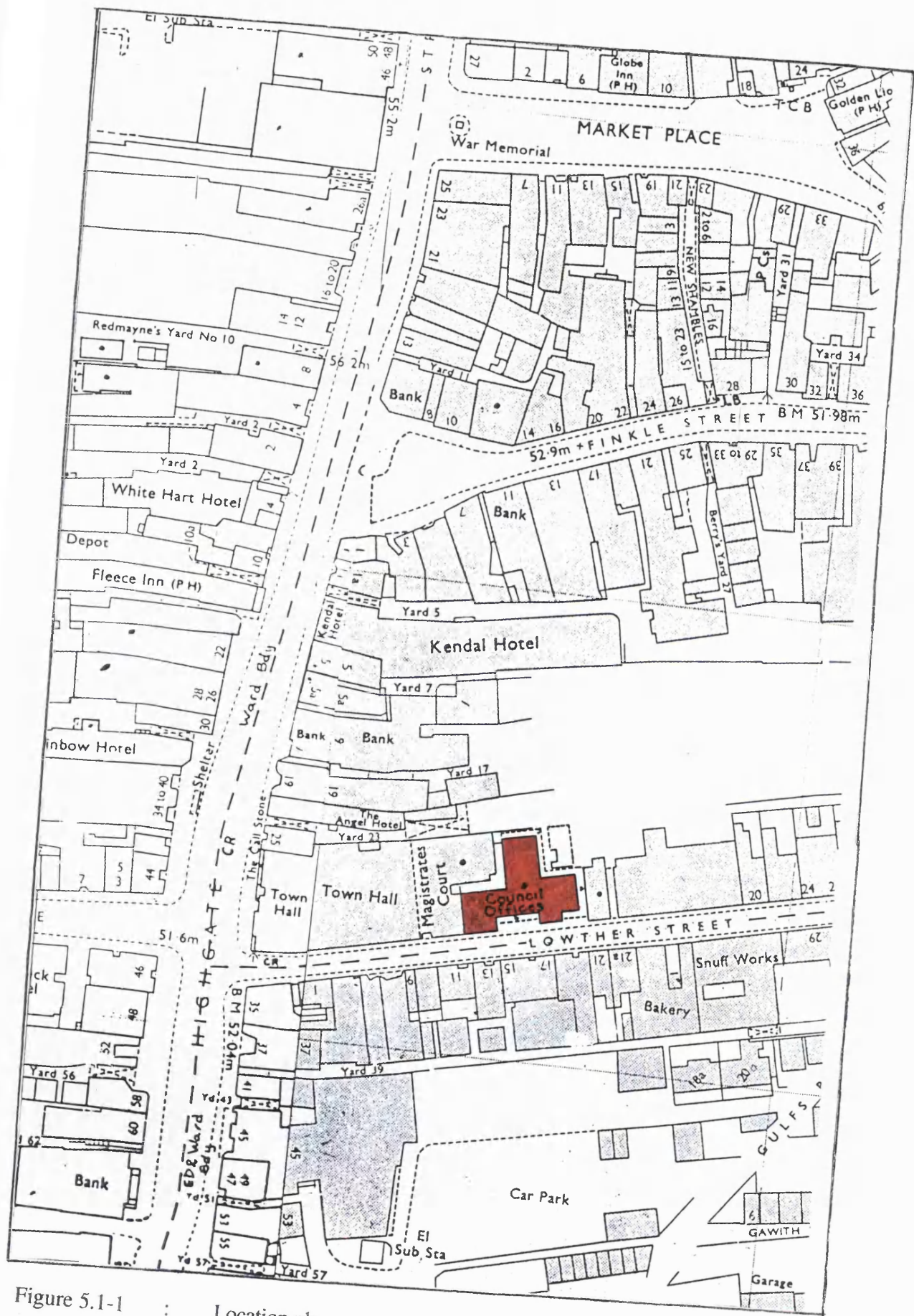


Figure 5.1-1 : Location plan



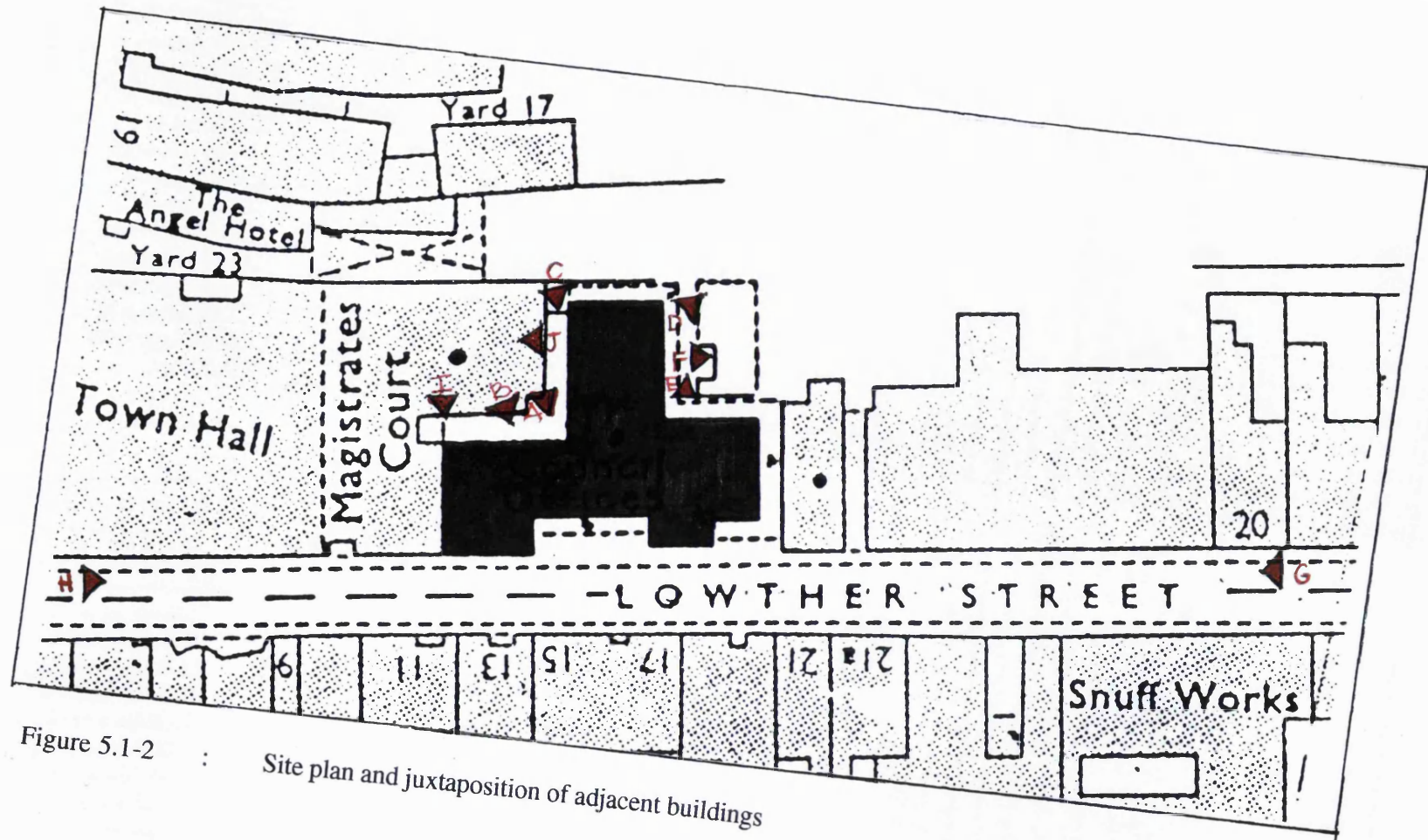


Figure 5.1-2 : Site plan and juxtaposition of adjacent buildings



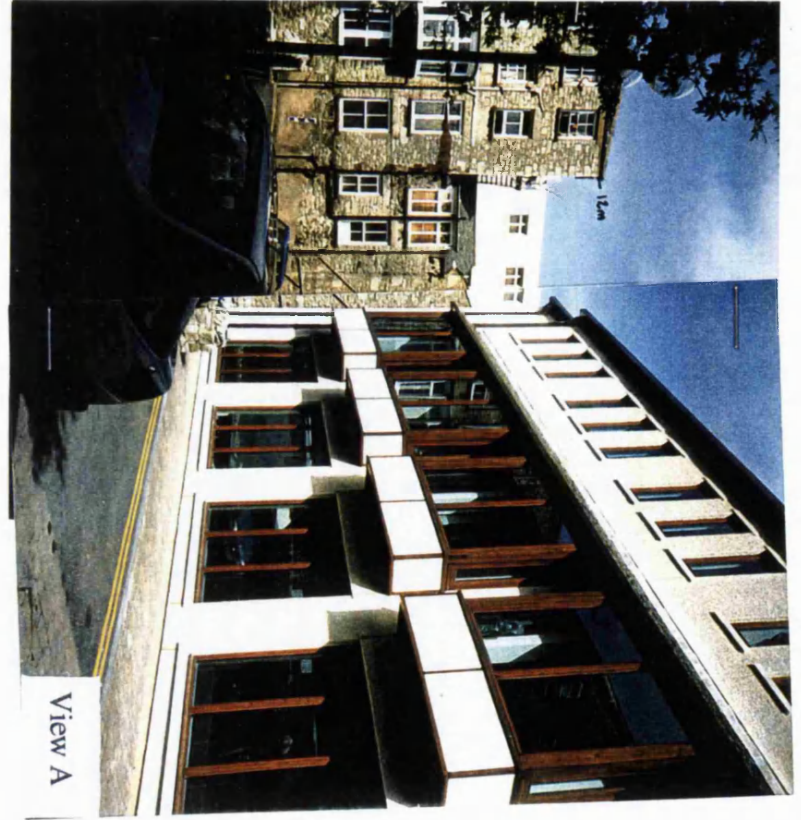
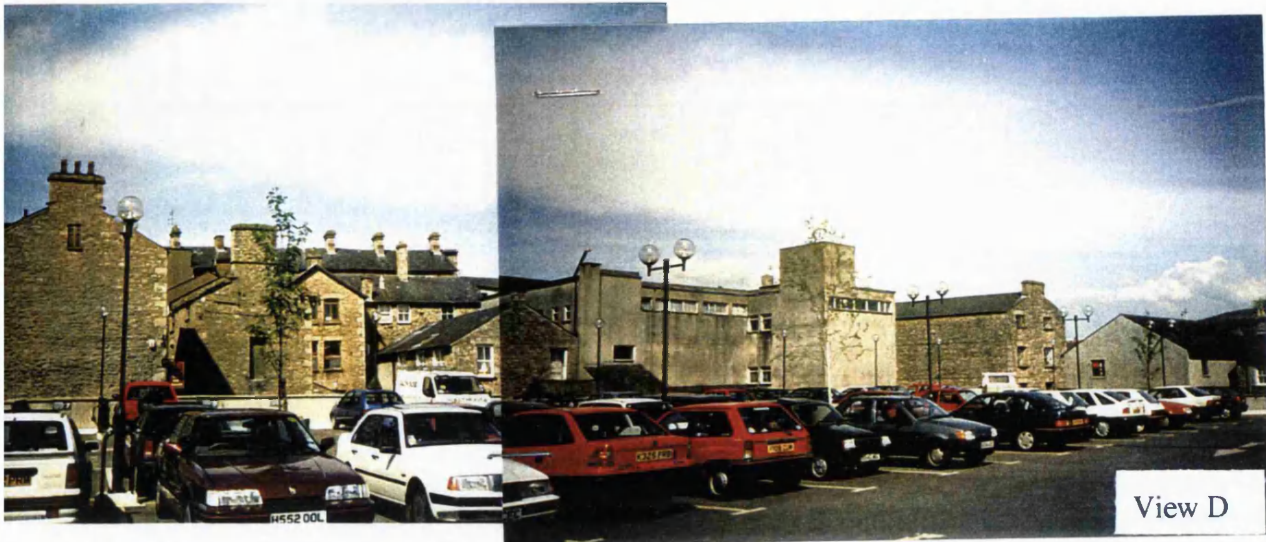


Plate 5.1-1 : Photographs of South Lakeland District Council and the buildings surrounding it.





View D

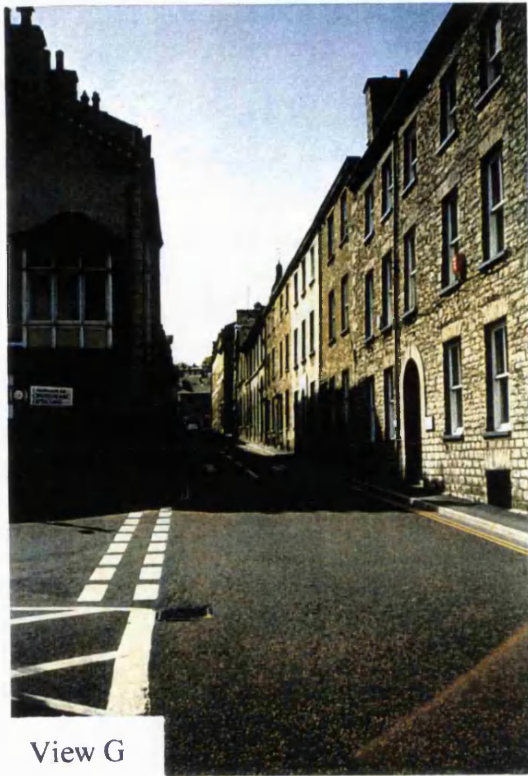


View E

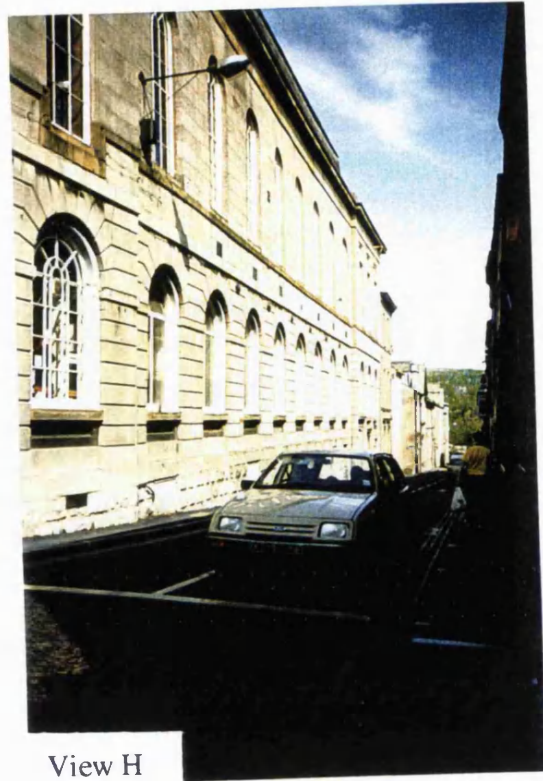


View F

Plate 5.1-2 : Photographs of South Lakeland District Council and the buildings surrounding it.



View G



View H



View I



View J

Plate 5.1-3 : Photographs of South Lakeland District Council and the buildings surrounding it.



**Table 5.4a: sample job classification**

		No of People	Female	Male
Job	Managerial	1	0	1
	Clerical	5	2	3
	Professional	7	4	3
	Technical	2	0	2
	Admin	2	1	1
	Others	1	1	0

**Table 5.4b: Age and gender of sample**

Age		16-19	20-29	30-39	40-49	50-65	unspec	Tot sample
Gender	male	0	2	1	5	2	0	10
	female	0	2	4	2	0	0	8
No of Sample		0	4	5	7	2	0	18

**Table 5.4c: distribution of sample over the floors**

Floor	No of Female	No of Male	No of workers
1	3	2	5
2	5	6	11
3	1	2	3
Total no of workers	9	10	19

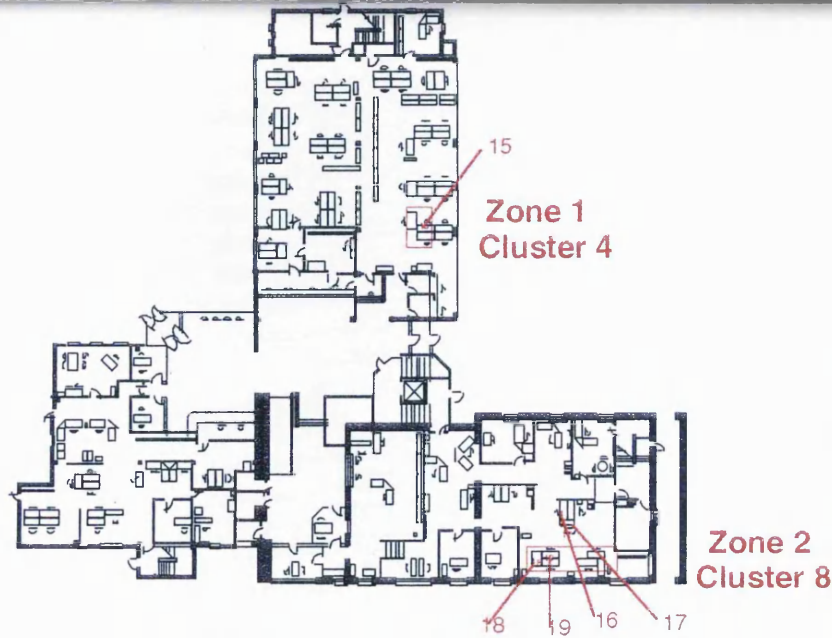


Figure 5.4a: Floor Plan of Level 1 showing target monitoring area and work position

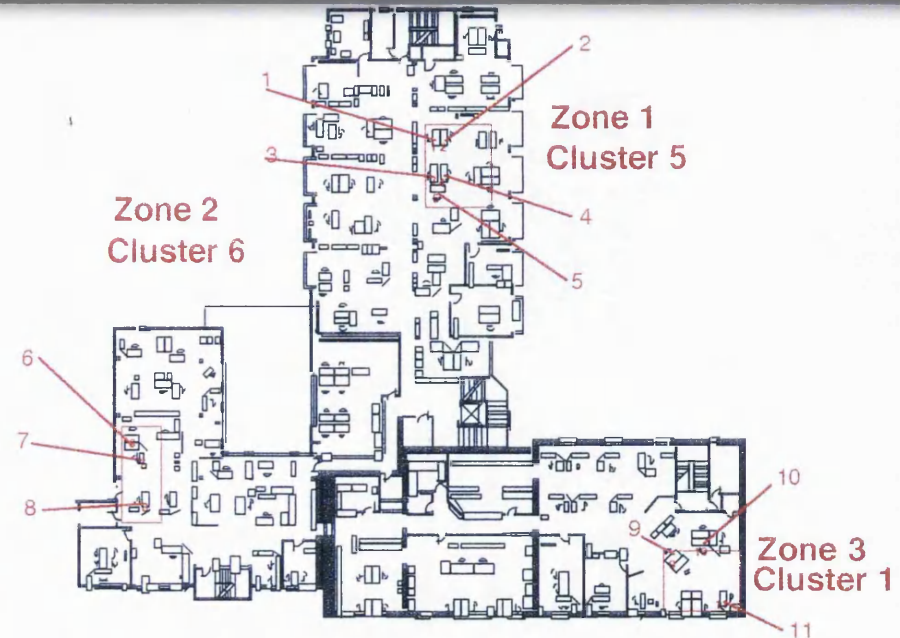


Figure 5.4b: Floor Plan of Level 2 showing target monitoring area and work position

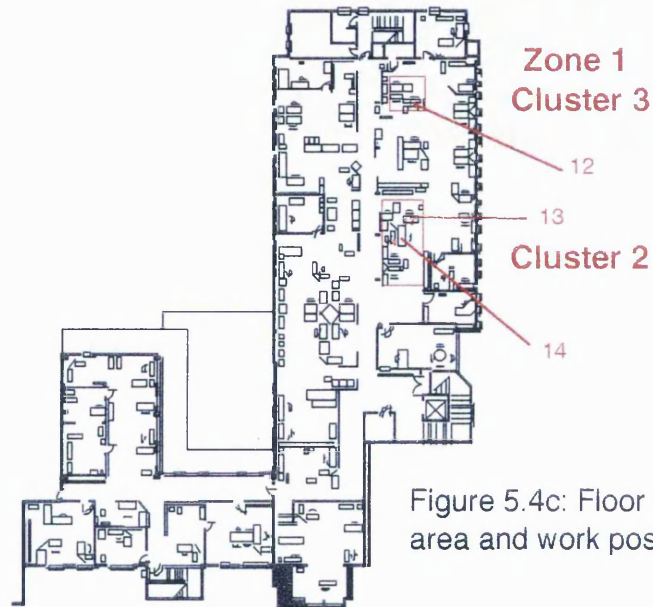


Figure 5.4c: Floor Plan of Level 3 showing target monitoring area and work position

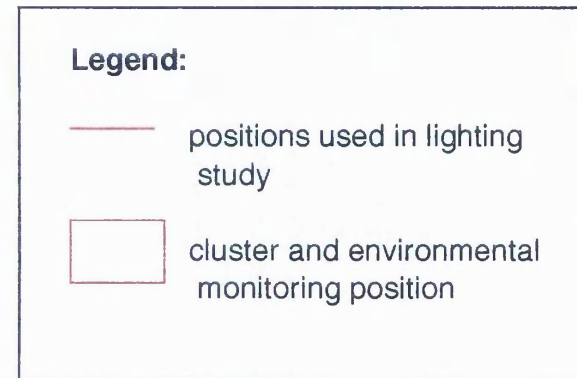




Plate 5.4a : photographs of work positions

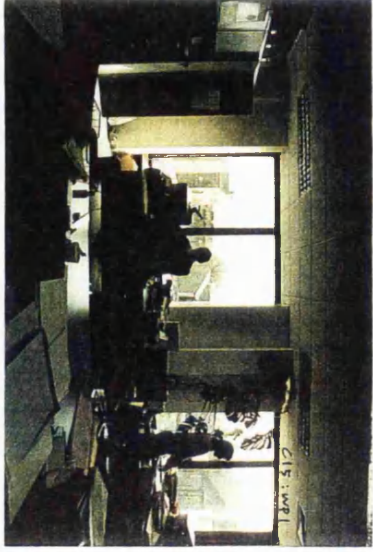
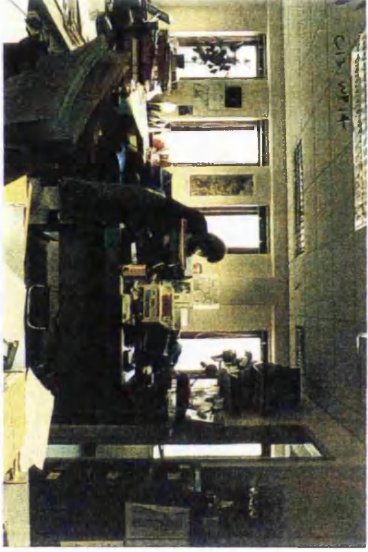
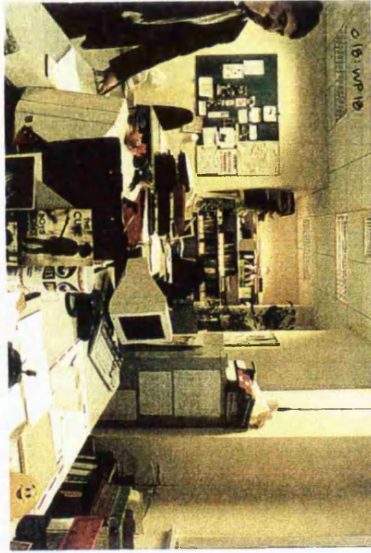




Plate 5.4b : photographs of work positions



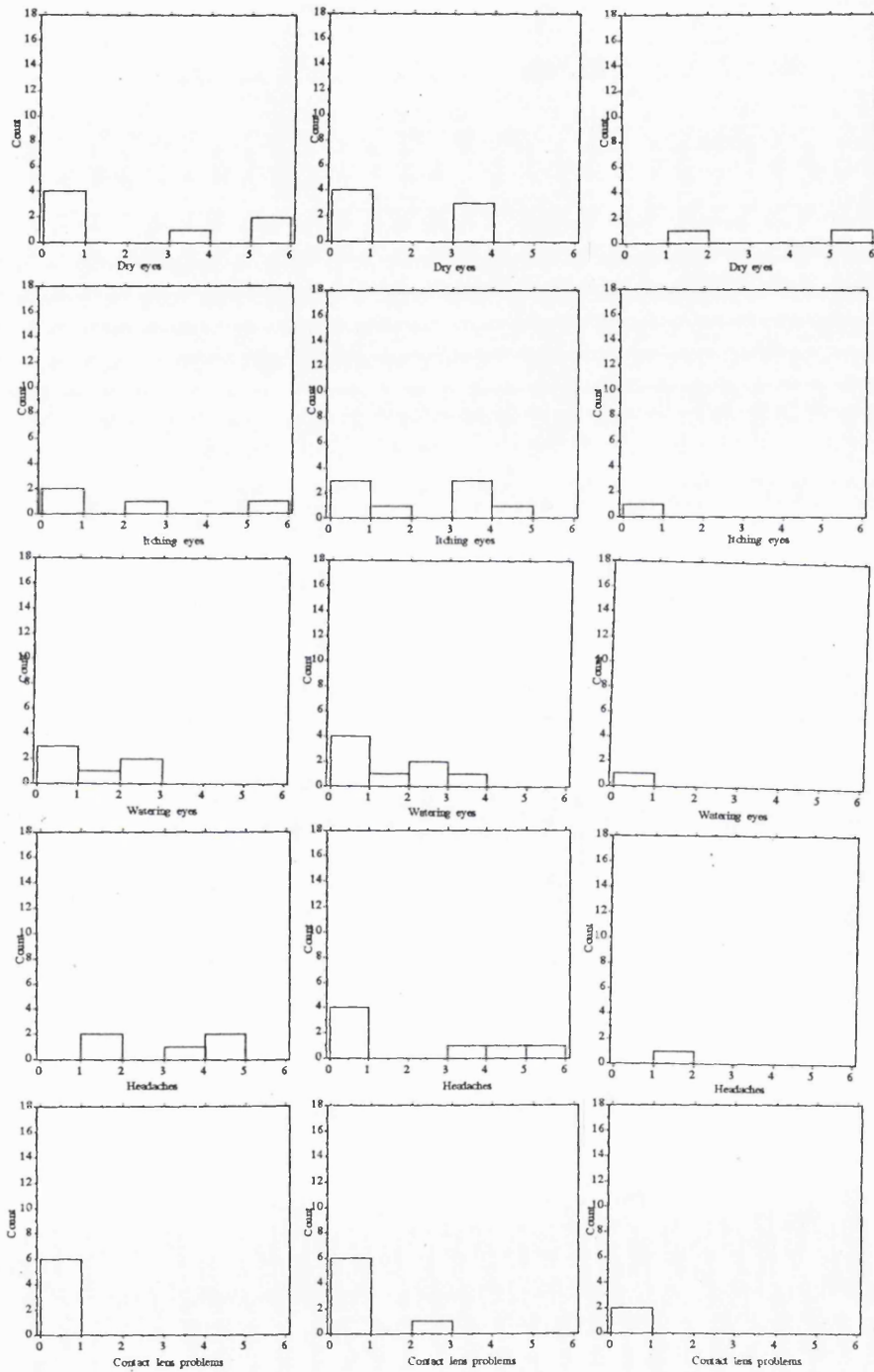
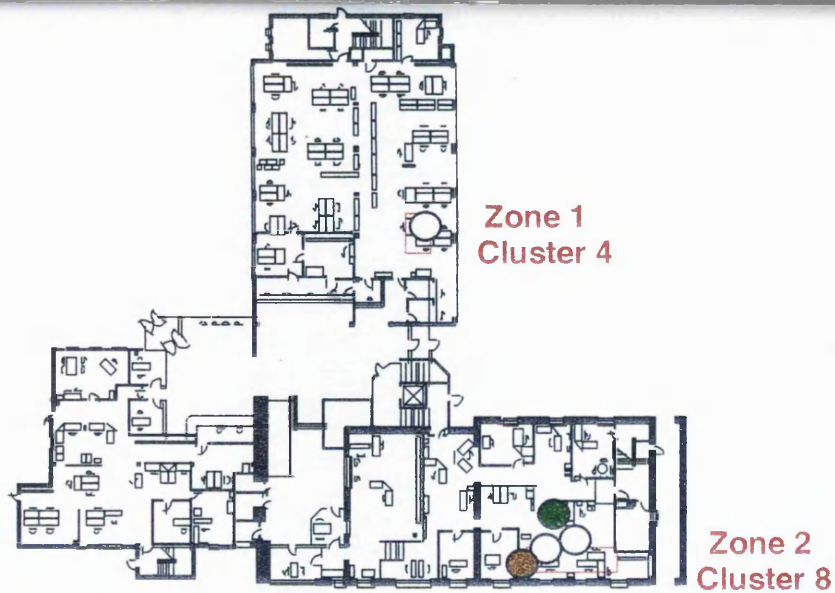
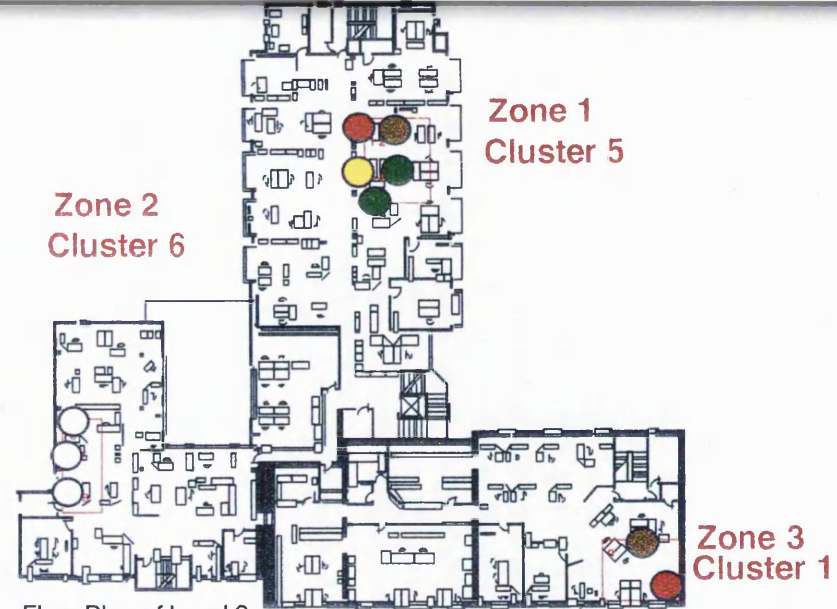


Figure 5.5.1a : Eyes Symptom Distribution in each group

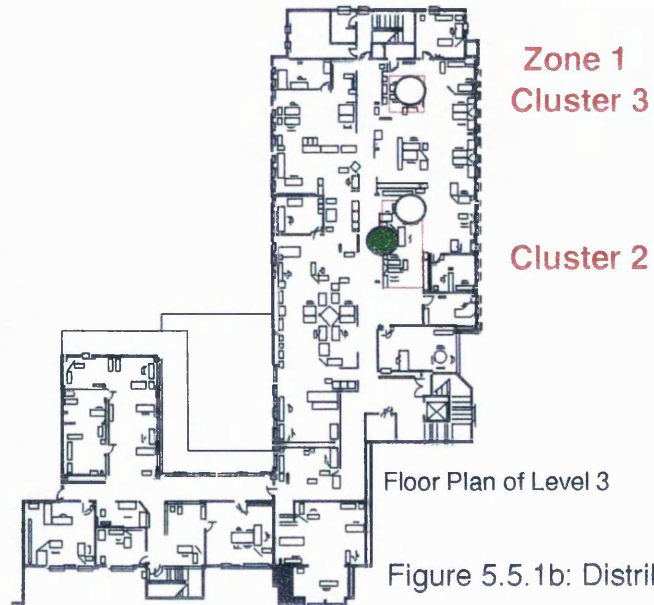




Floor Plan of level 1



Floor Plan of Level 2



Floor Plan of Level 3

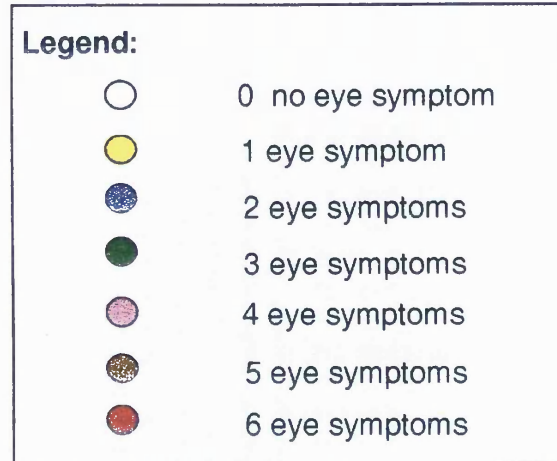
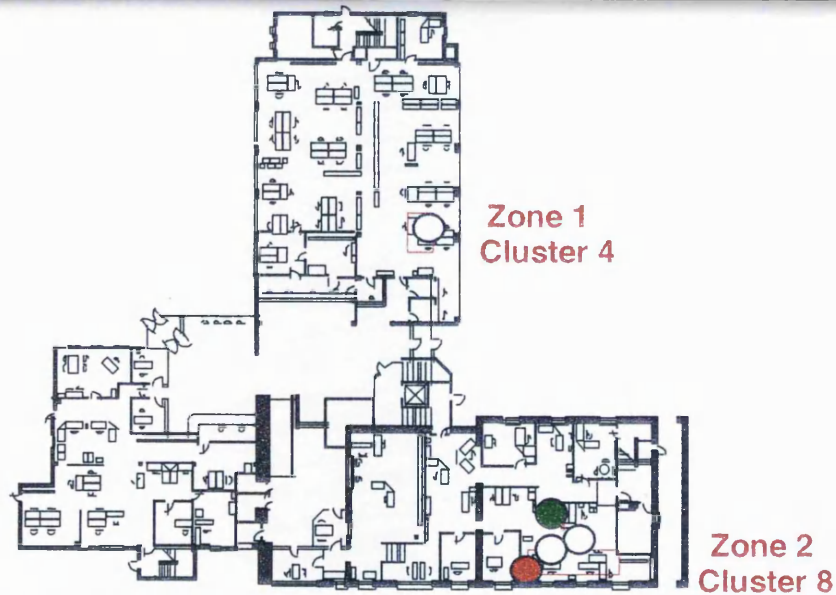
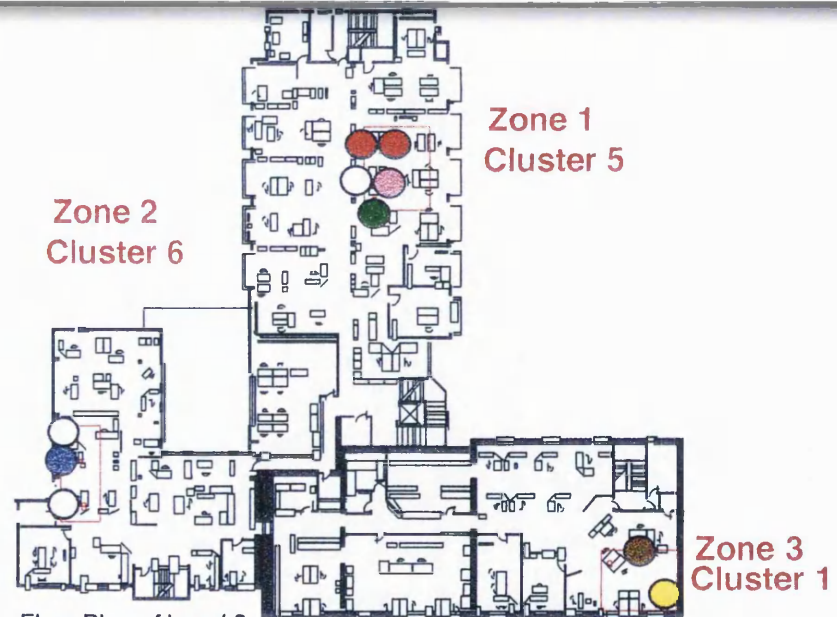


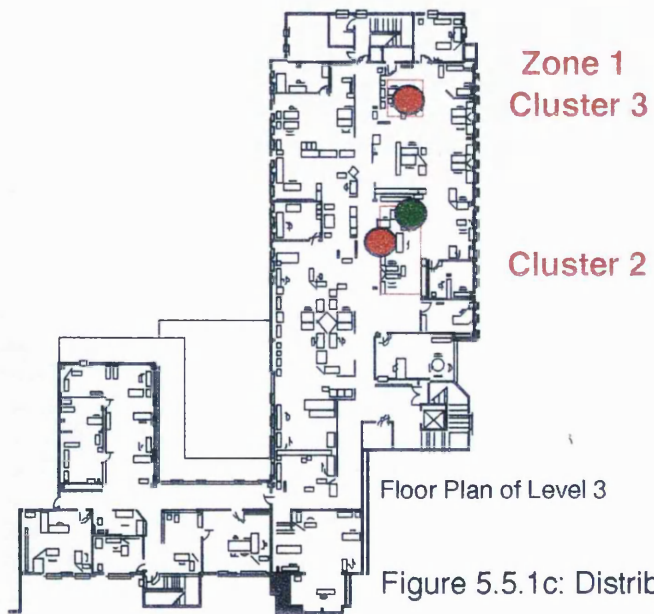
Figure 5.5.1b: Distribution of the occurrence of Dry Eyes



Floor Plan of level 1



Floor Plan of Level 2

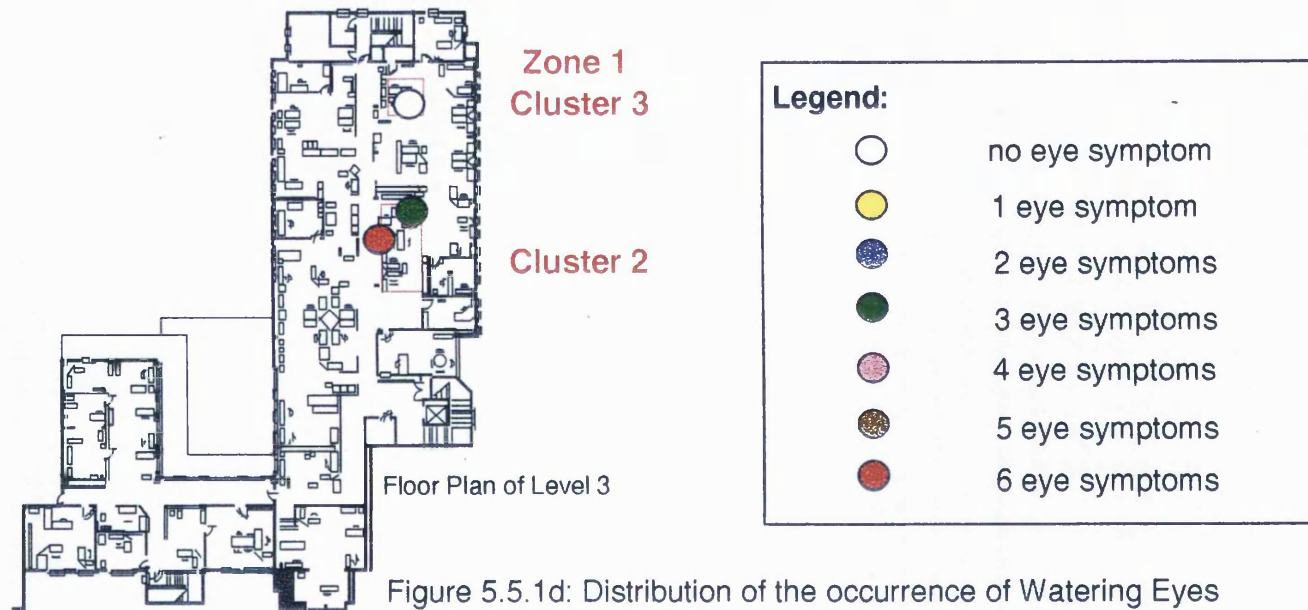
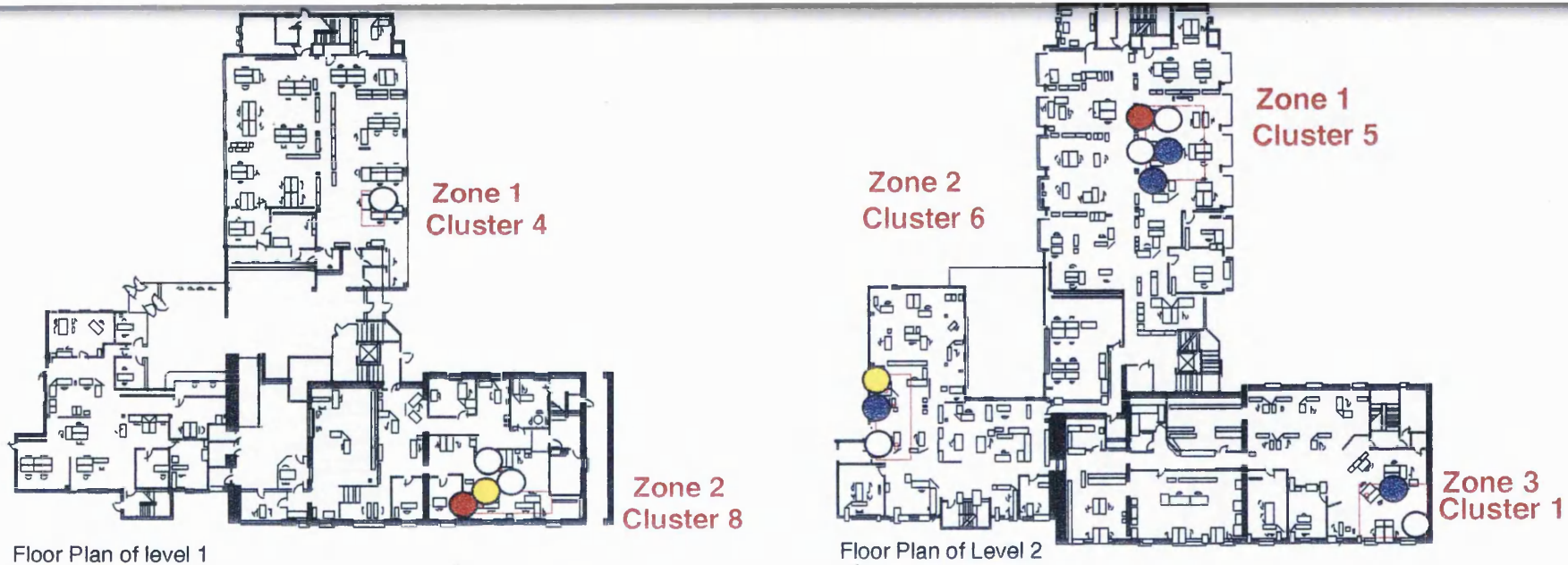


Floor Plan of Level 3

**Legend:**

○	0 no eye symptom
●	1 eye symptom
●	2 eye symptoms
●	3 eye symptoms
●	4 eye symptoms
●	5 eye symptoms
●	6 eye symptoms

Figure 5.5.1c: Distribution of the occurrence of Itching Eyes

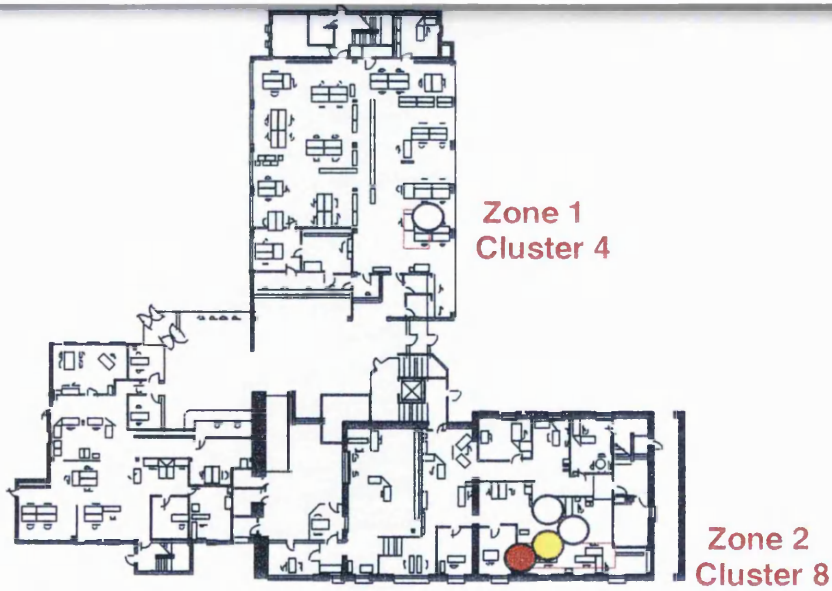


**Legend:**

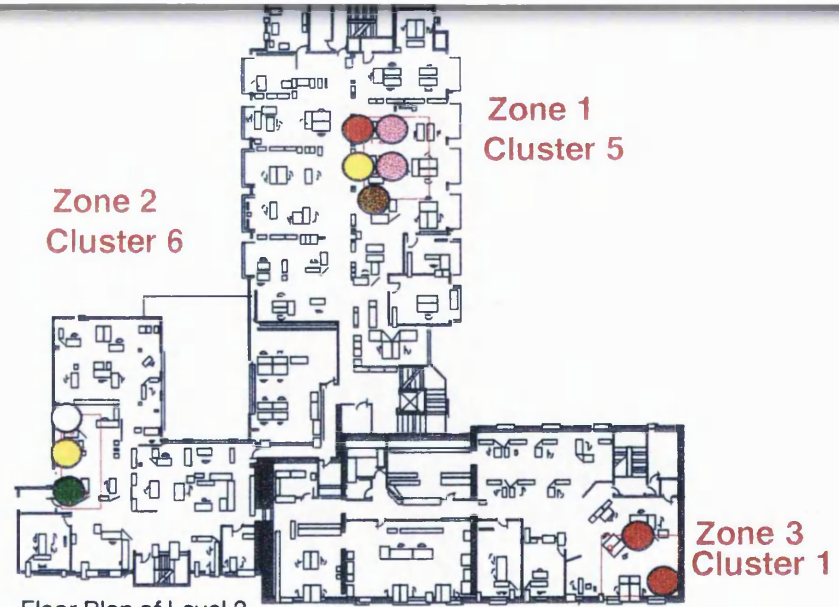
○	no eye symptom
●	1 eye symptom
●	2 eye symptoms
●	3 eye symptoms
●	4 eye symptoms
●	5 eye symptoms
●	6 eye symptoms

Figure 5.5.1d: Distribution of the occurrence of Watering Eyes

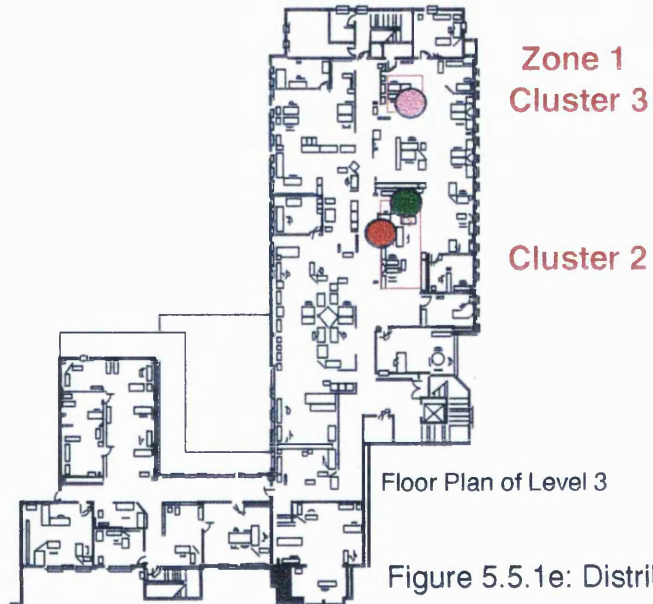




Floor Plan of level 1



Floor Plan of Level 2



Floor Plan of Level 3

**Legend:**

○	no eye symptom
●	1 eye symptom
●	2 eye symptoms
●	3 eye symptoms
●	4 eye symptoms
●	5 eye symptoms
●	6 eye symptoms

Figure 5.5.1e: Distribution of the occurrence of headaches

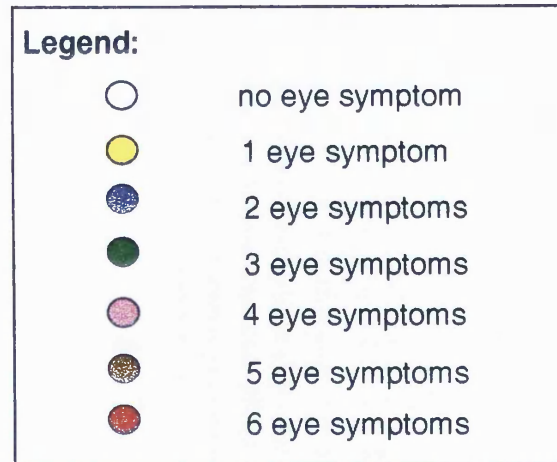
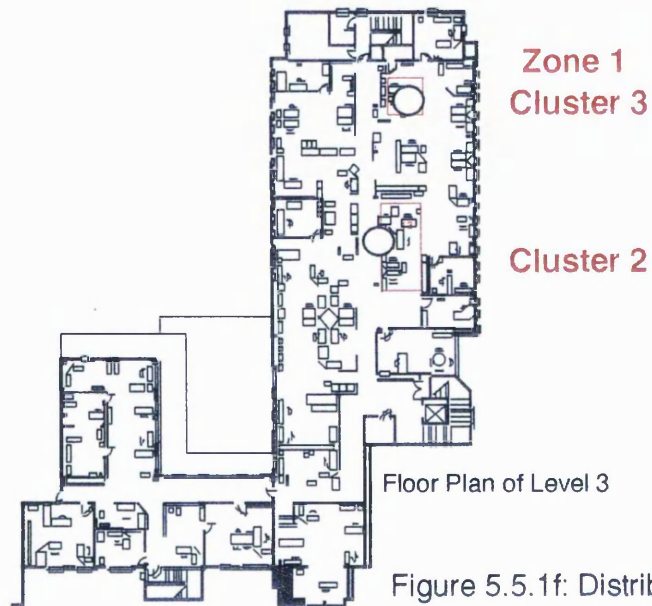
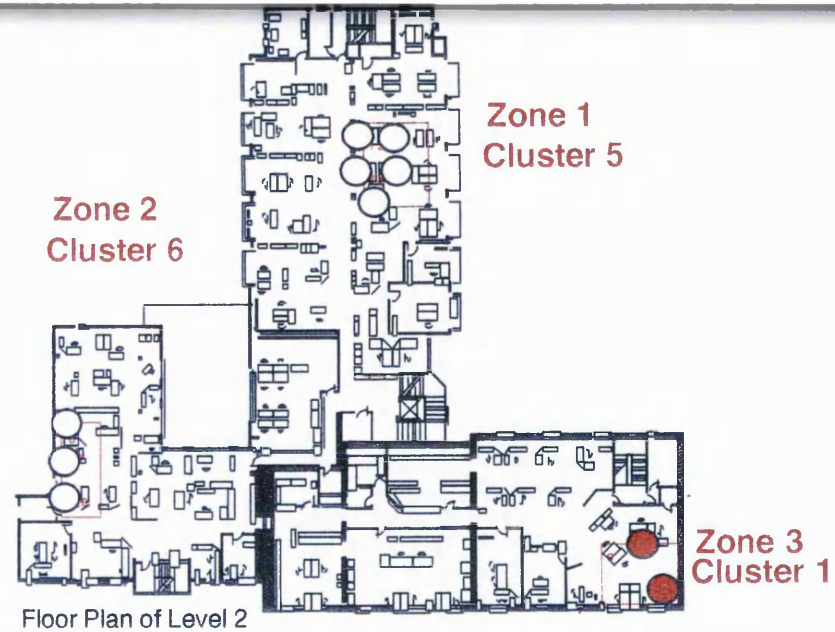
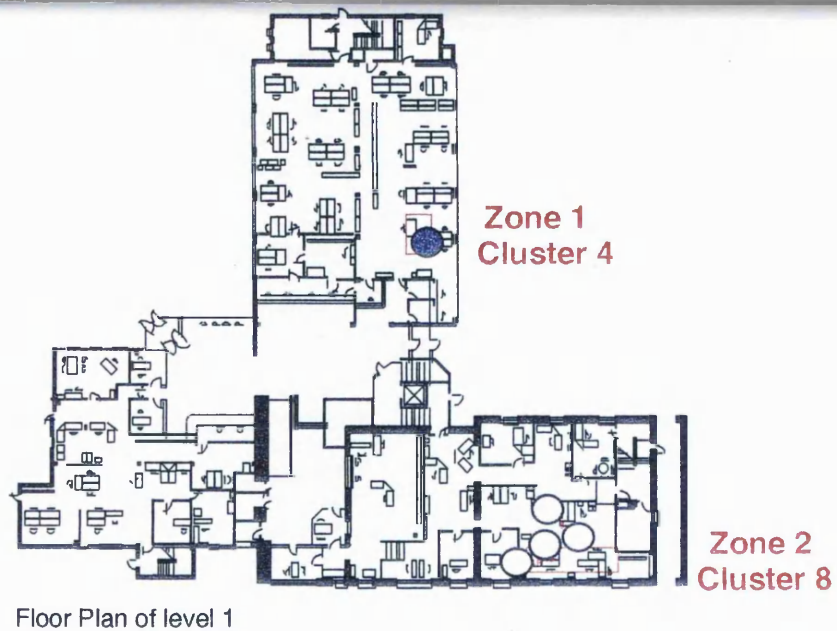


Figure 5.5.1f: Distribution of the occurrence of problem with wearing Contact Lens

Table 5.5.2 : Measured thermal, relative humidity and pollutant levels

Identity No	Floor	Light Cl	cluster	cluster(category)	logger	season	LnroomTemp	LnrxTemp	LMinTemp	LetdTemp	LRHmean	LRHmax	LRHmin	Vel 1.25m	Vel Grad
36	0	8	3.4	three4	3.060	Winter	20.6	22.2	17.0	1.1	37.1	48.6	23.8	-	-
36	0	8	-	-	3.060	Winter	20.6	22.2	17.0	1.1	37.1	48.6	23.8	.062	1.0E-3
42	0	8	-	-	3.060	Winter	20.6	22.2	17.0	1.1	37.1	48.6	23.8	-	-
43	0	8	-	-	3.060	Winter	20.6	22.2	17.0	1.1	37.1	48.6	23.8	-	-
61	0	1	3.4	three4	3.010	Winter	22.6	26.2	18.6	1.0	37.1	48.6	23.8	.066	6.0E-3
113	1	6	3.6	three6	3.120	Winter	22.3	30.0	18.6	1.6	37.1	48.6	23.8	.100	.1
114	1	6	3.6	three6	3.120	Winter	22.3	30.0	18.6	1.6	37.1	48.6	23.8	.141	.1
116	1	6	3.6	three6	3.120	Winter	22.3	30.0	18.6	1.6	37.1	48.6	23.8	.102	.1
119	1	6	3.6	three6	3.120	Winter	22.3	30.0	18.6	1.6	37.1	48.6	23.8	.166	.1
167	1	6	3.6	three6	3.160	Winter	22.1	27.8	18.2	1.2	37.1	48.6	23.8	.087	3.2E-2
168	1	6	3.6	three6	3.140	Winter	21.7	24.2	18.4	1.0	37.1	48.6	23.8	.048	.3
170	1	6	3.6	three6	3.140	Winter	21.7	24.2	18.4	1.0	37.1	48.6	23.8	.068	7.0E-3
207	2	3	3.2	three2	3.240	Winter	22.6	26.2	19.6	1.1	37.1	48.6	23.8	.074	9.0E-3
219	2	2	3.3	three3	3.240	Winter	22.6	26.2	19.6	1.1	37.1	48.6	23.8	.063	2.0E-3
239	2	3	3.2	three2	3.240	Winter	22.6	26.2	19.6	1.1	37.1	48.6	23.8	.197	.1
1102	1	1	3.1	three1	3.170	Winter	22.2	26.8	18.4	1.2	37.1	48.6	23.8	.074	6.0E-3
1106	1	1	-	-	3.170	Winter	22.2	26.8	18.4	1.2	37.1	48.6	23.8	.066	2.6E-2
3004	1	1	-	-	3.170	Winter	22.2	26.8	18.4	1.2	37.1	48.6	23.8	.069	.1

Identity No	Floor	Light Cl	cluster	cluster(category)	logger	season	Cluster CO2 room mean	Cluster CO2 room max	Cluster CO2 room min	Cluster CO2 room std	Cluster formaldehyde mean	Cluster formaldehyde max	Cluster formaldehyde min	Cluster CO mean	Cluster CO max
36	0	8	3.4	three4	3.060	Winter	724.8	860.0	321.2	131.4	.1	.2	.1	1.3	3.9
36	0	8	-	-	3.060	Winter	-	-	-	-	-	-	-	-	-
42	0	8	-	-	3.060	Winter	-	-	-	-	-	-	-	-	-
43	0	8	-	-	3.060	Winter	-	-	-	-	-	-	-	-	-
61	0	1	3.4	three4	3.010	Winter	724.8	860.0	321.2	131.4	.1	.2	.1	1.3	3.9
113	1	6	3.6	three6	3.120	Winter	471.8	912.0	269.7	78.4	.1	.2	.1	1.1	3.8
114	1	6	3.6	three6	3.120	Winter	471.8	912.0	269.7	78.4	.1	.2	.1	1.1	3.8
116	1	6	3.6	three6	3.120	Winter	471.8	912.0	269.7	78.4	.1	.2	.1	1.1	3.8
119	1	6	3.6	three6	3.120	Winter	471.8	912.0	269.7	78.4	.1	.2	.1	1.1	3.8
167	1	6	3.6	three6	3.160	Winter	678.8	782.0	288.0	120.3	.1	.6	.1	1.3	4.2
168	1	6	3.6	three6	3.140	Winter	678.8	782.0	288.0	120.3	.1	.6	.1	1.3	4.2
170	1	6	3.6	three6	3.140	Winter	678.8	782.0	288.0	120.3	.1	.6	.1	1.3	4.2
207	2	3	3.2	three2	3.240	Winter	898.0	1093.0	303.6	184.9	.1	1.1	.1	1.1	3.7
219	2	2	3.3	three3	3.240	Winter	833.4	900.0	323.6	112.1	.1	1.0	.1	1.1	3.6
239	2	3	3.2	three2	3.240	Winter	898.0	1093.0	303.6	184.9	.1	1.1	.1	1.1	3.7
1102	1	1	3.1	three1	3.170	Winter	689.7	861.0	310.1	120.2	.1	.1	.1	1.2	4.0
1106	1	1	-	-	3.170	Winter	-	-	-	-	-	-	-	-	-
3004	1	1	-	-	3.170	Winter	-	-	-	-	-	-	-	-	-

Identity No	Floor	Light Cl	cluster	cluster(category)	logger	season	Cluster TVOC mean	Cluster TVOC max	Cluster TVOC min	Cluster dust mite/g	Cluster antigen ng/g	Cluster shell factor	Cluster fleece factor	Cluster respirable dust mg/m3	Cluster max particle size micron
36	0	8	3.4	three4	3.060	Winter	.9	16.8	.1	0.0	380.0	.3	.6	-	-
36	0	8	-	-	3.060	Winter	-	-	-	-	-	-	-	-	-
42	0	8	-	-	3.060	Winter	-	-	-	-	-	-	-	-	-
43	0	8	-	-	3.060	Winter	-	-	-	-	-	-	-	-	-
61	0	1	3.4	three4	3.010	Winter	.9	16.8	.1	0.0	380.0	.3	.6	-	-
113	1	6	3.6	three6	3.120	Winter	.2	8.6	.1	0.0	440.0	.2	.6	-	-
114	1	6	3.6	three6	3.120	Winter	.2	8.6	.1	0.0	440.0	.2	.6	-	-
116	1	6	3.6	three6	3.120	Winter	.2	8.6	.1	0.0	440.0	.2	.6	-	-
119	1	6	3.6	three6	3.120	Winter	.2	8.6	.1	0.0	440.0	.2	.6	-	-
167	1	6	3.6	three6	3.160	Winter	.1	1.3	.1	11.0	800.0	.3	.6	-	-
168	1	6	3.6	three6	3.140	Winter	.1	1.3	.1	11.0	800.0	.3	.6	-	-
170	1	6	3.6	three6	3.140	Winter	.1	1.3	.1	11.0	800.0	.3	.6	-	-
207	2	3	3.2	three2	3.240	Winter	.6	33.6	.1	7.0	480.0	.4	.9	-	-
219	2	2	3.3	three3	3.240	Winter	1.1	66.1	.1	0.0	260.0	.2	.8	-	-
239	2	3	3.2	three2	3.240	Winter	.6	33.6	.1	7.0	480.0	.4	.9	-	-
1102	1	1	3.1	three1	3.170	Winter	.3	9.4	.1	8.0	420.0	.2	.4	-	-
1106	1	1	-	-	3.170	Winter	-	-	-	-	-	-	-	-	-
3004	1	1	-	-	3.170	Winter	-	-	-	-	-	-	-	-	-



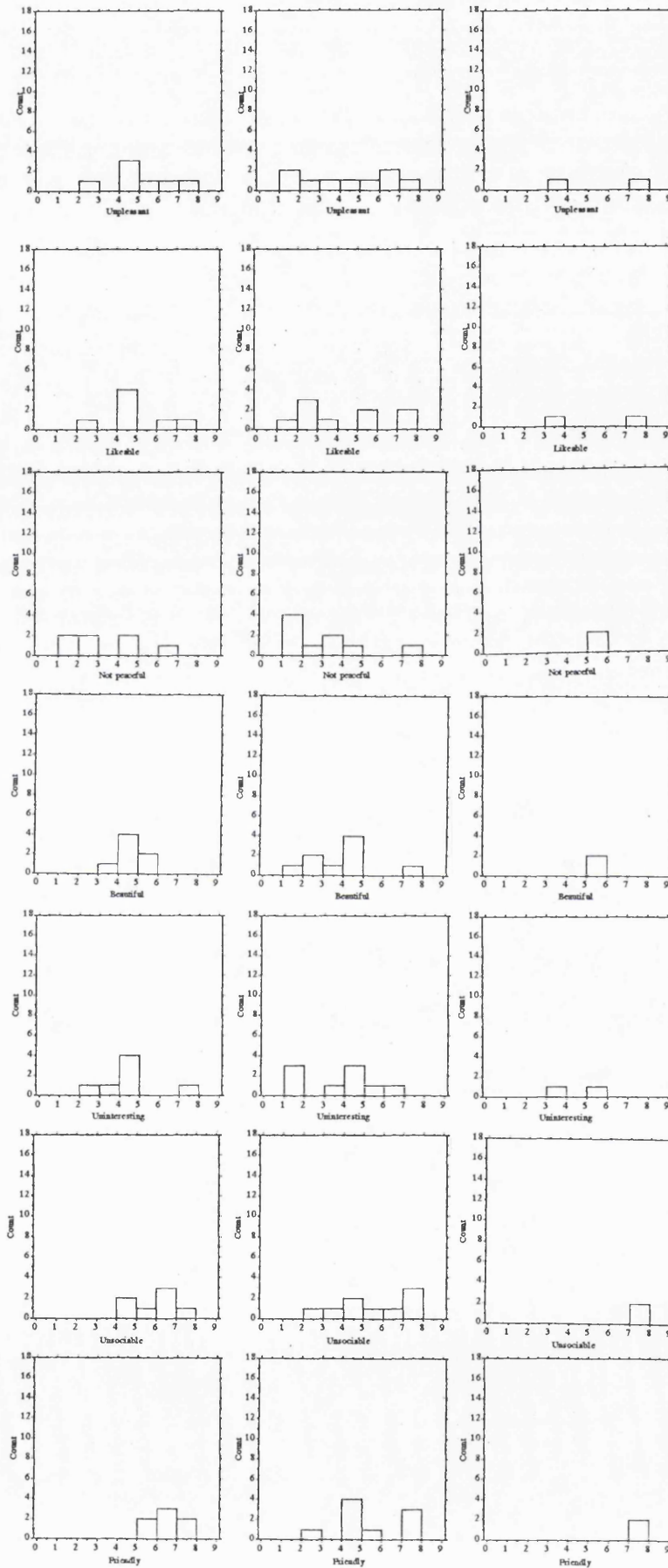


Figure 5.5.3a : Distribution of occupants assessments of Appearance of Work position

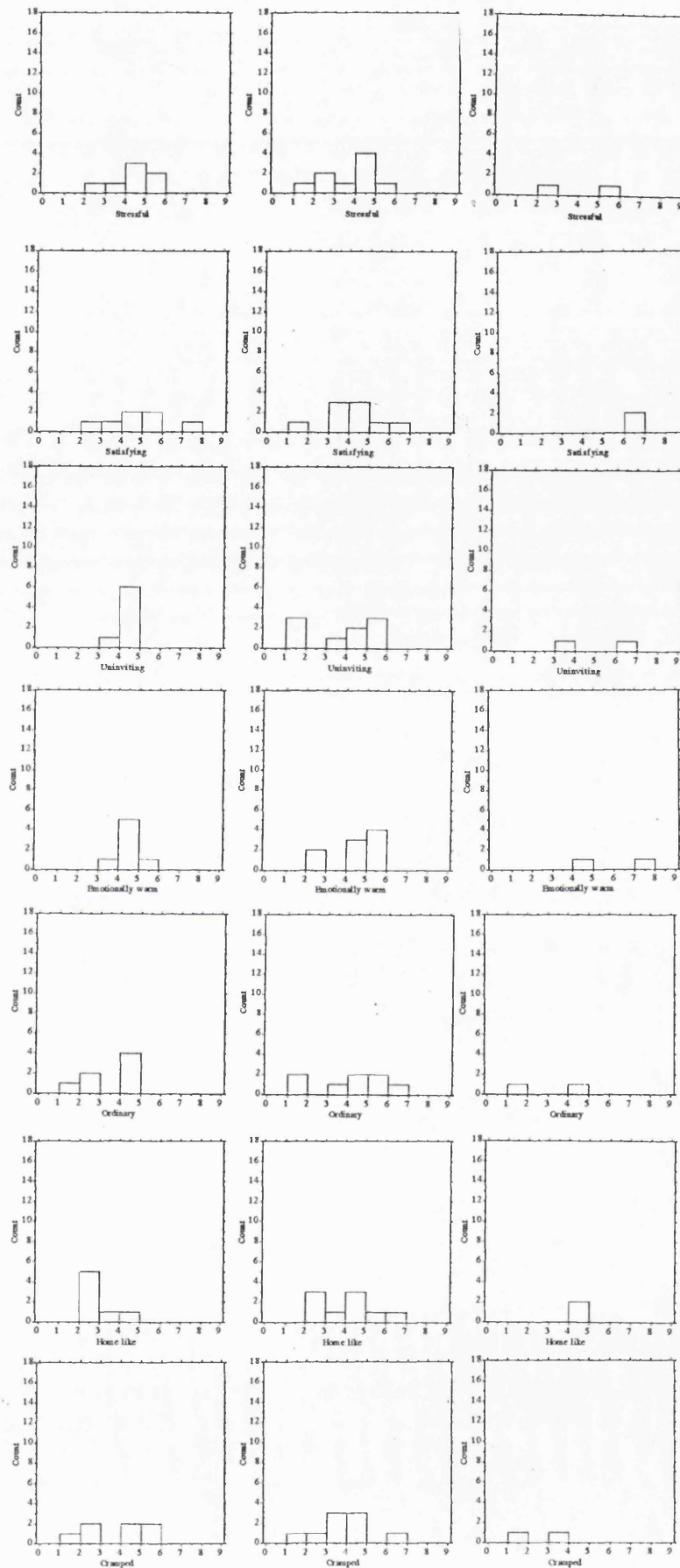


Figure 5.5.3b : Distribution of occupants assessments of Appearance of Work position



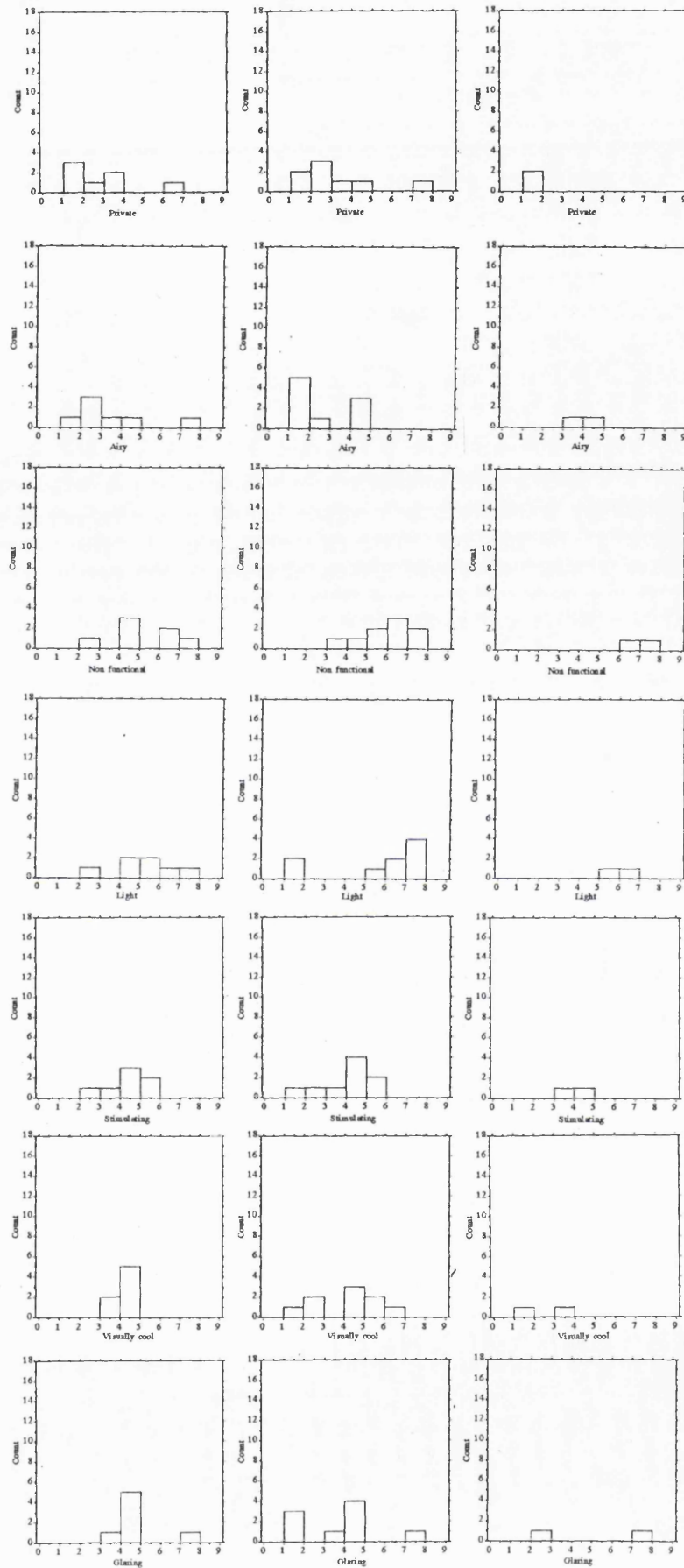


Figure 5.5.3c : Distribution of occupants assessments of Appearance of Work position

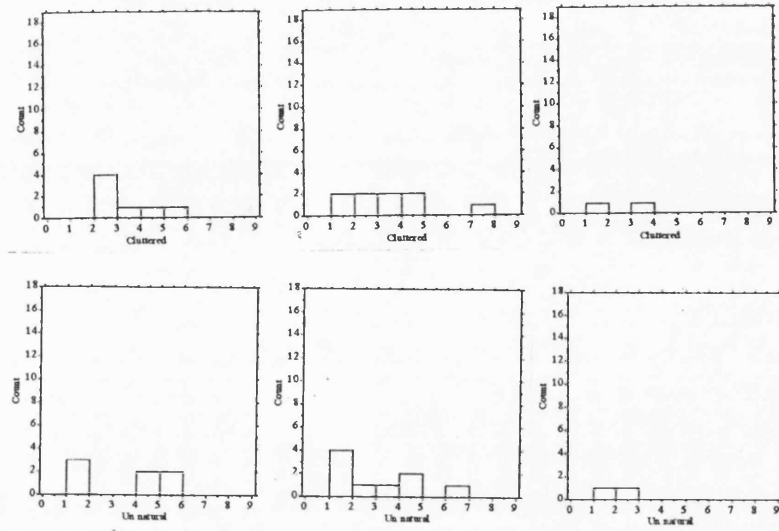


Figure 5.5.3d : Distribution of occupants assessments of Appearance of Work position

Table 5.5.4a: Work Position Physical Attributes

Pos	IA (m <sup>2</sup> )	WA/IPA	Seat orientat'n	Window Polarity	Win Dist (m)	Ave Lum (cd/m <sup>2</sup> )	Eye(E) (lux)	WT(E) (lux)	% DL(WT)
9	23.65	0.12	Front	South	6.65	112.6	435	627	20.3
10	5.18	0	Back	South	0	52.4	340	807	25.7
11	54.16	0.06	Side	South	6.65	167.9	532	822	22.2
12	39.12	0.07	Side	East	10.37	44.6	272	645	14.7
13	23.55	0	Side	East	6.21	18.8	375	773	8.2
14	24.77	0.11	Front	East	11.2	223.9	212	345	47.8
15	14.46	0.17	Side	East	9.36	86.6	392	765	34.6
1	30.79	0.27	Front	East	6.33	193.9	317	585	21.4
2	8.88	0	Back	West	4.59	29.8	202	647	27.4
3	37.23	0.30	Front	East	0	161.4	280	847	25.7
4	48.32	0.09	Front	West	1.64	40.8	212	385	21.3
5	36.4	0	Side	East	3.98	40.4	205	762	18.7
6	42.63	0.06	Side	South	4.41	56.3	345	815	23.9
7	14.09	0.01	Front	South	5.83	77.7	215	948	30.4
8	30.65	0.02	Side	South	2.62	67.0	166	940	30.9
16	19.73	0.05	Side	South	5.19	78.1	502	697	16.8
17	9.36	0.01	Back	South	0	58.4	392	652	21.8
18	30.36	0.10	Side	South	1.82	80.6	547	817	30.3
19	5.52	0.17	Front	South	2.16	111.9	415	790	21.5

Table 5.5.4b: The range of the measured physical light attributes for the group

SUBJECTIVE QUALITY	Range of Physical measurements		
	Facing Windows	Siding Windows	Backing Windows
Isoarea (IA)	5.52 - 48.3	14.4 - 54.2	5.18 - 9.36
isoperimeter	12.6 - 54.3	21.1 - 43.6	11.1 - 20.6
isoperimeter area	37.9 - 130.2	53.0 - 118.6	31.5 - 61.9
window area	0.65 - 20.7	0 - 8.76	0 - 0.32
WA/IPA	0.01 - 0.3	0 - 0.17	0 - 0.01
ave(L)	40.8 - 223.9	18.8 - 167.9	29.8 - 58.4
WT(E)	423.7 - 841.8	617.5 - 895.0	575.0 - 683.7
eye(E)	212.5 - 435.0	166.2 - 547.5	202.5 - 392.5

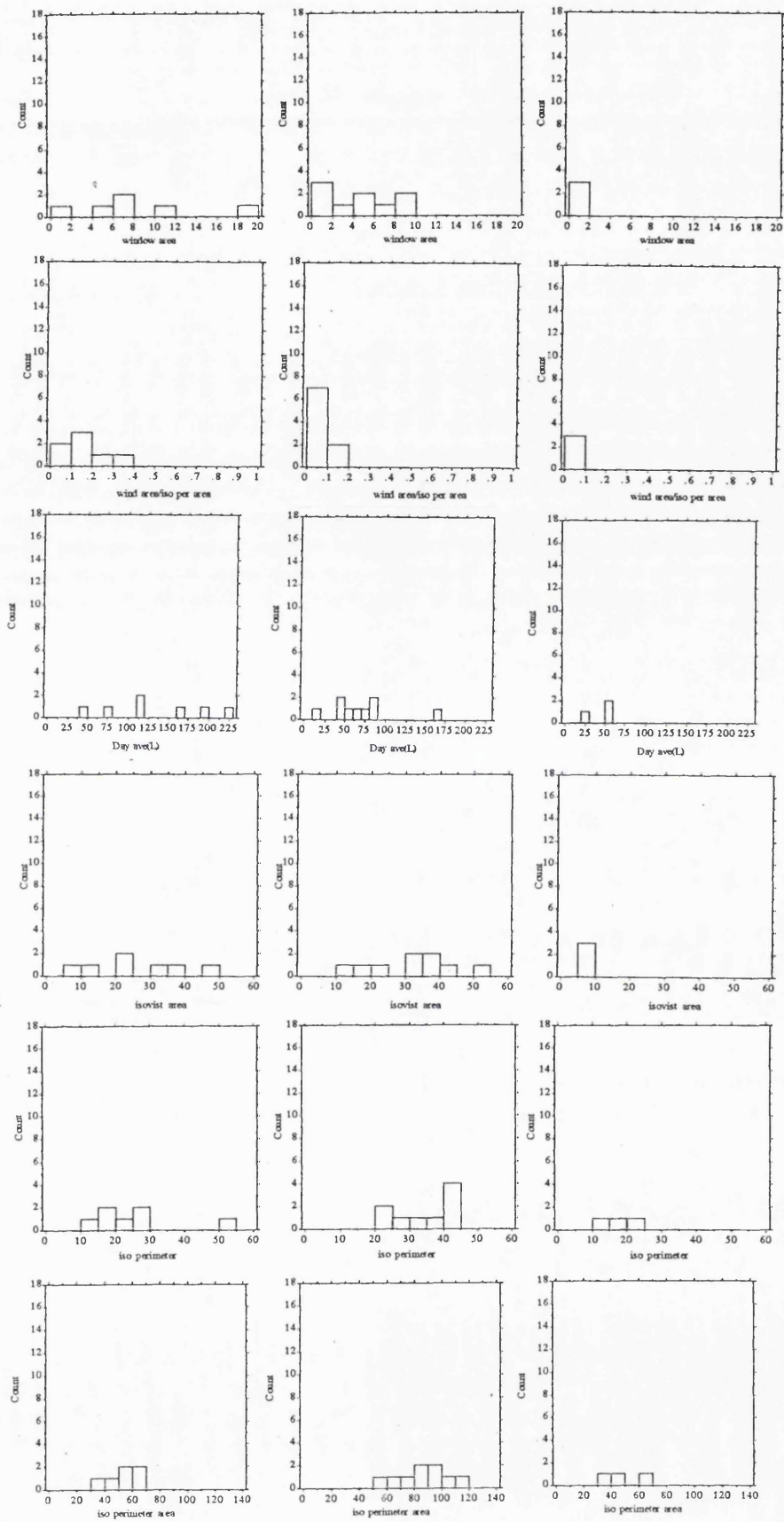


Figure 5.5.4a : The distribution of the measured physical light attributes for the group

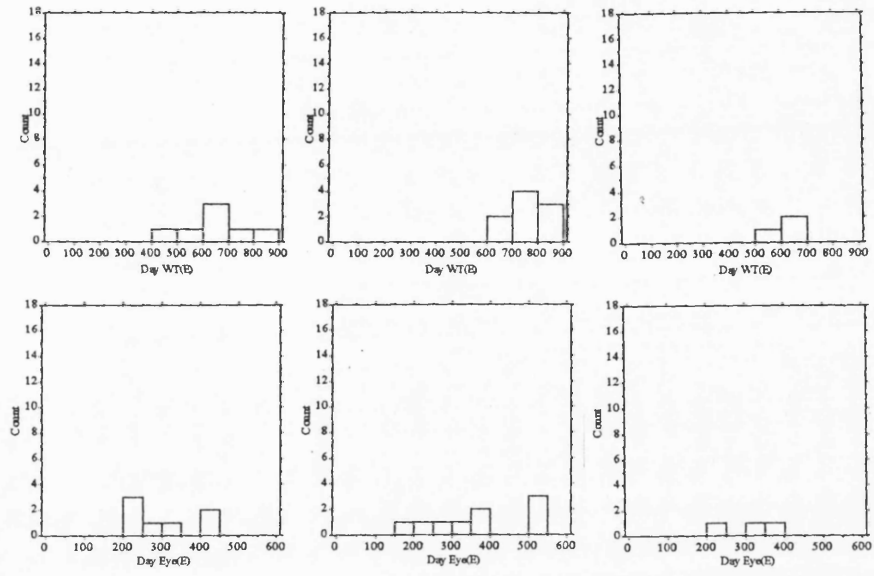


Figure 5.5.4b : The distribution of the measured physical light attributes for the group

Table 5.8a: Difference of symptom occurrence with respect to occupants Location

Symptom	Kruscal-Wallis Analysis		Mean Comparison					
			7		9		2	
	Seat orientation wrt window		Facing Window		Siding Window		Backing Window	
	H	p	Mean	STD	Mean	STD	Mean	STD
Dry Eyes	0.779	0.68	1.9	2.4	2.3	2.5	3.0	2.8
Itching Eyes	0.902	0.64	3.6	2.8	2.2	2.9	3.0	4.2
Watering Eyes	0.139	0.93	1.6	2.1	1.5	2.0	3.0	4.2
Headaches	0.990	0.61	3.6	2.1	2.7	2.7	3.5	3.5
Contact Lense Prob	0.654	0.72	0.8	2.3	1.0	2.1	0	0

N.B: H indicated is corrected for ties

Table 5.8b: Comparison of Occupants Perception of Work Position Appearance between Seat Orientation

SUBJECTIVE QUALITY	Kruscal-Wallis Analysis		Mean Comparison					
			7		9		2	
	Seat orientation wrt window		Facing Window		Siding Window		Backing Window	
	H	p	Mean	STD	Mean	STD	Mean	STD
Pleasant	0.63	0.72	4.5	1.6	3.9	2.3	5.0	2.8
Likeable	0.81	0.66	4.4	1.6	3.8	2.3	5.0	2.8
Peaceful	3.19	0.20	2.8	0.9	2.6	2.0	5.0	0
Beautiful	4.63	0.09	4.1	0.7	3.4	1.7	5.0	0
Interesting	0.54	0.76	4.0	1.5	3.2	1.8	4.0	1.4
Friendly	4.04	0.13	6.0	0.8	4.9	1.8	7.0	0
Relaxing	0.97	0.61	3.8	1.0	3.2	1.3	3.5	2.1
Satisfying	4.02	0.13	4.3	1.6	3.7	1.4	6.0	0
Inviting	0.45	0.79	3.9	0.4	3.2	1.8	4.5	2.1
Emotionally warm	1.44	0.48	4.0	0.6	4.0	1.2	5.5	2.1
Unusual	1.15	0.56	3.0	1.3	3.6	1.8	2.5	2.1
Homelike	4.55	0.10	2.4	0.8	3.6	1.4	4.0	0
Spacious	1.49	0.47	3.3	1.6	3.3	1.4	2.0	1.4
Airy	2.20	0.33	3.0	2.0	2.1	1.5	3.5	0.7
Light	1.34	0.51	4.7	1.6	5.2	2.5	5.5	0.7
Cheerful	0.92	0.62	4.1	0.9	4.3	1.5	5.0	1.4
Stimulating	0.42	0.80	3.9	1.1	3.5	1.3	3.5	0.7
Visually Warm	2.92	0.23	3.7	0.5	3.7	1.7	2.0	1.4
Non-glaring	1.54	0.46	4.3	1.3	3.2	2.0	4.5	3.5
Colourful	4.34	0.11	3.4	1.0	3.2	1.6	1.0	0
Clean	3.53	0.17	5.3	0.9	6.1	1.2	6.5	0.7
Uncluttered	0.63	0.72	2.8	1.2	3.0	1.9	2.0	1.4
Natural	0.77	0.67	3.0	1.9	2.5	1.8	1.5	0.7
Sat visual appearance	1.50	0.47						
Sat charac& atmosph	0.12	0.93						
Sat extent of view	3.12	0.21						
Sat spaciousness	0.97	0.61						
Sat decoration	2.35	0.30						

N.B: The higher the mean the better the subjective assessment

Table 5.8c: Comparison of Measured Lighting Variables between Cluster and Seat Orientation

SUBJECTIVE QUALITY	Kruscal-Wallis Analysis		Mean Comparison					
	Seat orientation wrt window		Facing Window		Siding Window		Backing Window	
	H	p	Mean	STD	Mean	STD	Mean	STD
Isoarea (IA)	6.5	0.03	26.3	14.2	32.3	12.3	7.8	2.3
Isoperimeterarea IPA	6.6	0.04	65.2	30.7	85.2	20.4	46.5	15.2
Win. Height (WH)								
Win Width (WW)								
Win Area (WA)	7.5	0.02	10.0	7.2	4.5	3.3	0.1	0.2
WW/IP								
WA/IPA	8.5	0.01	0.15	0.1	0.6	0.05	0.003	0.006
Floor height (FH)								
Dnw								
Hws								
Average luminance	5.61	0.06	131.7	64.8	71.1	42.4	46.8	15.1
Eye Illuminance	0.90	0.63	298.2	95.5	370.9	139.1	311.6	98.1
WT(E)	5.77	0.42	644.3	229.4	766.3	87.7	702.5	90.9
%DL(WT)	0.40	0.81	24.0	13.9	22.2	8.6	24.9	2.8

N.B: H indicated is corrected for ties

Legend:

Hws - Height of Workstation from street level

Dnw - Distance of nearest window

WT(E) - Worktop Illuminance Level

% DL(WT) - percentage of Daylight on worktop

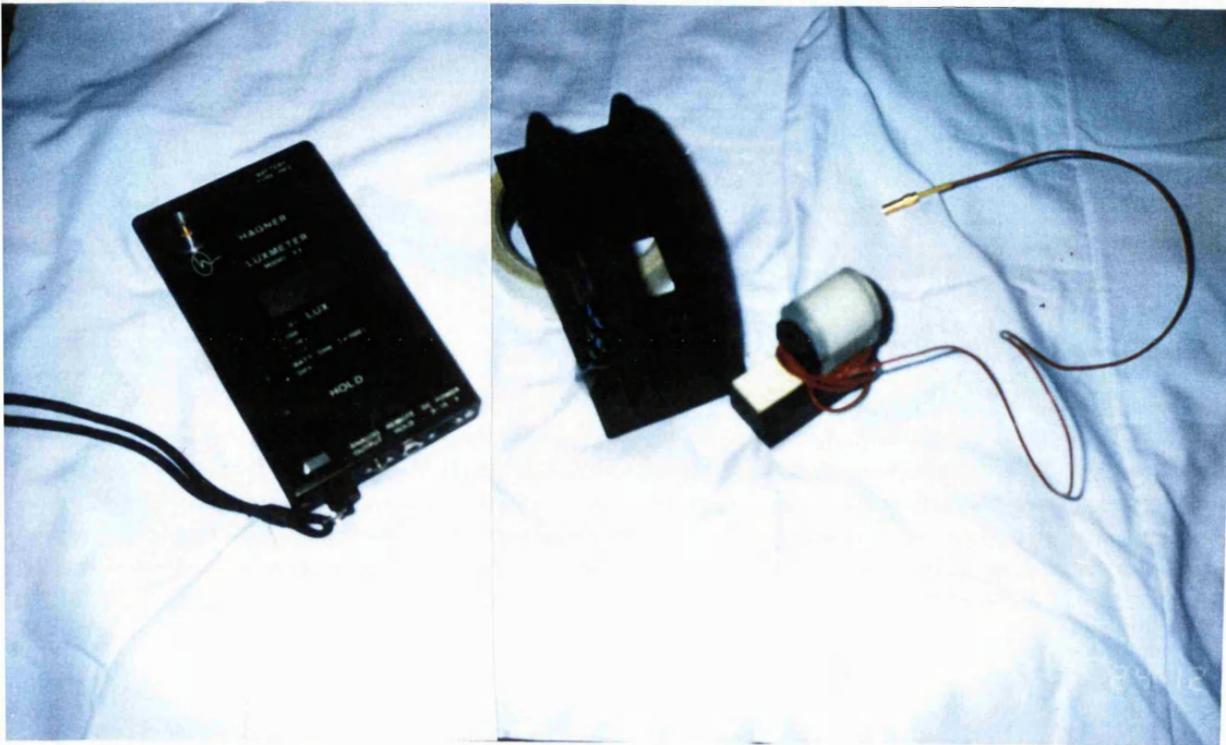


Plate 5.9.2a : Hagner lux meter and semi cylindrical cell

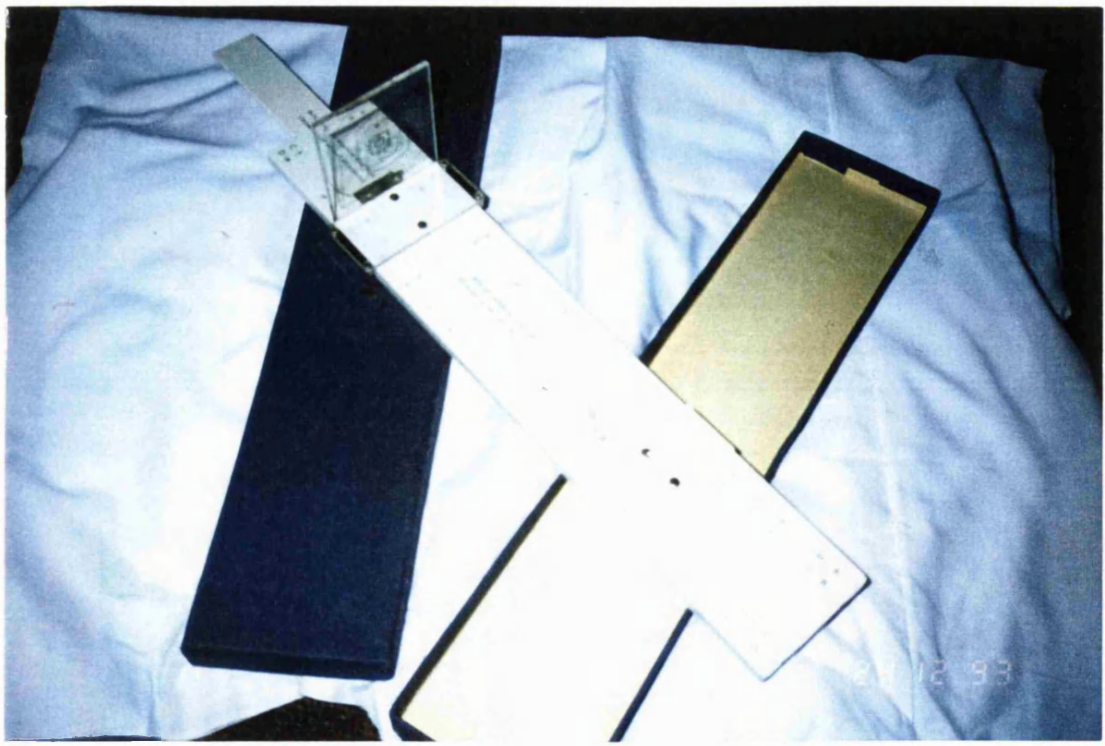


Plate 5.9.2b : Solid angle slide ruler



## **Chapter 6: Case Study 1**

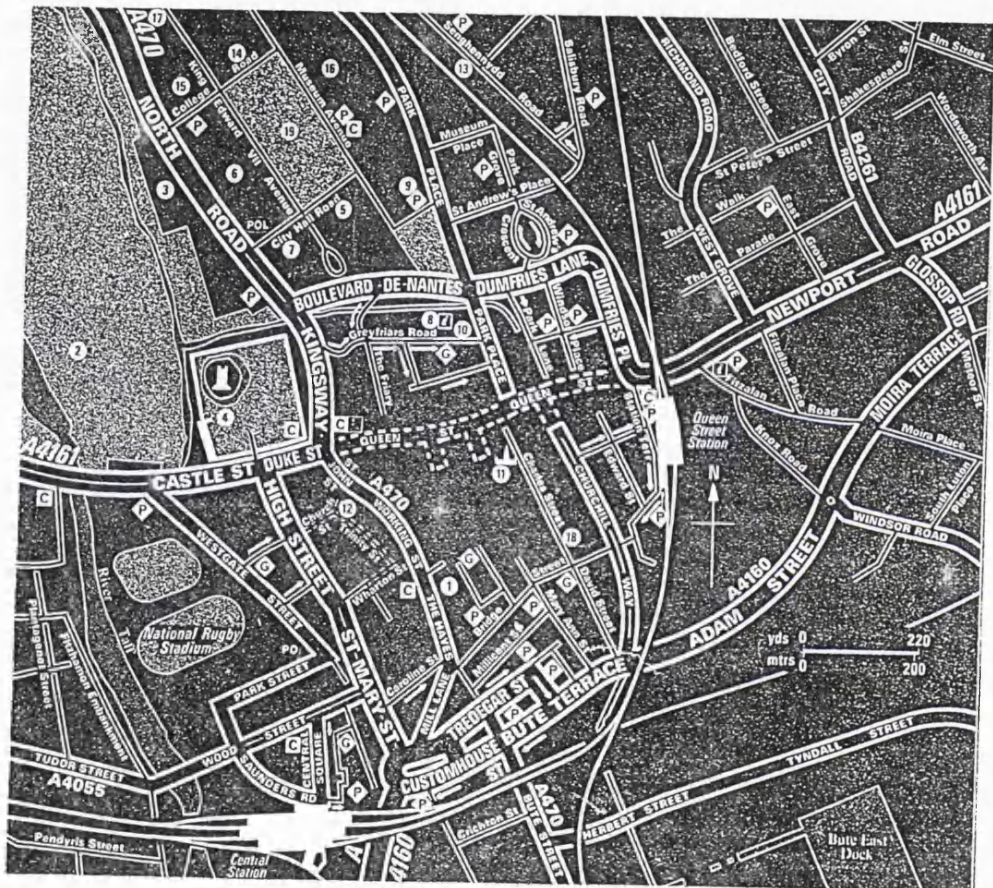


Figure 6.0-1 : Location plan



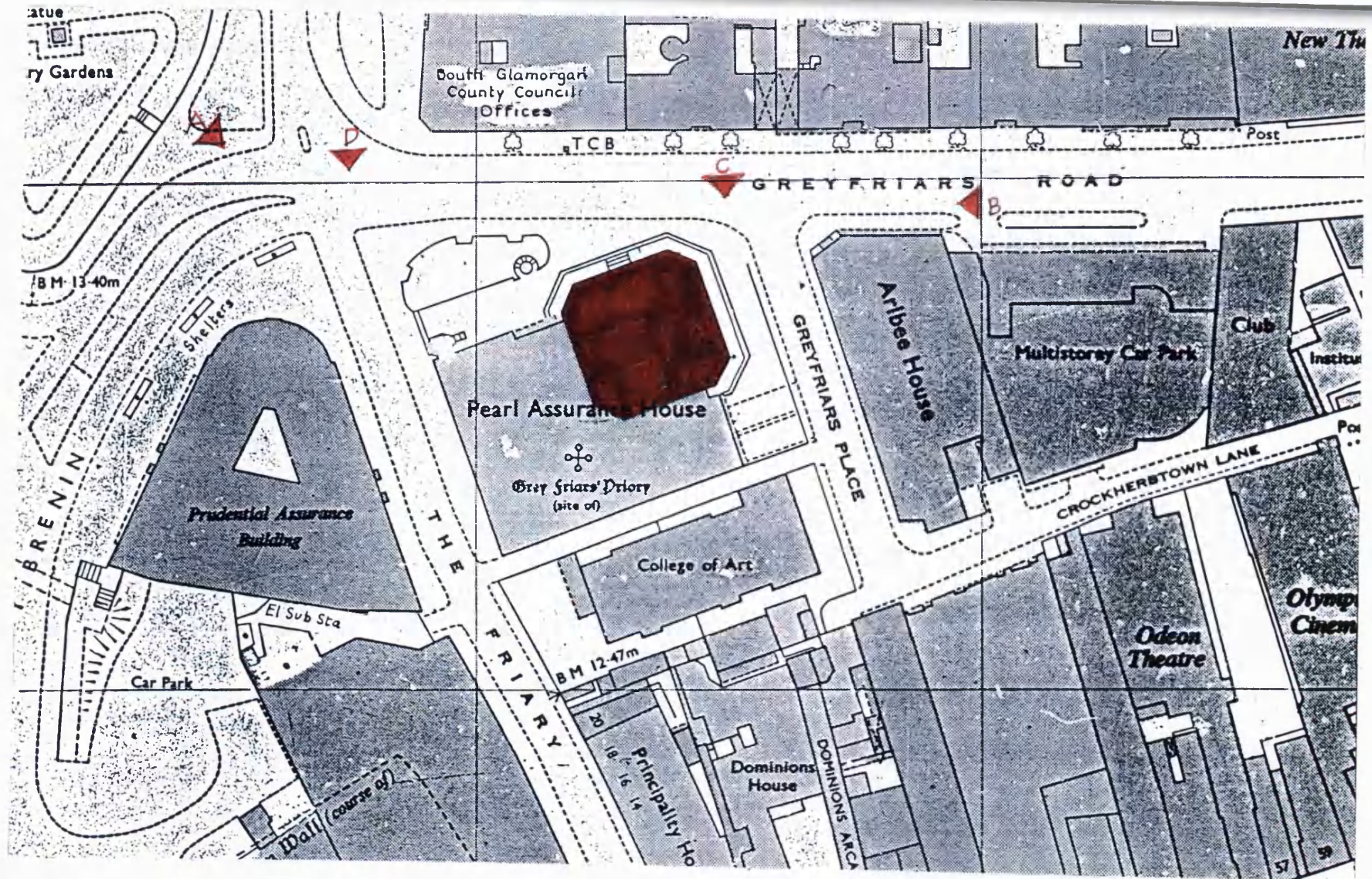


Figure 6.0-2 : Site plan and juxtaposition of adjacent buildings





View A



View B



View C



View D

Plate 6.0-1 : Photographs of Pearl Assurance Building and the buildings surrounding it.

Table 6.3a: sample job classification

		No of People	Female	Male
Job	Managerial	28	7	21
	Clerical	16	15	1
	Professional	32	17	15
	Technical	10	4	6
	Admin	29	20	9
	Others	7	6	1

Table 6.3b: Age and gender of sample

Age		16-19	20-29	30-39	40-49	50-65	unspec	Tot sample
Gender	male	1	14	13	18	6	1	53
	female	4	33	19	6	4	3	69
No of Sample		5	47	32	24	10	4	122

Table 6.3c: distribution of sample over the floors

Floor	No of Female	No of Male	No of workers
8	4	10	14
11	7	11	18
12	13	4	17
14	2	2	4
15	10	8	18
16	11	5	16
17	7	5	12
22	15	8	23
Total no of workers	69	53	122



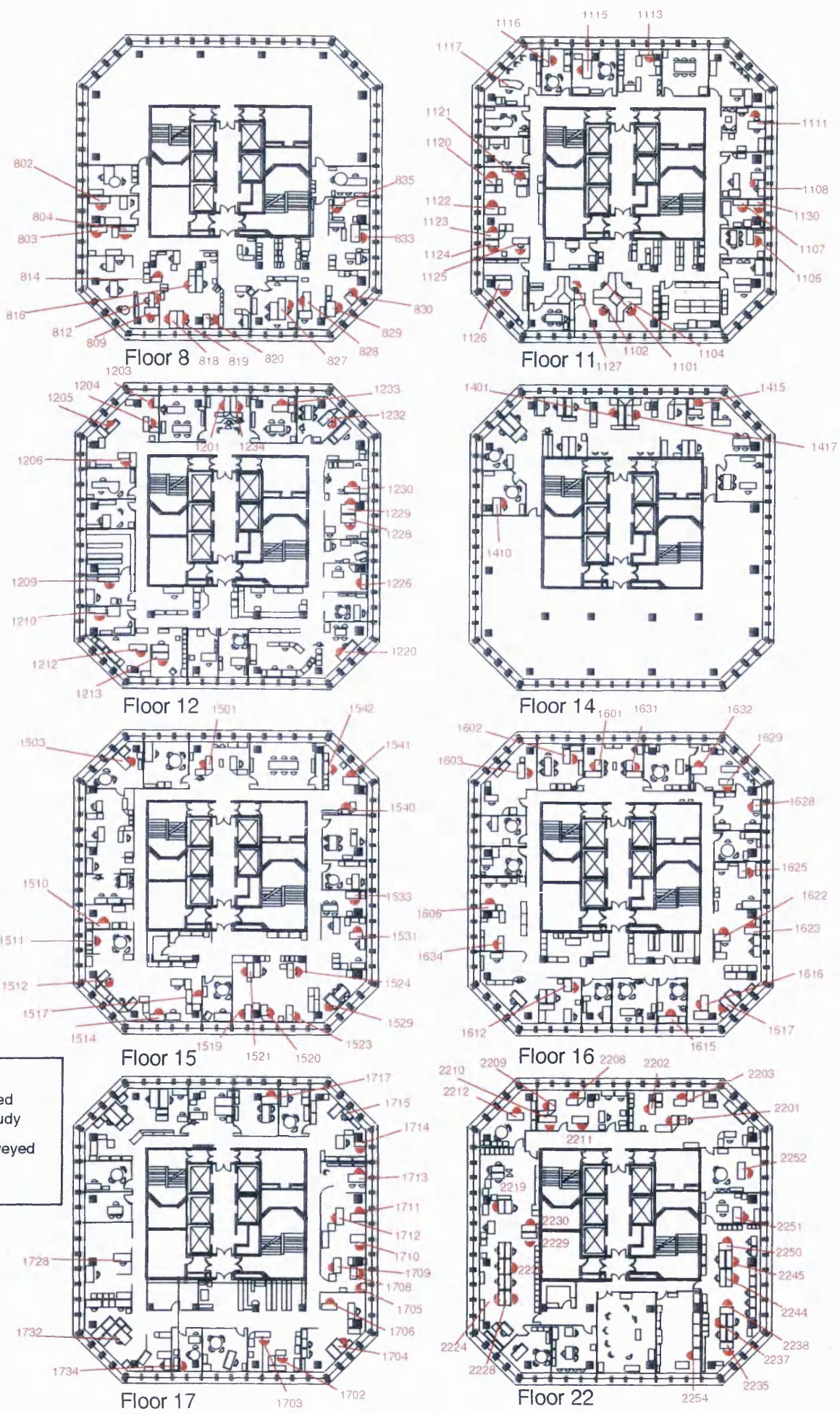


Figure 6.3 : The location of the 122 work positions used in the lighting study 38





Plate 6.3a : photographs of work positions





Plate 6.3b : photographs of work positions





Plate 6.3c : photographs of work positions









Plate 6.3e : photographs of work positions





Plate 6.3f : photographs of work positions

Figure 6.4.1a : Distribution of occurrence of eye symptom in the sample (as experienced by occupants)

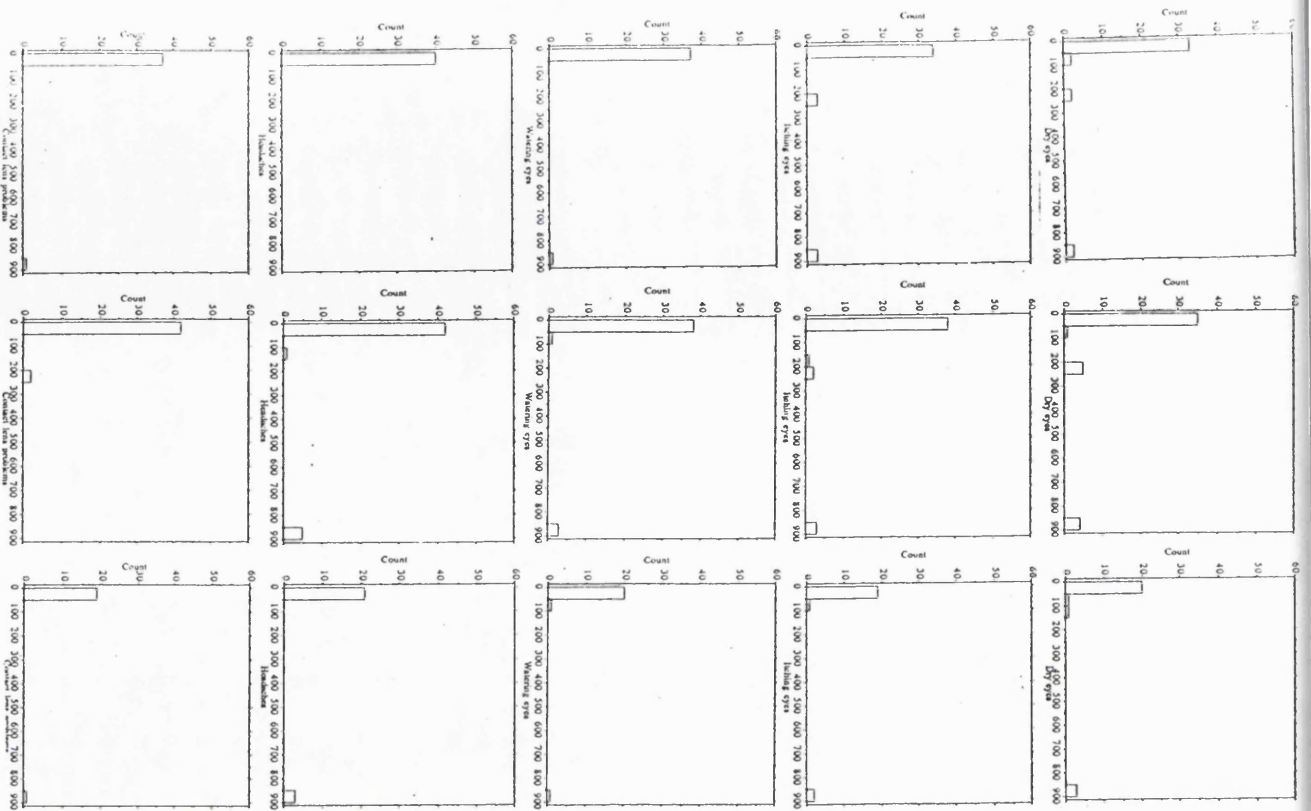
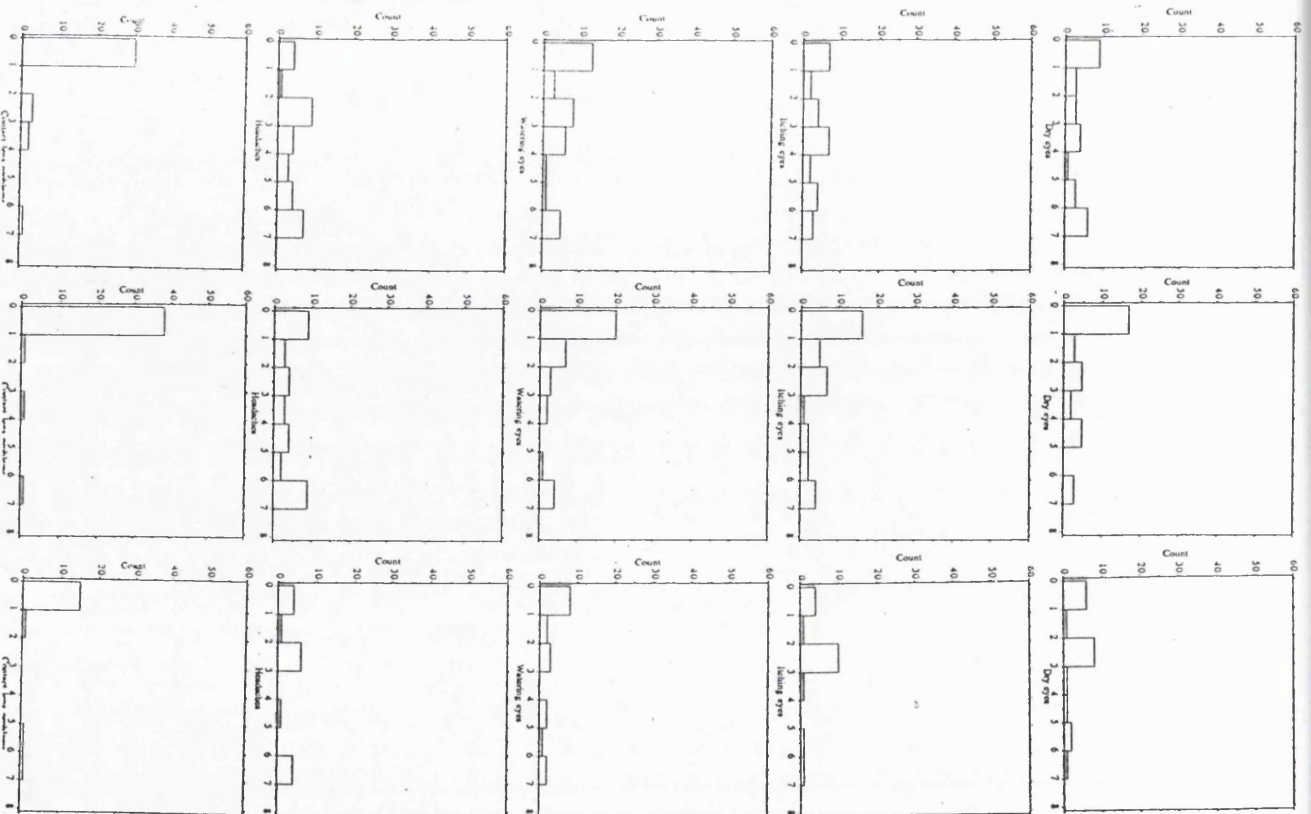


Figure 6.4.1b : Distribution of occurrence of eye symptom in the sample (range 0-50)





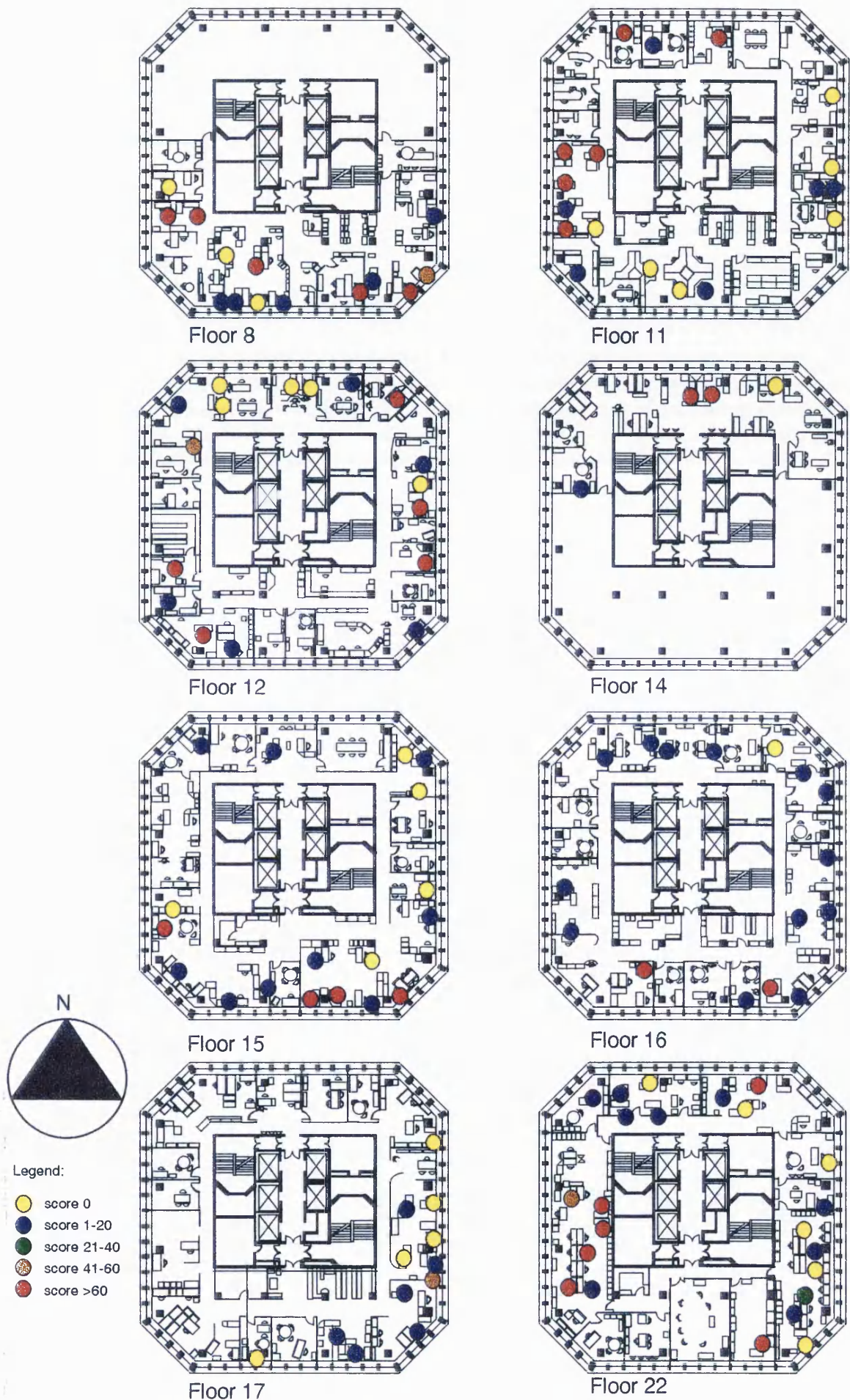
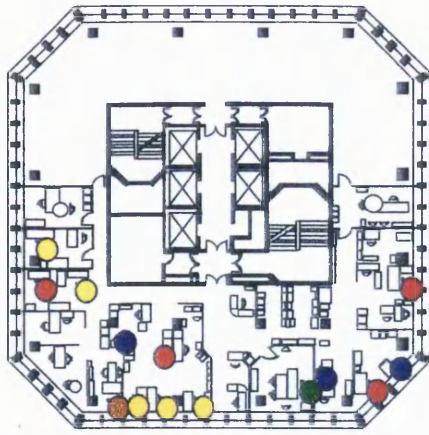
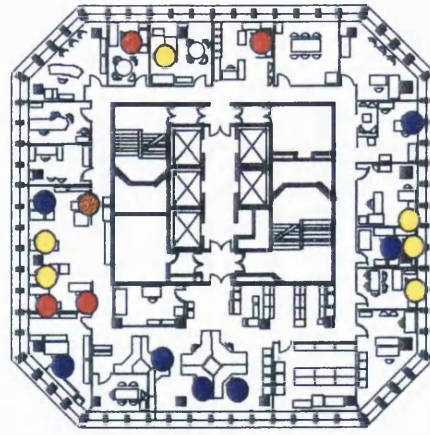


Figure 6.4.1c : Dry eyes occurrence distribution

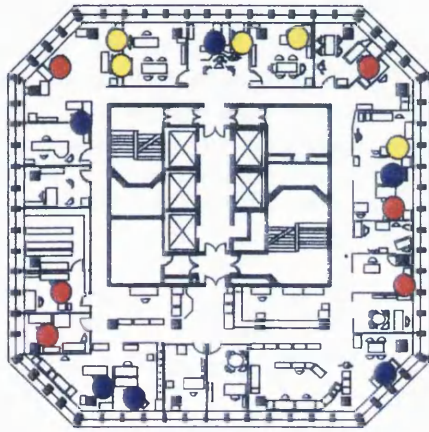




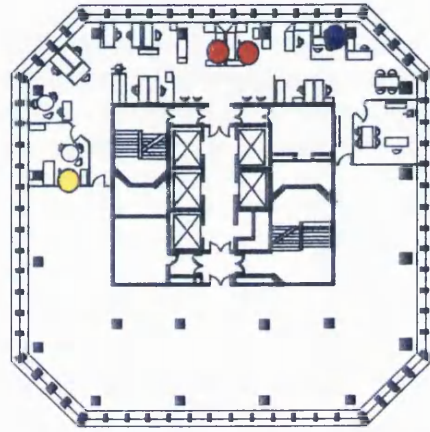
Floor 8



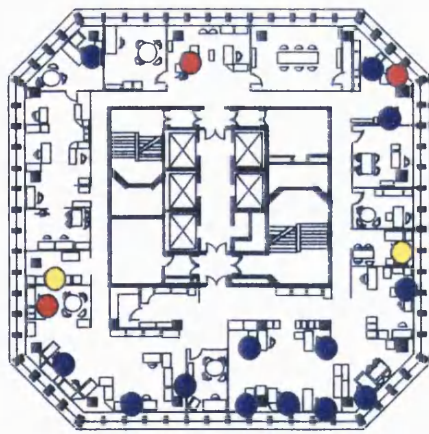
Floor 11



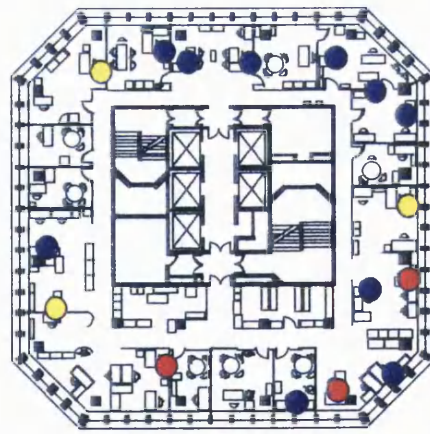
Floor 12



Floor 14



Floor 15

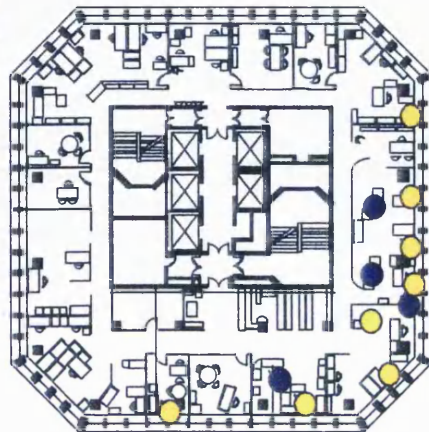


Floor 16

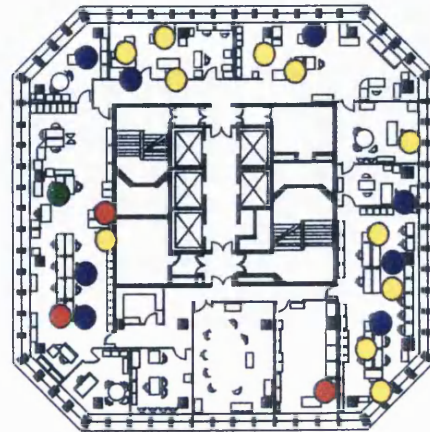


Legend:

- score 0
- score 1-20
- score 21-40
- score 41-60
- score >60



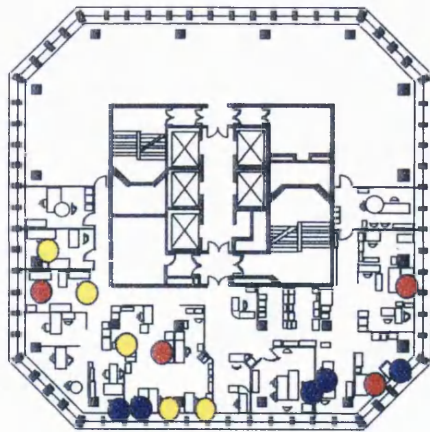
Floor 17



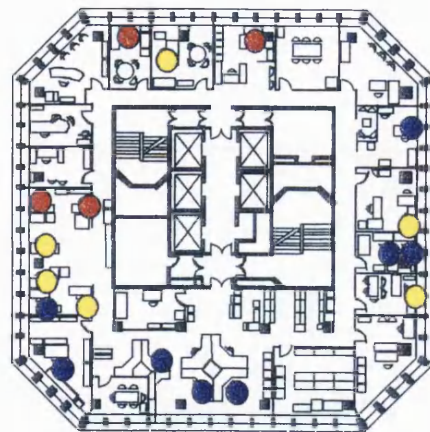
Floor 22

Figure 6.4.1d : Watering eyes occurrence distribution

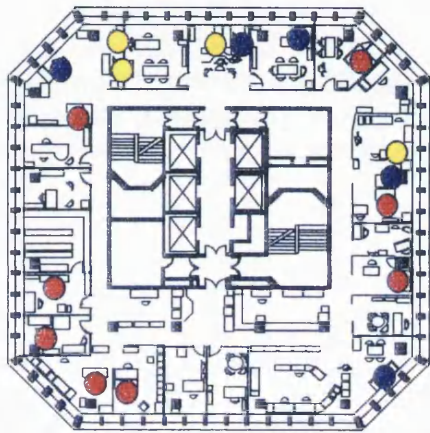




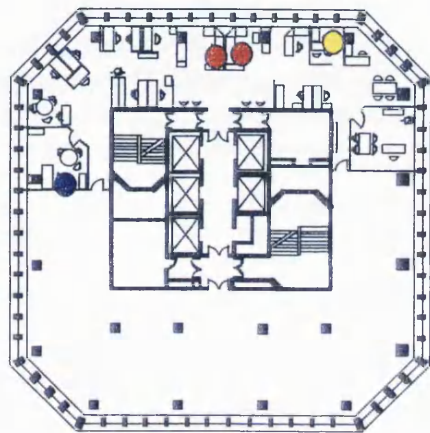
Floor 8



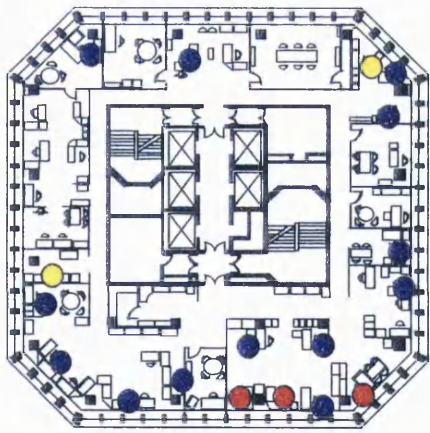
Floor 11



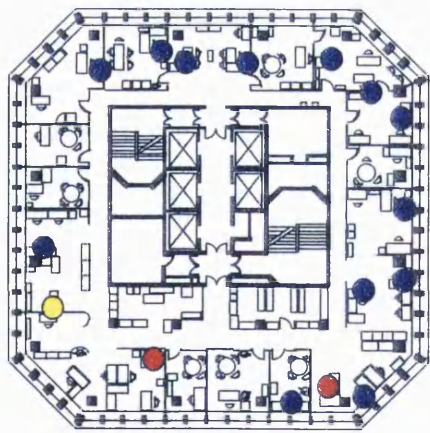
Floor 12



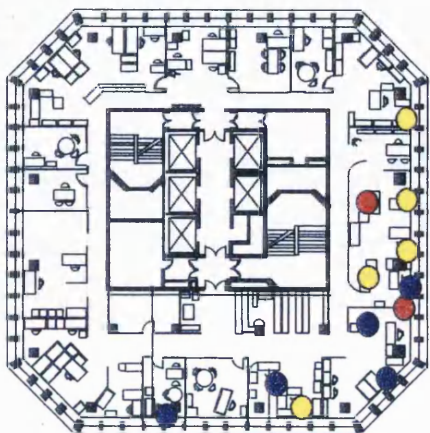
Floor 14



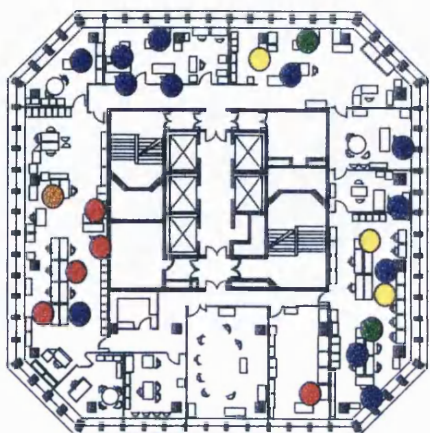
Floor 15



Floor 16



Floor 17



Floor 22

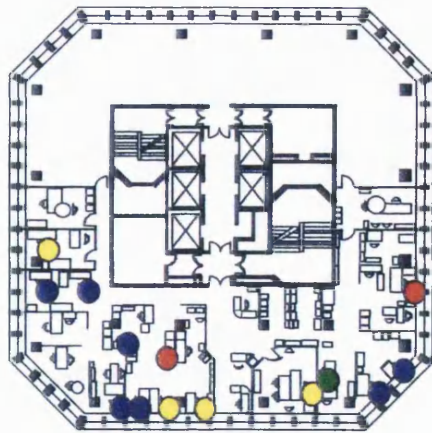


Legend:

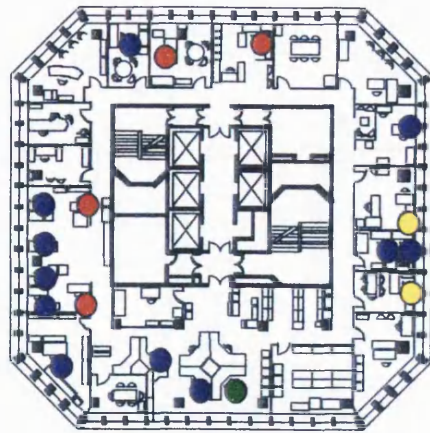
- score 0
- score 1-20
- score 21-40
- score 41-60
- score >60

Figure 6.4.1e : Itching Eyes occurrence distribution

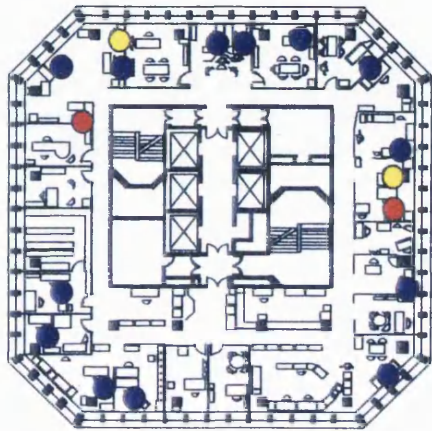




Floor 8

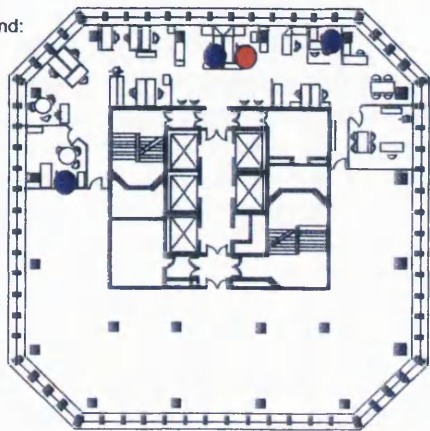


Floor 11

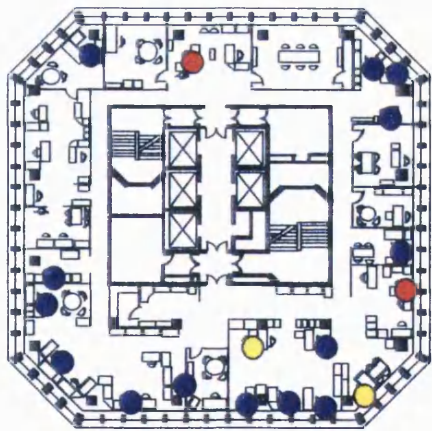


Floor 12

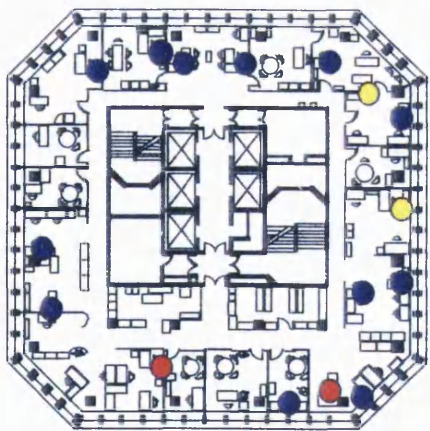
Legend:



Floor 14



Floor 15

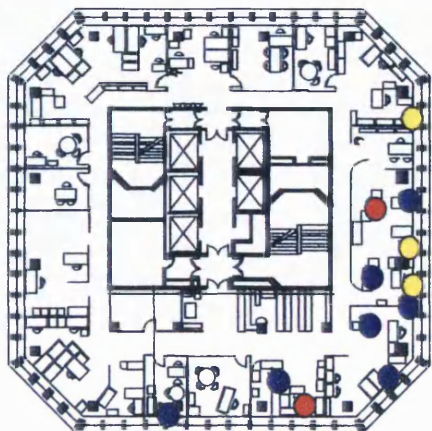


Floor 16

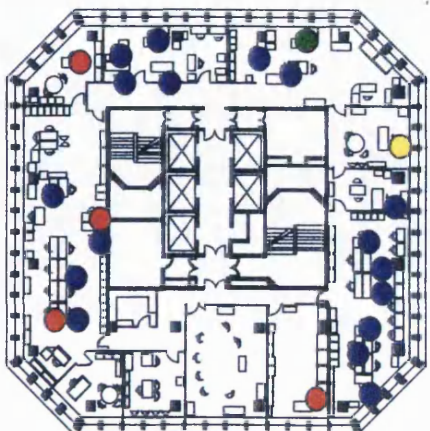


Legend:

- score 0
- score 1-20
- score 21-40
- score 41-60
- score >60



Floor 17



Floor 22

Figure 6.4.1f : Headaches occurrence distribution



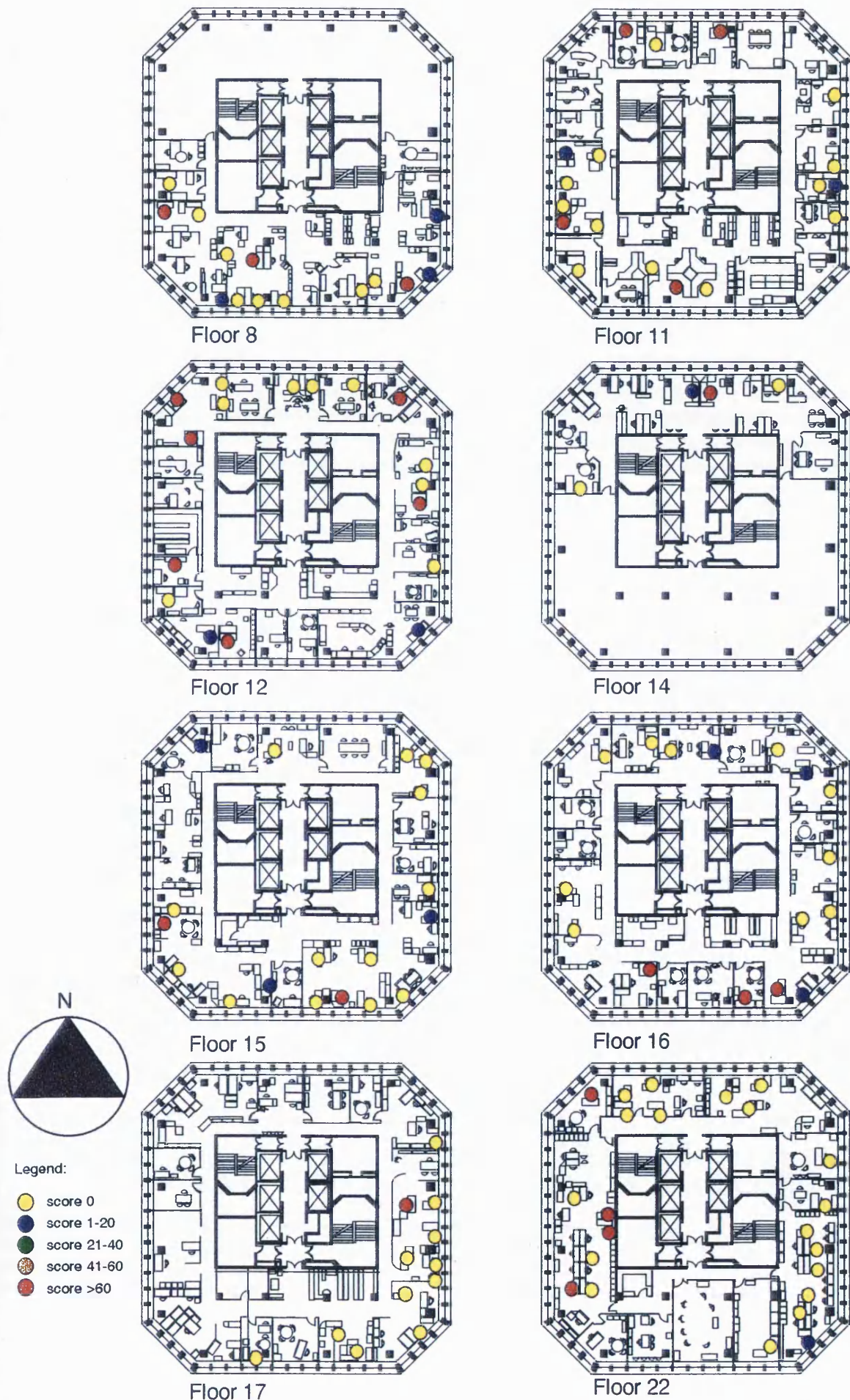


Figure 6.4.1g : occurrence of problem with wearing contact lenses distribution

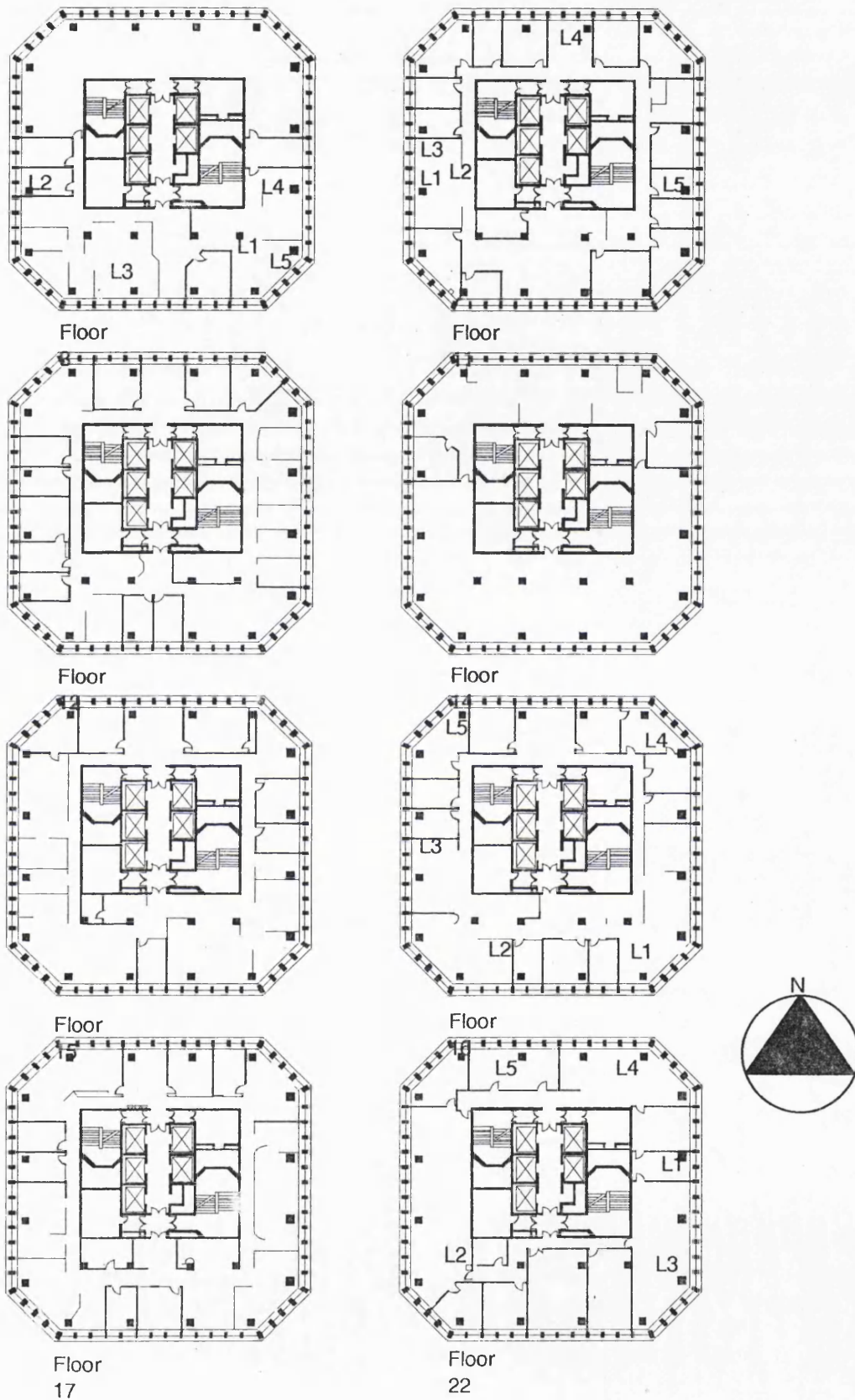


Figure 6.4.2: LINK Environmental Monitoring Locations



Table 6.4.2 : Measured thermal, relative humidity and pollutant levels

Floor	Light Cl	cluster	cluster(category)	logger	season	LmeanTemp	LmaxTemp	LMinTemp	LstdTemp	LRHmean	LRHmax	LRHmin	Vel 1.25m	Vel Grad
8	*	4.8	four81	4.080	Summer	22.9	26.4	19.8	.9	63.7	67.6	42.7	.066	2.3E-2
8	*	4.8	four81	4.080	Summer	22.9	26.4	19.8	.9	63.7	67.6	42.7	.111	3.6E-2
8	*	4.8	four82	*	Summer	-	-	-	-	-	-	-	.068	-1.0E-2
8	*	4.8	four82	*	Summer	-	-	-	-	-	-	-	.046	1.4E-2
11	*	*	*	4.113	Summer	23.6	26.2	19.8	1.1	63.7	67.6	42.7	-	-
11	*	*	*	4.111	Summer	23.2	26.2	19.8	.8	63.7	67.6	42.7	-	-
11	*	4.1	four112	4.112	Summer	23.0	33.0	19.0	1.1	63.7	67.6	42.7	.088	-.1
11	*	*	*	4.112	Summer	23.0	33.0	19.0	1.1	63.7	67.6	42.7	.077	3.8E-2
11	*	*	*	4.113	Summer	23.6	26.2	19.8	1.1	63.7	67.6	42.7	-	-
12	*	*	*	4.121	Summer	22.3	27.6	18.4	1.4	63.7	67.6	42.7	-	-
12	*	*	*	4.122	Summer	22.8	26.4	18.4	1.0	63.7	67.6	42.7	-	-
14	*	*	*	4.142	Summer	21.6	26.8	18.0	1.3	63.7	67.6	42.7	-	-
16	*	*	*	4.162	Summer	22.9	26.0	19.6	1.1	63.7	67.6	42.7	-	-
16	*	*	*	4.161	Summer	22.1	26.0	19.6	.9	63.7	67.6	42.7	-	-
16	*	4.2	four162	*	Summer	-	-	-	-	-	-	-	.049	.1
16	*	*	*	4.162	Summer	23.2	26.8	18.8	1.2	63.7	67.6	42.7	-	-
16	*	4.2	four161	*	Summer	-	-	-	-	-	-	-	.068	-3.0E-2
16	*	*	*	4.161	Summer	22.2	24.2	19.2	.8	63.7	67.6	42.7	-	-
16	*	4.2	four161	*	Summer	-	-	-	-	-	-	-	.051	2.8E-2
17	*	*	*	4.172	Summer	24.2	26.8	20.2	.9	63.7	67.6	42.7	-	-
22	*	*	*	4.221	Summer	22.4	26.0	18.8	.9	63.7	67.6	42.7	-	-
22	*	4.2	four222	4.222	Summer	20.4	28.0	19.8	1.2	63.7	67.6	42.7	.063	.1
22	*	4.2	four222	4.222	Summer	20.4	28.0	19.8	1.2	63.7	67.6	42.7	.084	3.2E-2
22	*	4.2	four221	*	Summer	-	-	-	-	-	-	-	.144	-4.6E-2
22	*	4.2	four221	*	Summer	-	-	-	-	-	-	-	.107	1.3E-2

Floor	cluster	cluster(category)	logger	season	Cluster CO2 room mean	Cluster CO2 room max	Cluster CO2 room min	Cluster CO2 room std	Cluster formaldehyde mean	Cluster formaldehyde max	Cluster formaldehyde min	Cluster CO mean	Cluster CO max	Cluster CO min
8	4.8	four81	4.080	Summer	491.8	621.1	368.8	48.3	.1	.1	.1	3	1.6	.2
8	4.8	four82	*	Summer	636.9	776.0	362.7	79.3	.1	.1	.1	4	1.8	.2
11	4.1	four111	*	Summer	-	-	-	-	.1	.1	.1	2	1.1	.2
11	4.1	four112	4.112	Summer	480.6	612.4	352.8	61.4	.2	9.1	.1	2	9	.2
11	4.1	four111	*	Summer	-	-	-	-	.1	.1	.1	2	1.1	.2
16	4.2	four162	*	Summer	463.3	629.8	334.0	64.6	.1	.1	.1	2	9	.2
16	4.2	four161	*	Summer	493.6	609.6	337.0	60.4	.1	.1	.1	2	1.1	.2
16	4.2	four161	*	Summer	493.6	609.6	337.0	60.4	.1	.1	.1	2	1.1	.2
16	4.2	four162	*	Summer	463.3	629.8	334.0	64.6	.1	.1	.1	2	9	.2
22	4.2	four222	4.222	Summer	482.1	699.8	355.2	47.8	.1	.1	.1	2	1.1	.2

Floor	cluster	cluster(category)	logger	season	Cluster TVOC mean	Cluster TVOC max	Cluster TVOC min	Cluster dust mite/g	Cluster antigen ng/g	Cluster shell factor	Cluster feces factor	Cluster respirable dust mg/m3	Cluster max particle size micron
8	4.8	four81	4.080	Summer	.1	3.8	.1	0.0	-	.3	.7	2.0E-2	60.0
8	4.8	four82	*	Summer	.2	14.7	.1	-	-	260.0	.1	2.0E-2	-
11	4.1	four111	*	Summer	.2	7.8	.1	0.0	-	.3	.6	2.0E-2	-
11	4.1	four112	4.112	Summer	20.1	728.0	.1	-	-	260.0	.3	1.6E-2	60.0
11	4.1	four111	*	Summer	.2	7.8	.1	0.0	-	.3	.6	2.0E-2	-
16	4.2	four162	*	Summer	.1	4.0	.1	0.0	-	.3	.6	4.0E-2	25.0
16	4.2	four161	*	Summer	.1	16.2	.1	-	-	260.0	.3	2.0E-2	26.0
16	4.2	four161	*	Summer	.1	16.2	.1	-	-	260.0	.3	2.0E-2	26.0
16	4.2	four162	*	Summer	.1	4.0	.1	0.0	-	.3	.6	4.0E-2	26.0
22	4.2	four222	4.222	Summer	.1	.1	.1	6.0	-	2	.6	3.0E-2	26.0

Figure 6.4.3a : Distribution of Occupants assessments of Appearance of Work position

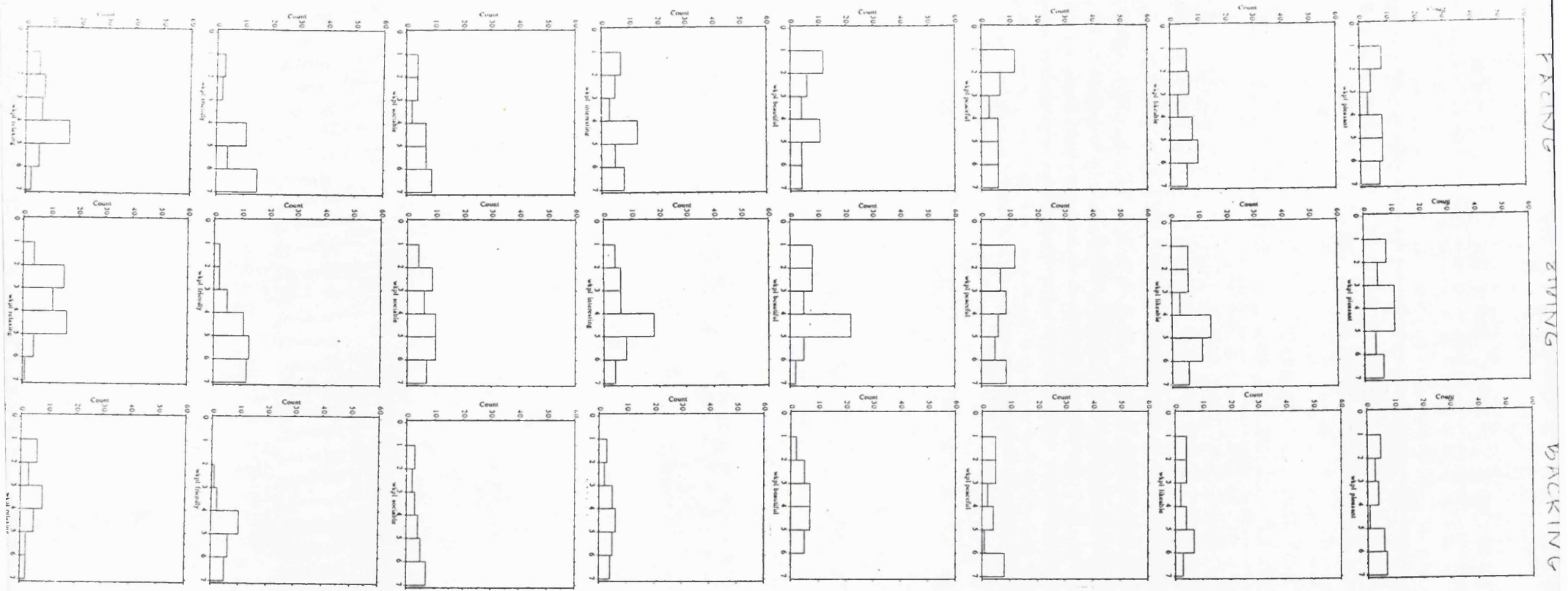


Figure 6.4.3b : Distribution of Occupants assessments of Appearance of Work position

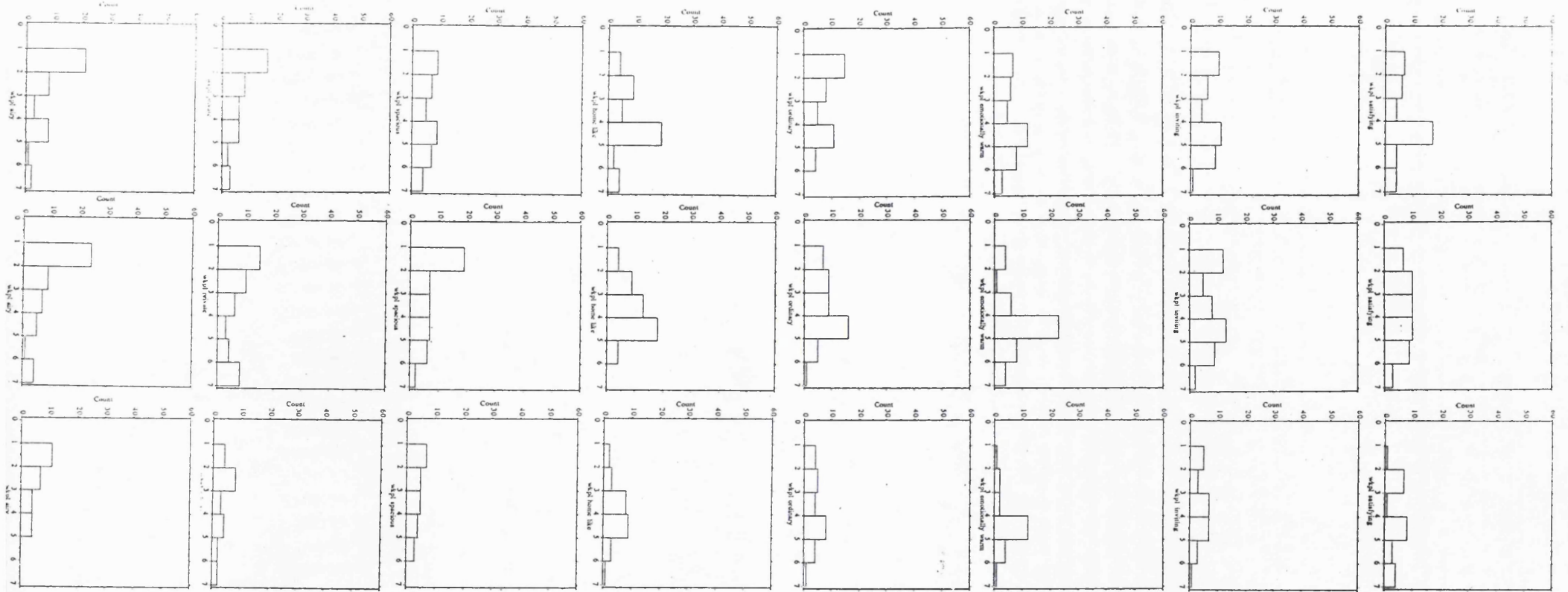


Figure 6.4.3c : Distribution of Occupants assessments of Appearance of Work position

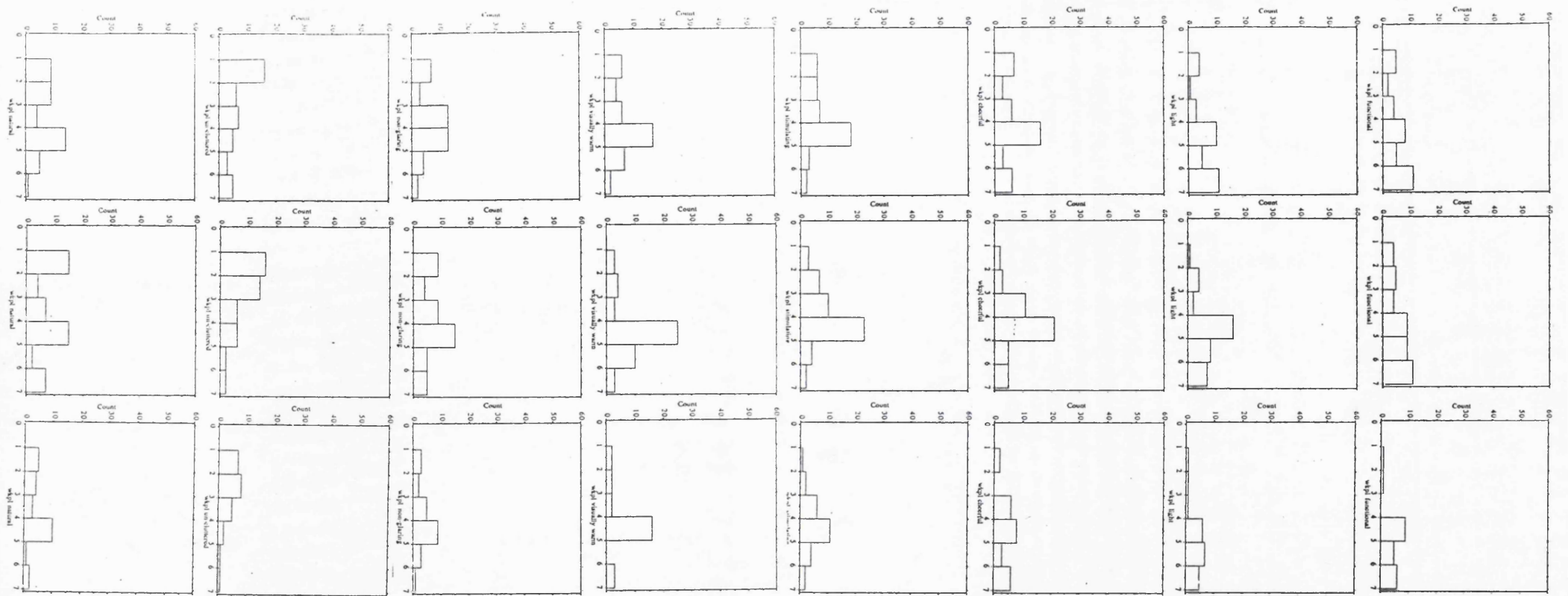
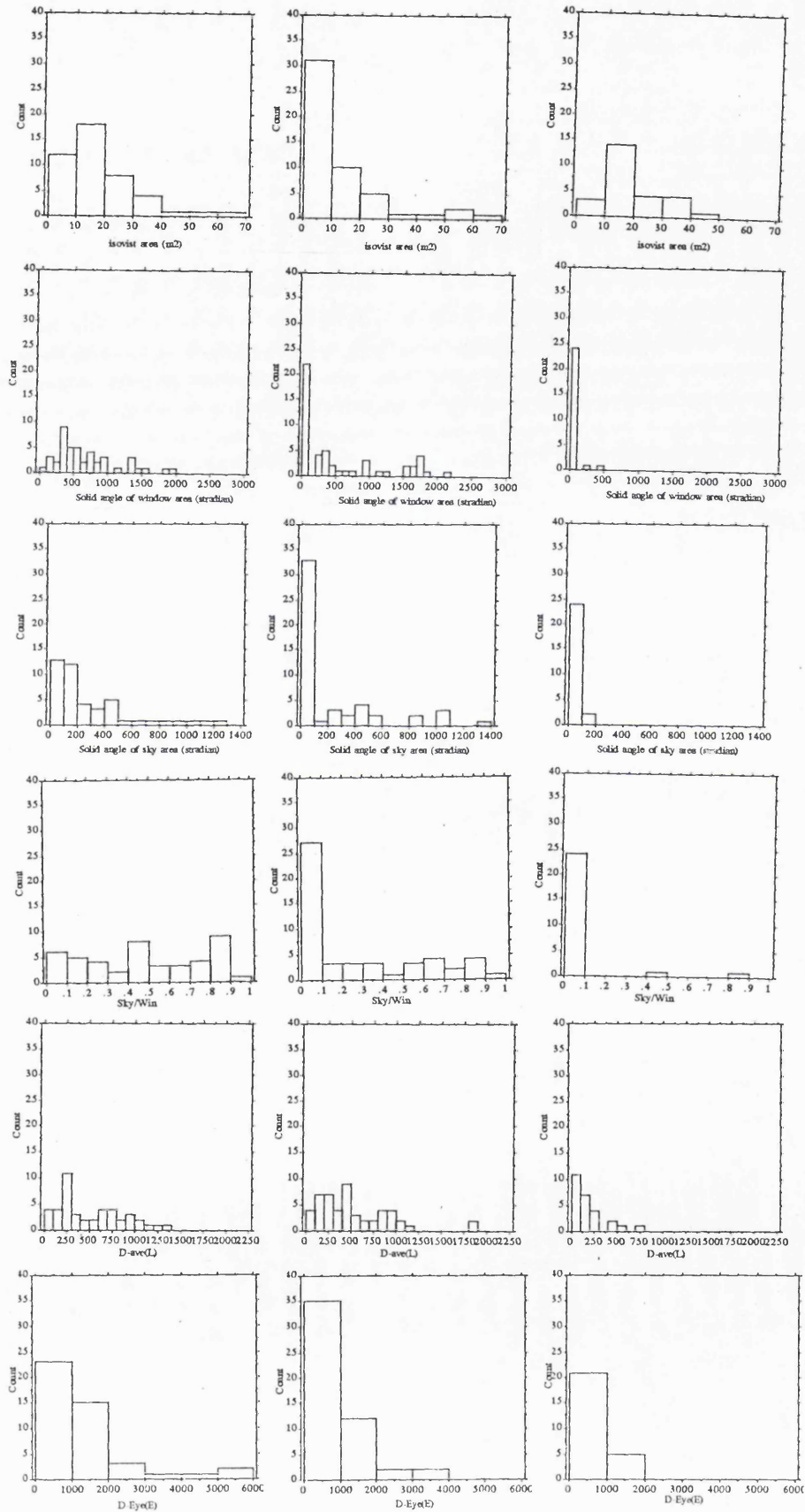


Table 6.4.4: The range of the measured physical light attributes for the group

SUBJECTIVE QUALITY	Range of Physical measurements		
	Facing Windows	Siding Windows	Backing Windows
Isoarea (IA)	0.96-61.5	0.24-65.57	1.24-46.84
Win solid <	52.4-2824	0-2183.5	0-498.9
Blind solid<			
Sky solid <	0-1200	0-1341	0-188.15
Sky/Win	0-0.9	0-0.9	0-0.8
D ave(L)	24-2200	49-1890	45-771
D WT(E)	157-8640	117-20000	129-3930
Deve(E)	167-5520	99-3800	104-1359
Dmax(L)	96-21630	46.3-15040	136.1-2603
Dmin(L)	1-35.9	0.7-59.6	0.7-41
Dmax/min	48.9-2785.7	4.9-2400	12.7-2124.4



Figure 6.4.4a : The distribution of the measured physical light attributes for the group



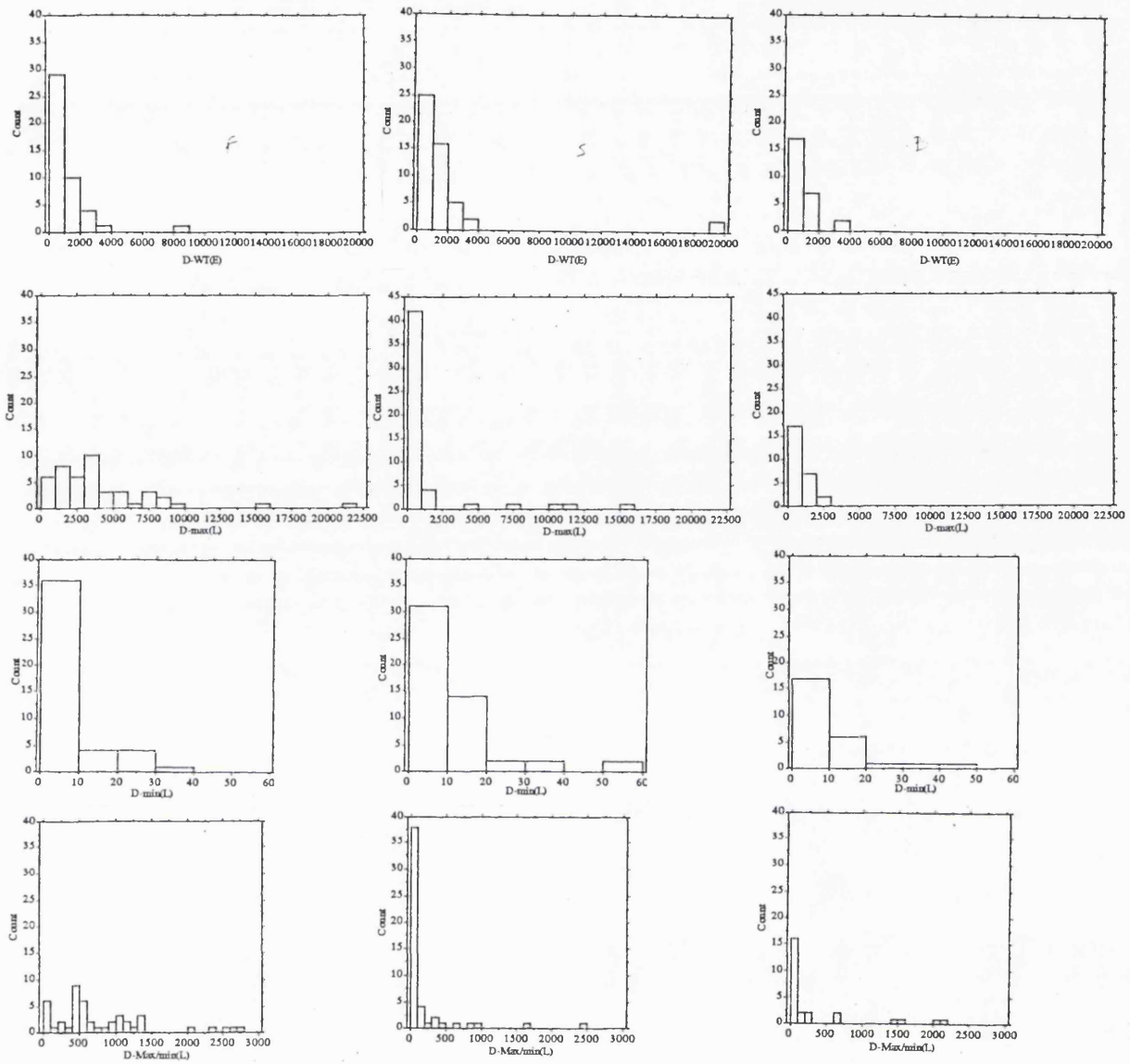


Figure 6.4.4b : The distribution of the measured physical light attributes for the group

Table 6.6a: Difference of symptom occurrence with respect to occupants Location

no of occupants	Kruscal-Wallis Analysis		Mean Comparison					
			45		51		26	
	Symptom	Seat orientation wrt window	Facing Window		Siding Window		Backing Window	
H			p	Mean	STD	Mean	STD	Mean
Dry Eyes	1.50	0.47	63.1	200.4	105.8	256.5	114.2	292.4
Itching Eyes	5.34	0.07	86.7	238.1	76.0	227.9	85.9	259.8
Watering Eyes	1.55	0.46	25.4	143.7	66.5	230.8	46.6	188.4
Headaches	0.34	0.84	5.3	4.8	99.0	272.3	117.4	297.7
Contact Lense Prob	1.33	0.52	24.4	143.9	10.5	46.3	46.0	198.2

N.B: H indicated is corrected for ties

Table 6.6b: Comparison of Occupants Perception of Work Position Appearance between Seat Orientation

No of Occupants	Kruscal-Wallis Analysis		Mean Comparison					
			45		51		26	
	SUBJECTIVE QUALITY	Seat orientation wrt window	Facing Window		Siding Window		Backing Window	
H			p	Mean	STD	Mean	STD	Mean
Pleasant	0.61	0.74	4.1	2.0	3.7	1.9	3.8	0.9
Likeable	0.25	0.88	3.9	1.9	4.0	1.8	3.8	1.8
Peaceful	0.62	0.73	3.4	2.1	3.4	1.9	3.7	2.1
Beautiful	0.52	0.77	3.1	1.8	3.3	1.4	3.3	1.2
Interesting	0.02	0.99	3.8	1.8	3.9	1.6	3.9	1.7
Sociable	3.89	0.14	4.8	2.0	4.1	1.8	4.3	1.8
Friendly	2.73	0.26	5.1	1.7	4.7	1.5	4.6	1.2
Relaxing	2.46	0.29	3.5	1.5	3.1	1.2	3.0	1.5
Satisfying	2.66	0.26	3.5	1.6	3.3	1.5	3.9	1.7
Inviting	0.32	0.85	3.3	1.7	3.2	1.6	3.1	1.4
Emotionally warm	2.74	0.25	3.6	1.7	4.1	1.4	4.2	1.5
Ordinary	<b>6.06</b>	<b>0.05</b>	2.6	1.4	3.3	1.6	3.2	1.4
Homelike	0.52	0.77	3.4	1.4	3.3	1.2	3.4	1.2
Spacious	2.87	0.24	3.4	1.8	2.8	1.9	2.9	1.8
Private	2.51	0.28	2.7	1.8	3.1	2.1	3.4	2.0
Airy	0.00	1.00	2.2	1.5	2.2	1.6	2.0	1.1
Functional	0.32	0.85	4.6	1.9	4.6	1.8	4.9	1.5
Light	0.04	0.98	4.9	1.8	4.9	1.6	5.0	1.5
Cheerful	1.44	0.49	3.7	1.7	4.0	1.4	4.2	1.5
Stimulating	2.31	0.32	3.3	1.3	3.6	1.2	3.8	1.1
Visually Warm	2.85	0.24	3.6	1.5	4.0	1.3	3.7	1.3
Non-glaring	1.18	0.55	3.4	1.5	3.6	1.7	3.8	1.7
Colourful	3.64	0.16	2.8	1.6	3.2	1.6	3.4	1.2
Quiet	0.27	0.87	3.0	1.7	3.1	1.7	3.2	1.8
Hot	0.76	0.68	5.4	1.4	5.4	1.5	5.1	1.7
Clean	2.77	0.25	3.5	1.9	4.0	1.7	4.2	1.4
Cluttered	0.15	0.93	2.8	1.8	2.6	1.7	2.7	1.8
Natural	0.25	0.89	3.1	1.6	3.1	1.7	3.3	1.7
Sat charac & atmosph								
Sat visual appearance								

N.B: The higher the mean the better the subjective assessment

Table 6.6c: Comparison of Measured Lighting Variables between Seat Orientation

SUBJECTIVE QUALITY	Kruscal-Wallis Analysis		Mean Comparison					
	Seat orientation wrt window		45		51		26	
			Facing Window		Siding Window		Backing Window	
H	p	Mean	STD	Mean	STD	Mean	STD	
Isoarea (IA)	13.8	0.001	17.2	13.7	12.4	15.2	18.9	10.4
Win solid <	42.7	0.0001	733.2	558.5	549.7	677.2	27.4	104.9
Sky solid <	39.9	0.0001	307.6	317.3	214.4	343.5	13.8	48.9
Sky/Win	34.7	0.0001	0.4	0.3	0.2	0.3	0.1	0.17
D ave(L)	21.2	0.0001	549.5	437.6	528.8	405.7	200.6	181.5
D WT(E)	4.3	0.11	1102.8	1350.5	2214.0	4456.7	986.7	937.8
Deye(E)	15.4	0.0004	1242.2	1184.6	953.9	767.3	493.5	369.5
Dmax(L)	43.7	0.0001	4164.9	4048.0	1382.2	3034.6	858.6	689.6
Dmin(L)	4.0	0.13	7.3	7.4	11.0	12.0	0.1	10.7
Dmax/min	44.6	0.0001	815.2	699.4	197.7	429.9	383.5	638.0

N.B: H indicated is corrected for ties

## **Chapter 7: Case Study 2**

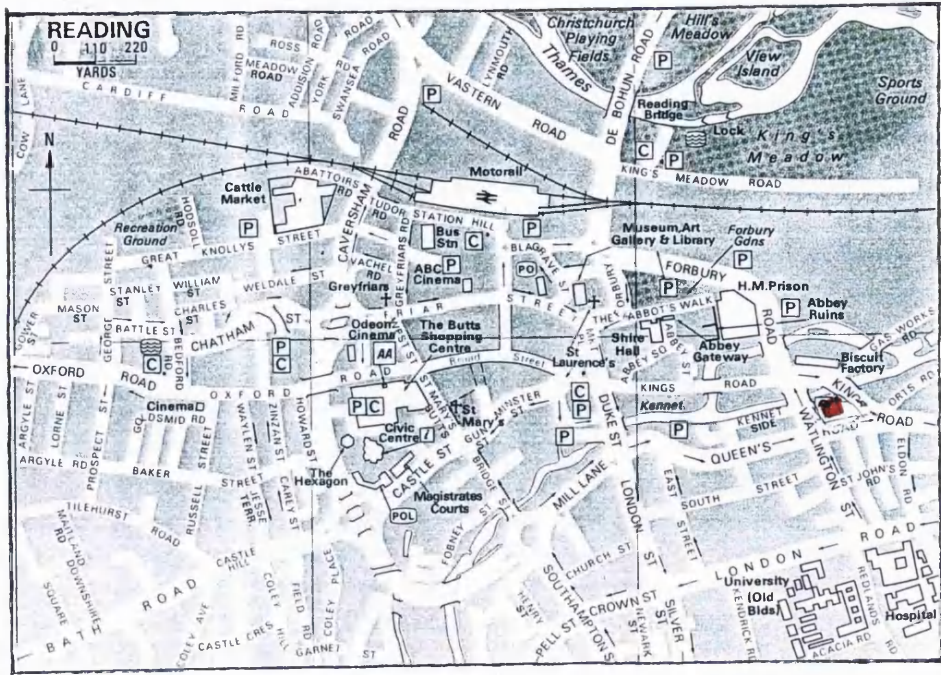


Figure 7.0-1 : Location plan

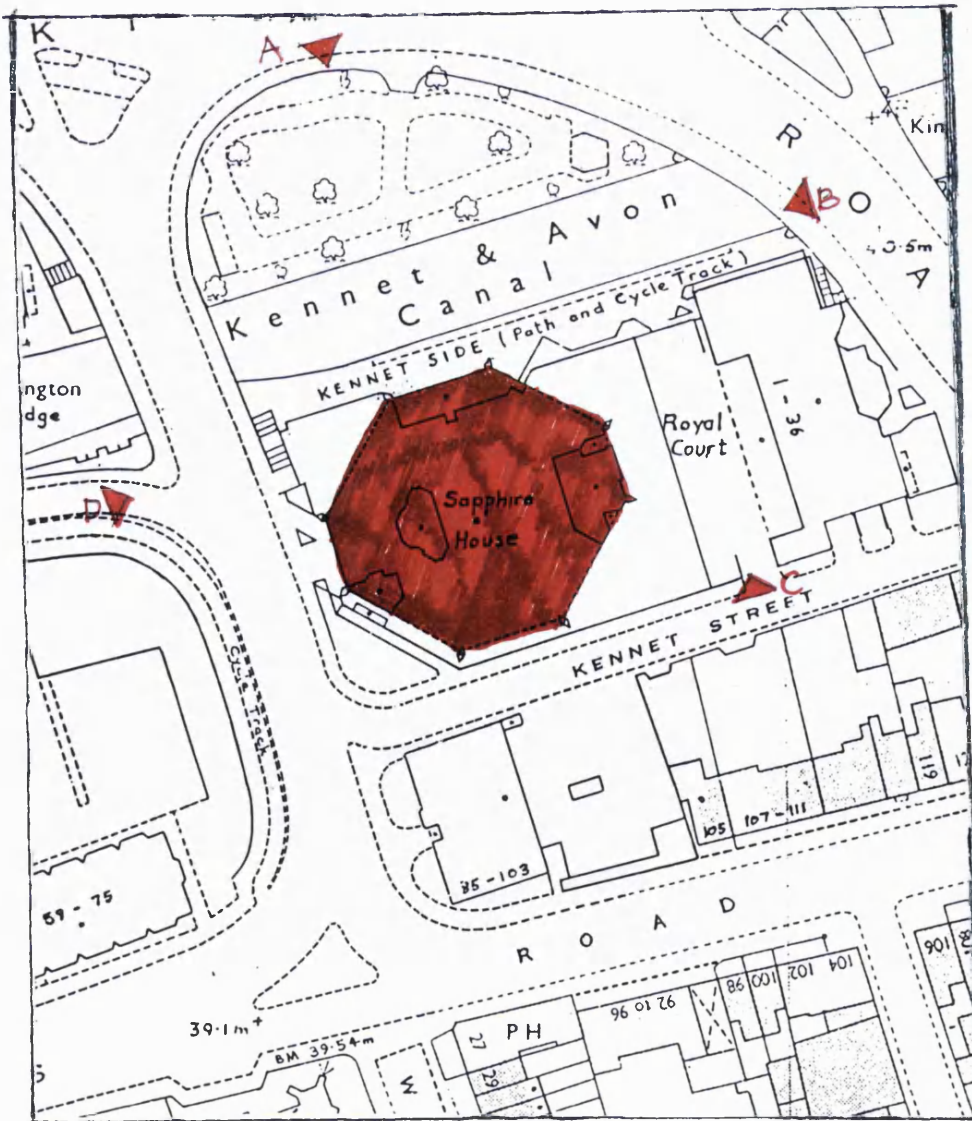
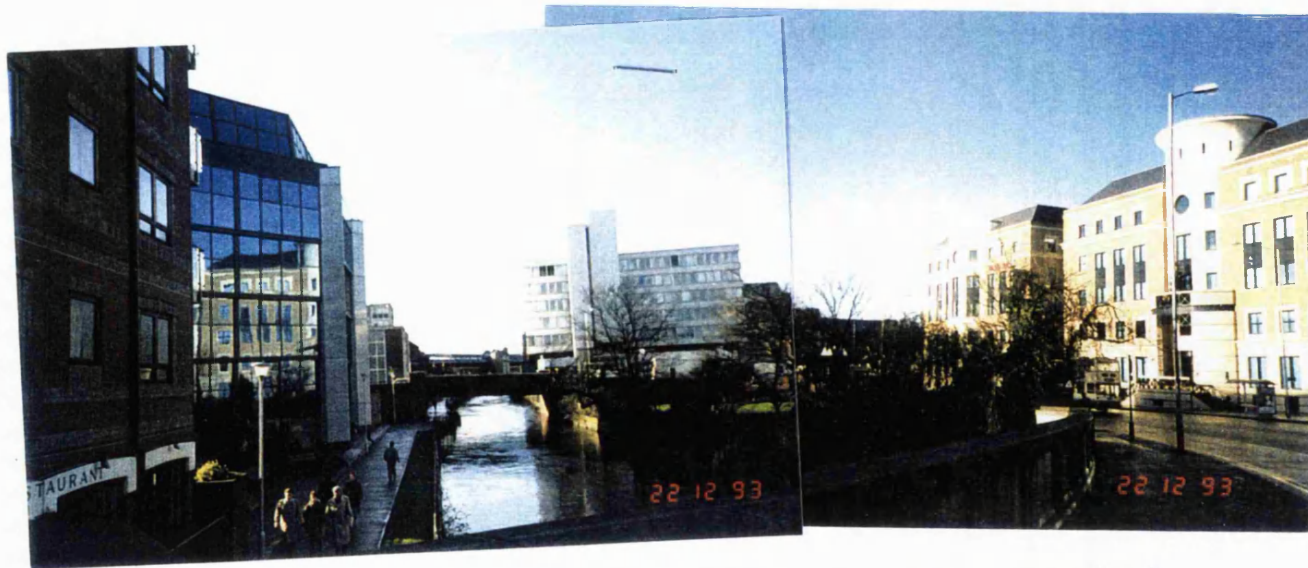


Figure 7.0-2 : Site plan and juxtaposition of adjacent buildings





View A



View B

Plate 7.0-1 : Photographs of Sapphire Building and the buildings surrounding it.

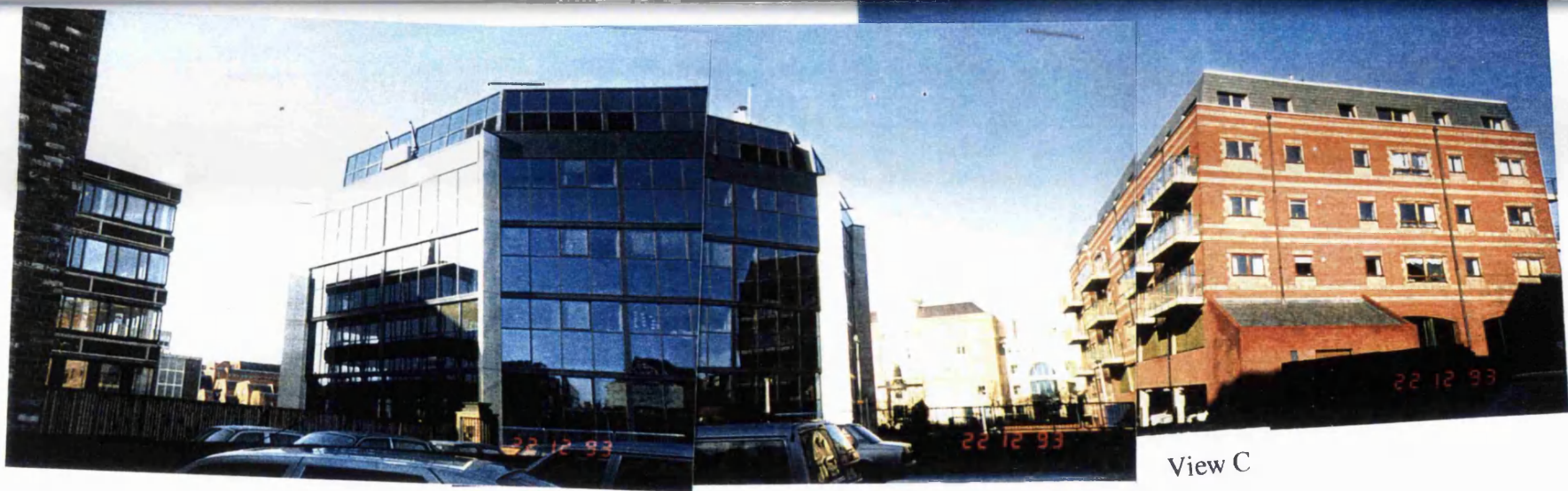


Plate 7.0-2 : Photographs of Sapphire Building and the buildings surrounding it.



**Table 7.3a: sample job classification**

Job category	No of People	Female	Male
Managerial	14	9	5
Clerical	64	47	17
Professional	10	5	5
Technical	20	5	15
Admin	5	2	3
Others	1	1	0

**Table 7.3b: Age and gender of sample**

Age			16-19	20-29	30-39	40-49	50-65	unspec
Gender	male	47	0	5	20	14	8	0
	female	85	1	21	18	19	26	0
No Sample		132	1	26	38	33	34	0

**Table 7.3c: Distribution of sample over the floors**

Floor	No of Female	No of Male	No of workers
0	31	13	44
1	20	13	33
2	18	8	26
3	11	10	21
4	5	3	8
Total no of workers	85	47	132

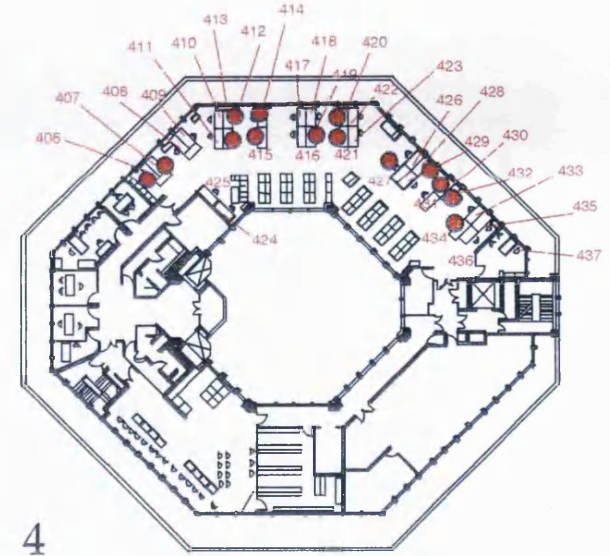
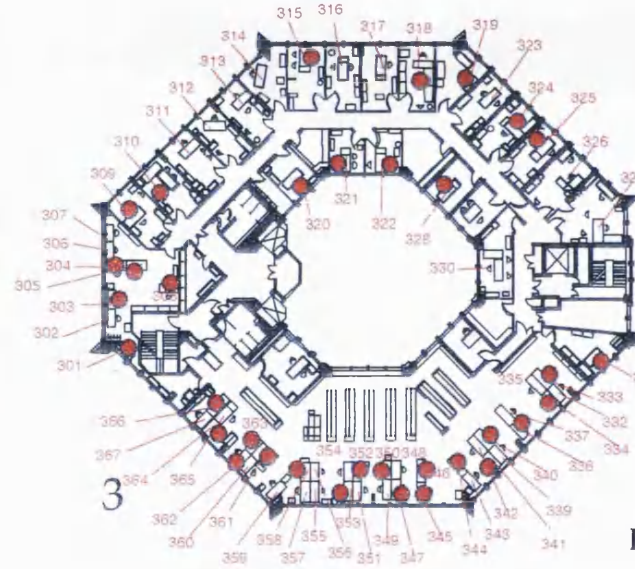
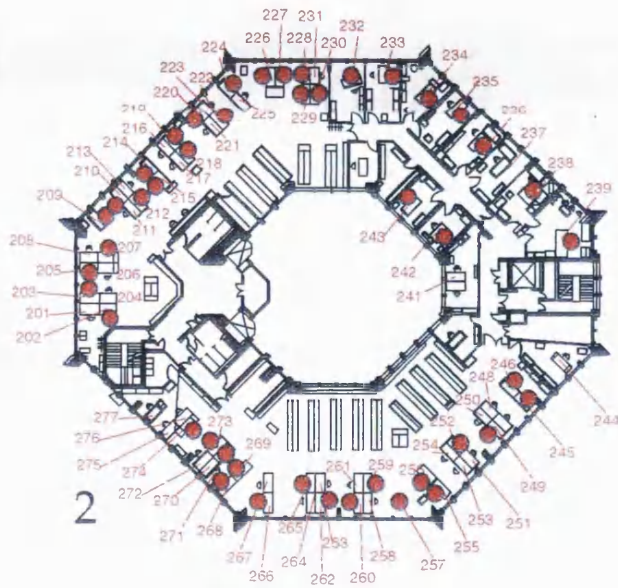
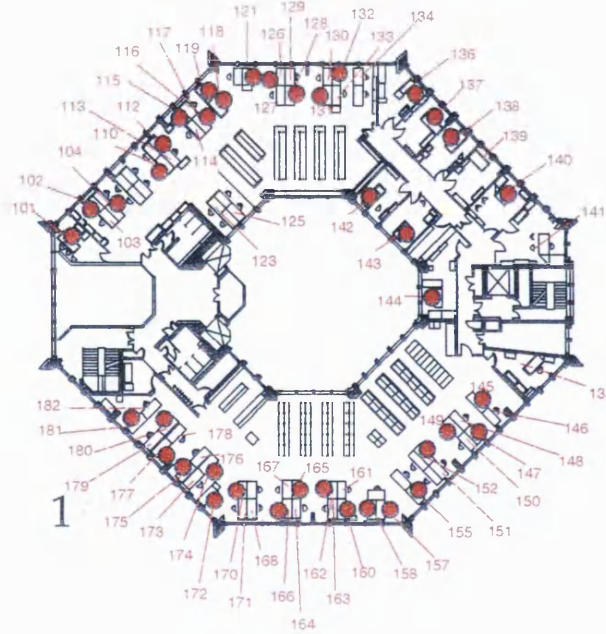
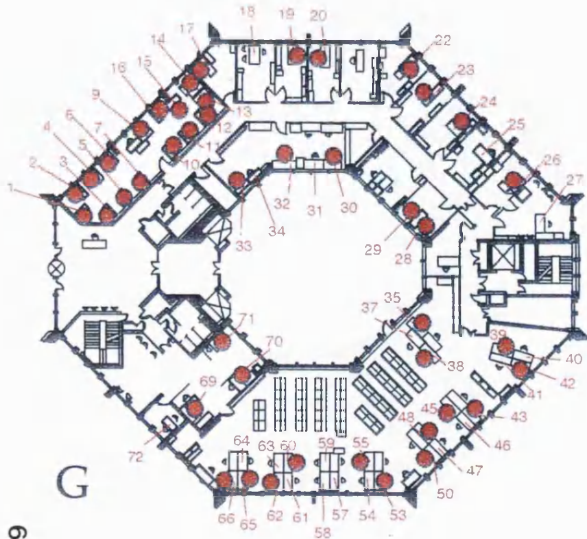


Figure 7.3 : The location of the 132 work positions used in the lighting study and positions surveyed by LINK



Legend:



-  positions used in lighting study
-  positions surveyed by LINK





Plate 7.3(a) : photographs of work positions

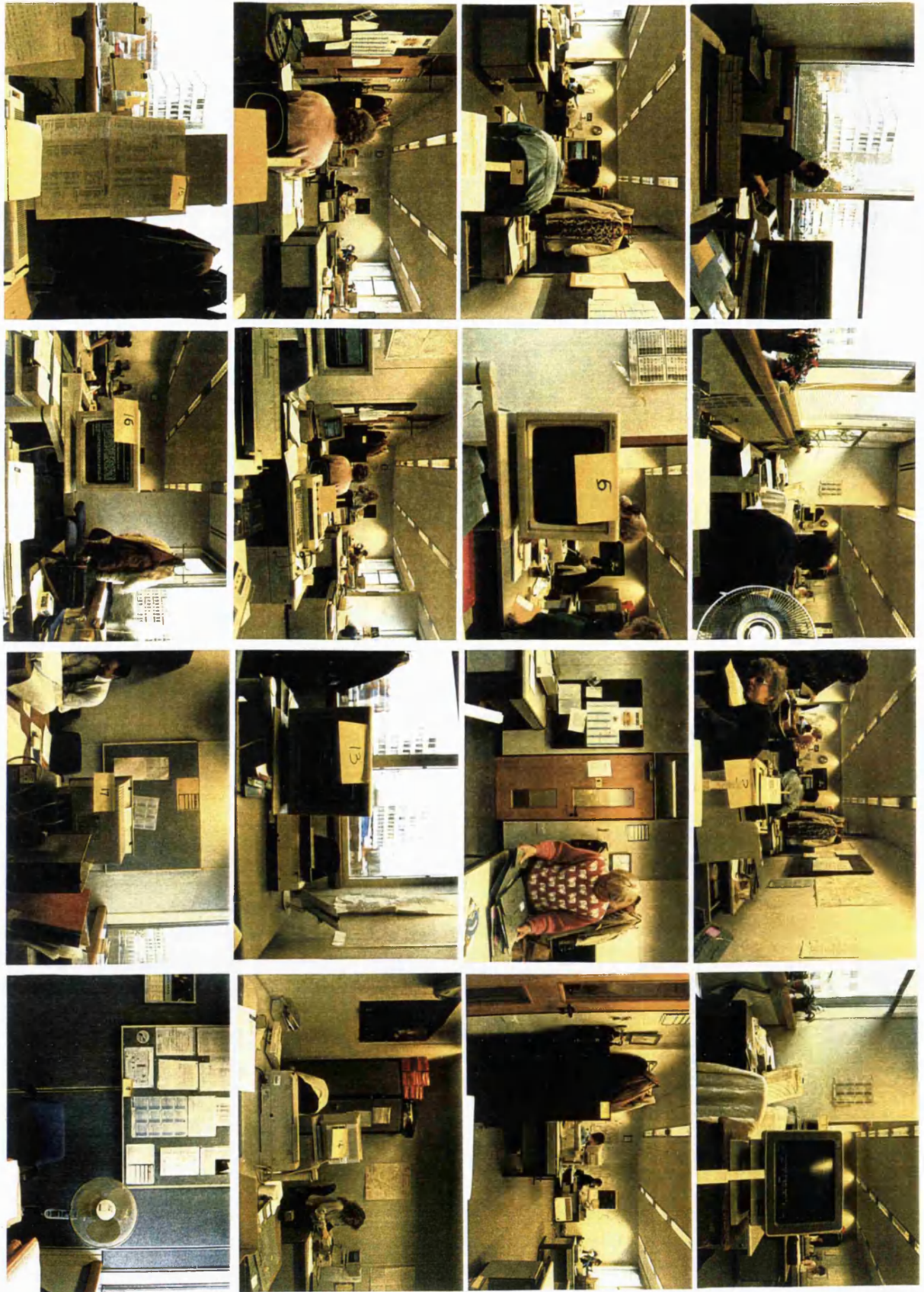




Plate 7.3(b) : photographs of work positions

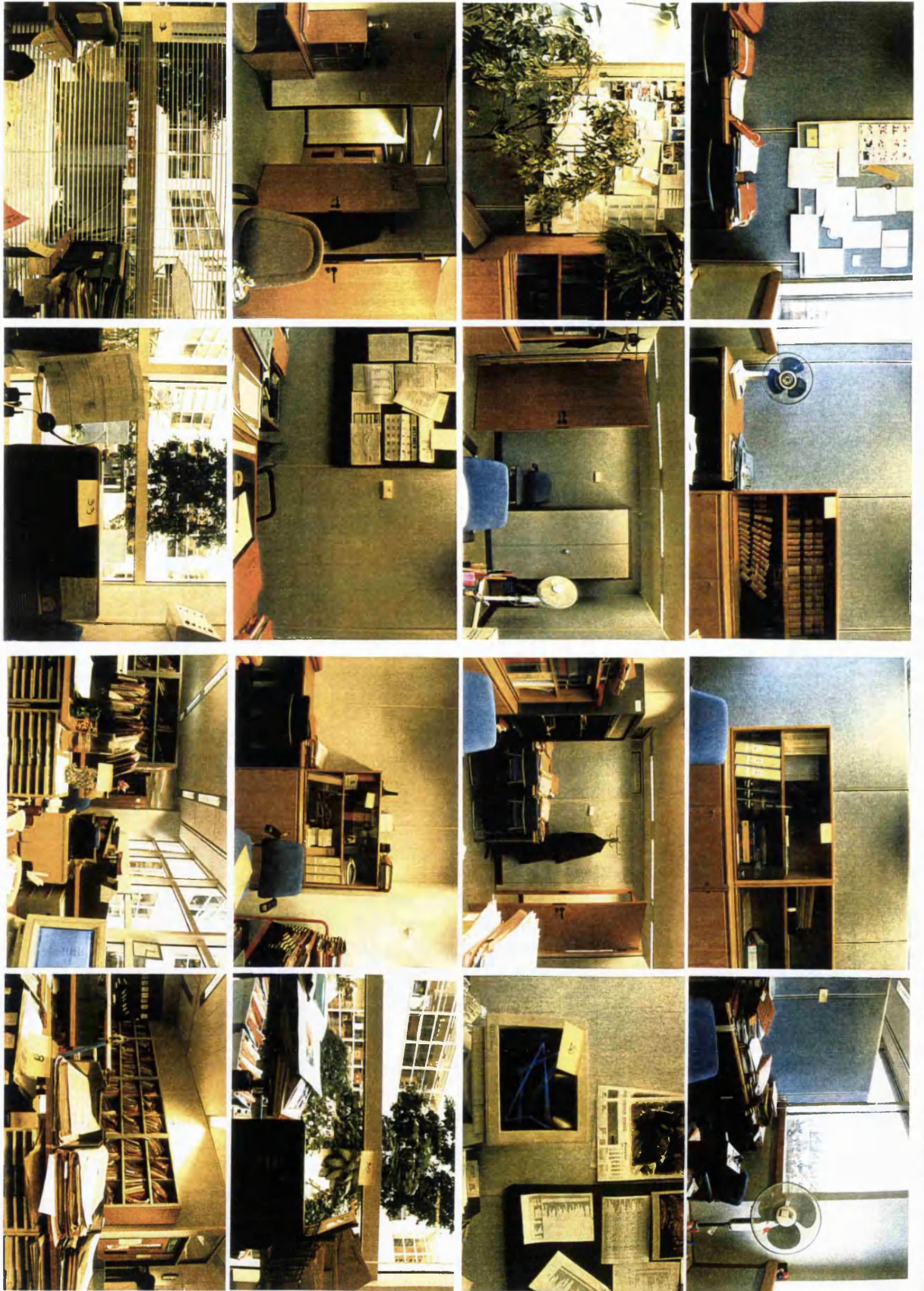




Plate 7.3(c) : photographs of work positions





Plate 7.3(d) : photographs of work positions





Plate 7.3(e) : photographs of work positions





Plate 7.3(f) : photographs of work positions

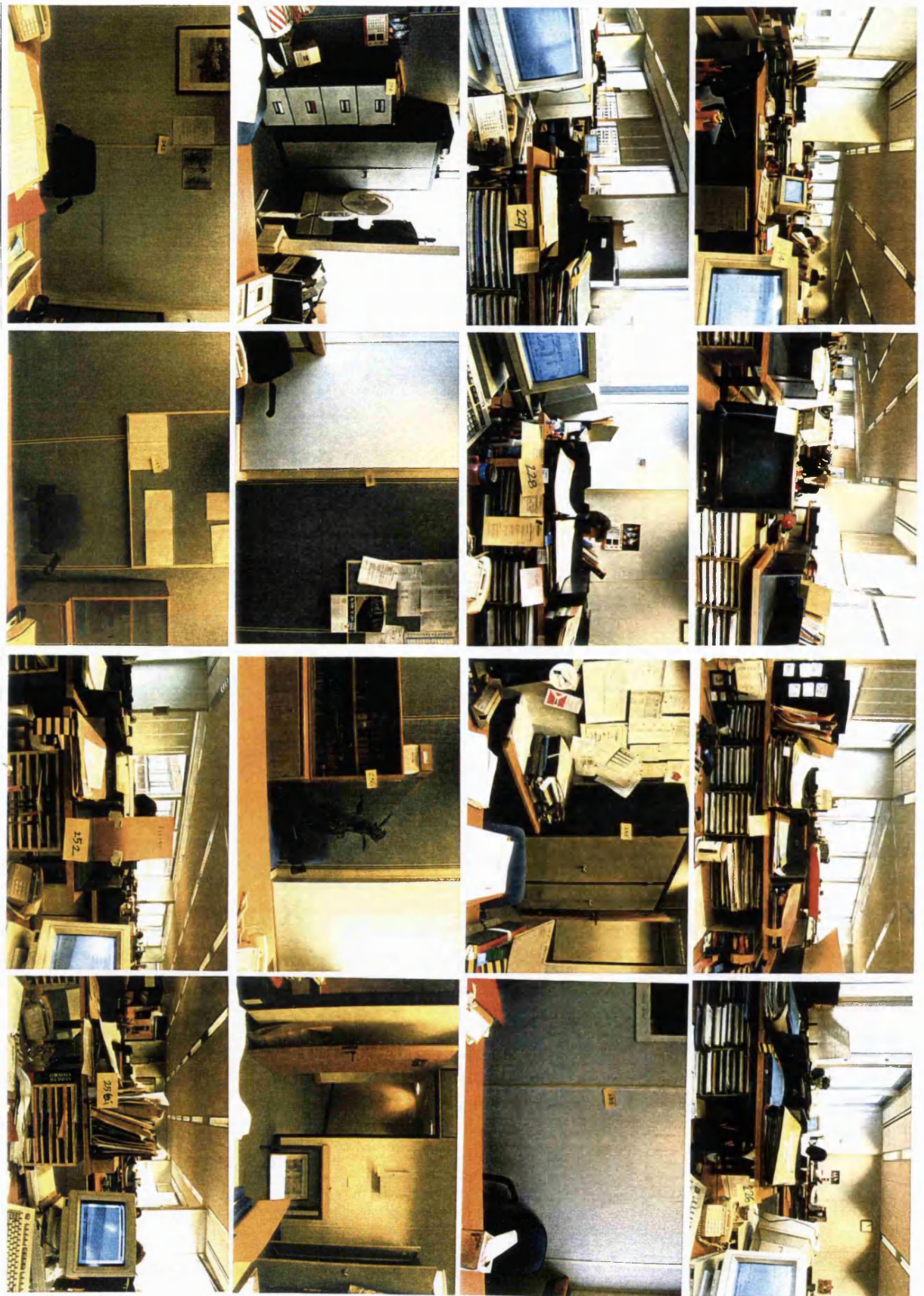




Plate 7.3(g) : photographs of work positions





Plate 7.3(h) : photographs of work positions





Figure 7.4.1a : Distribution of occurrence of eye symptom in the sample (as experienced by occupants)

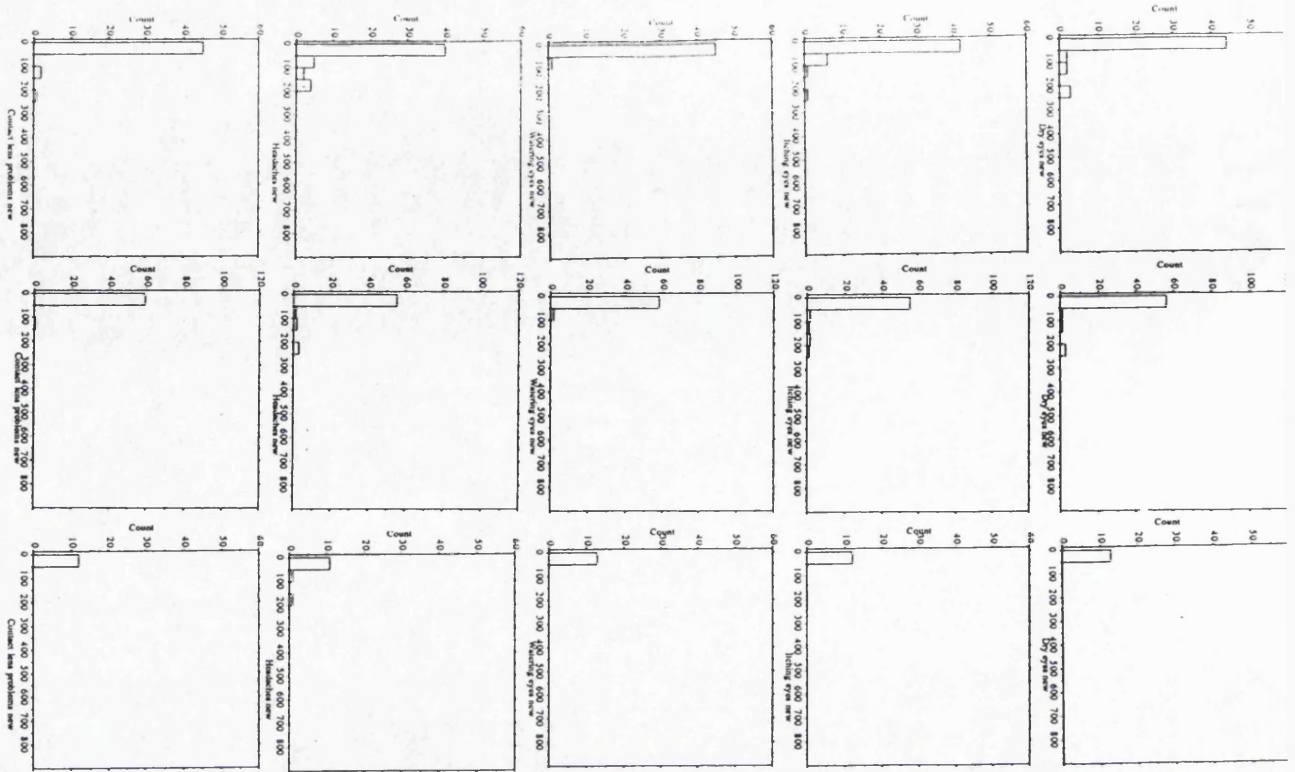
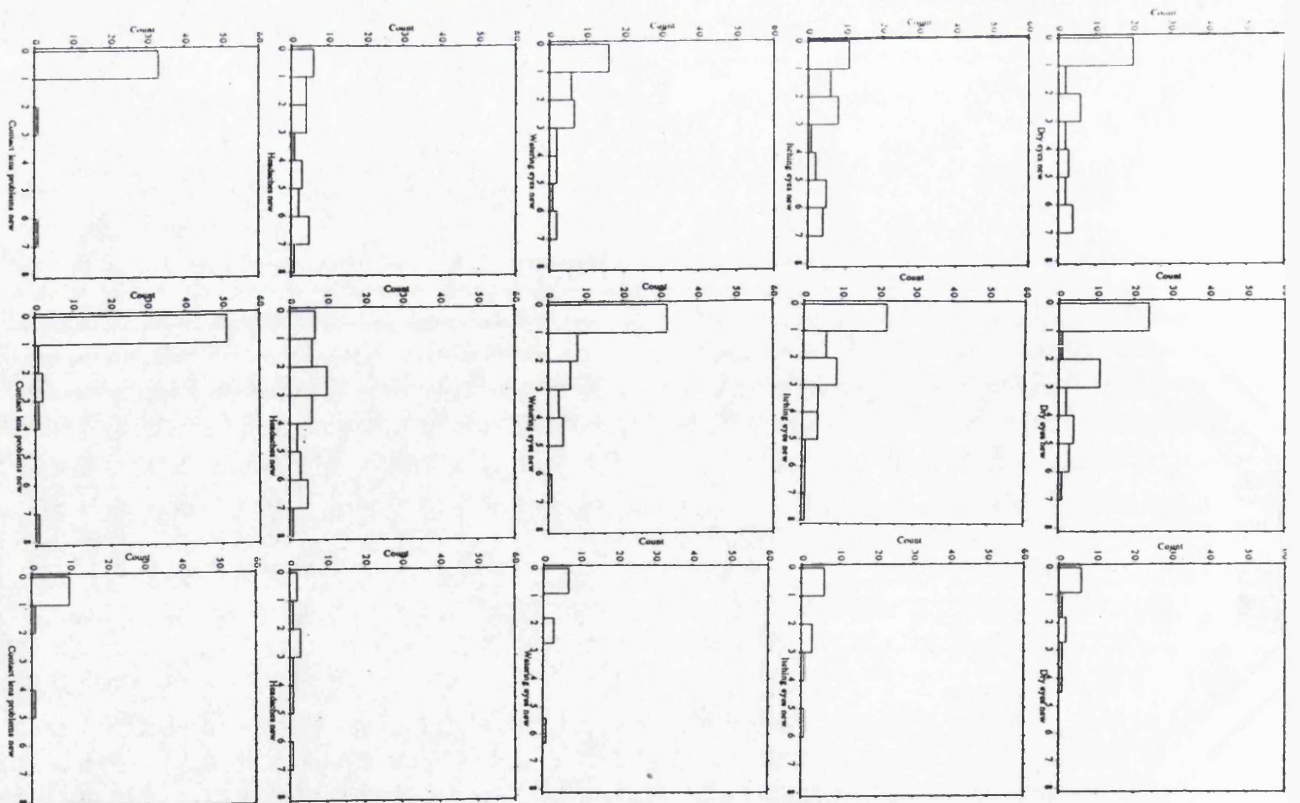


Figure 7.4.1b : Distribution of occurrence of eye symptom in the sample (range 0-50)



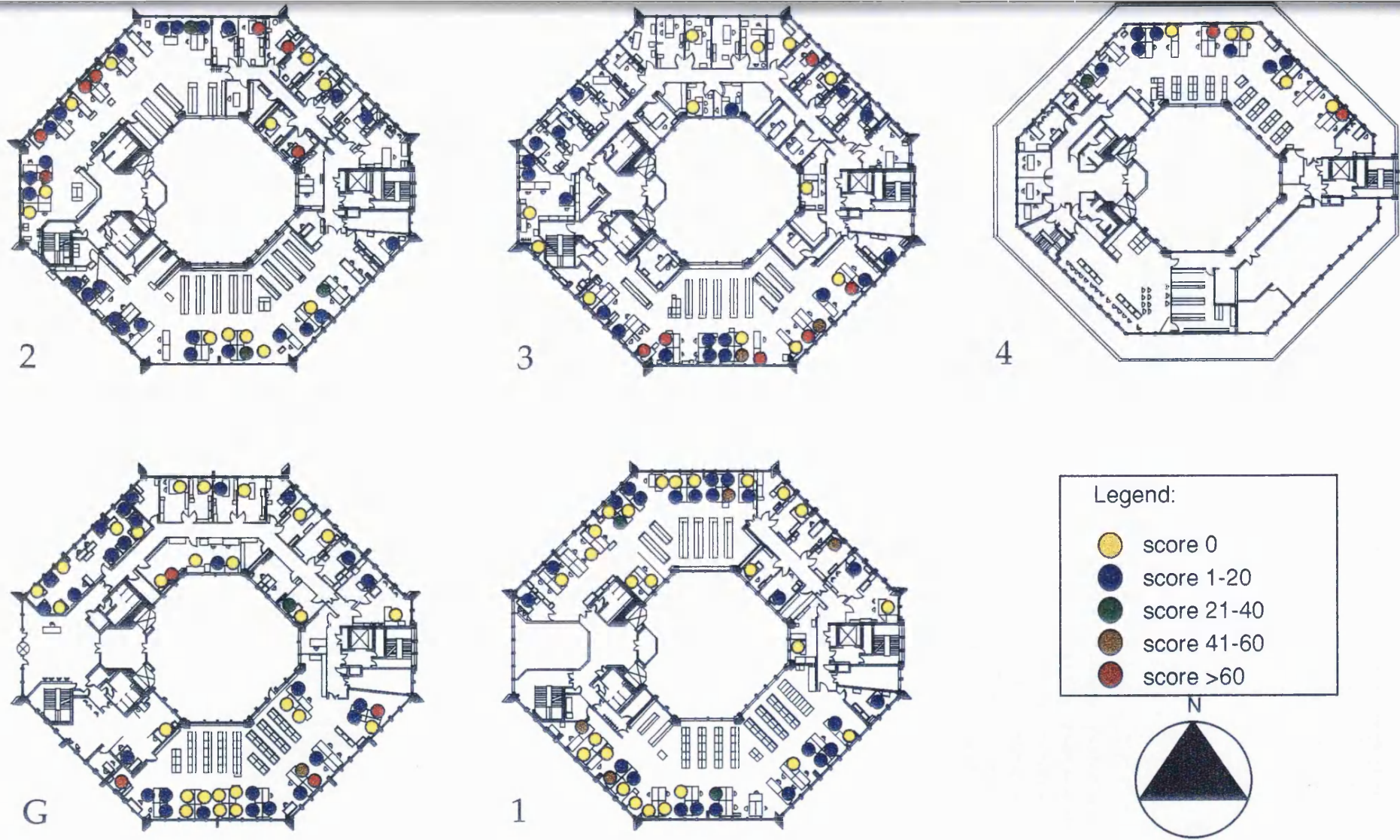


Figure 7.4.1c : Dry eyes occurrence distribution



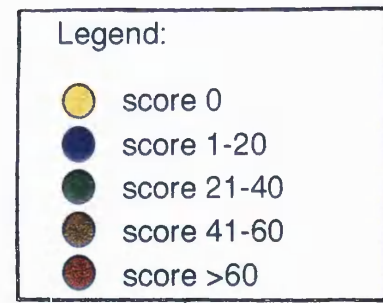
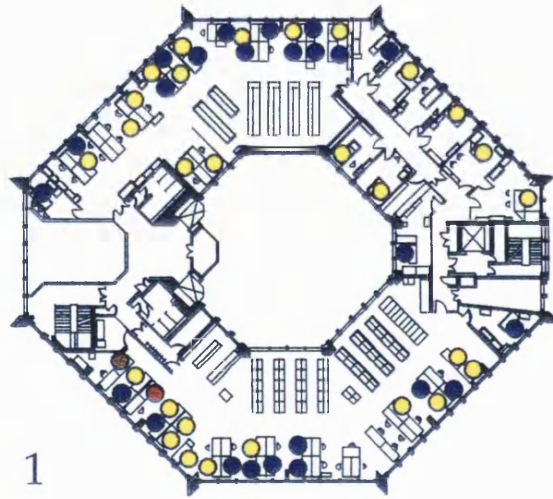
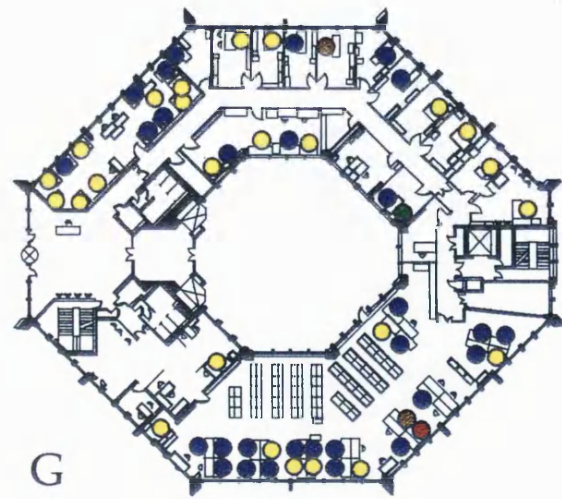
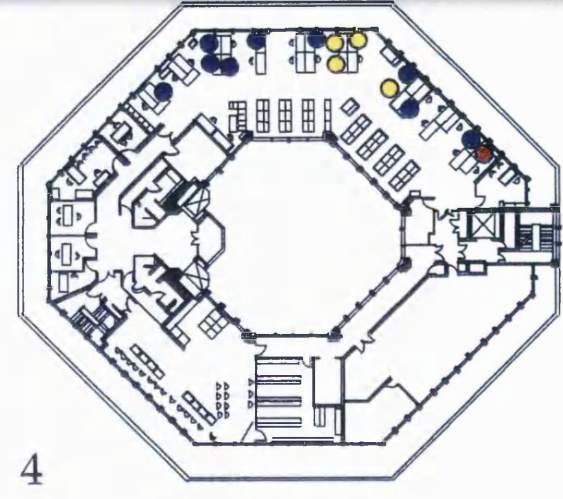
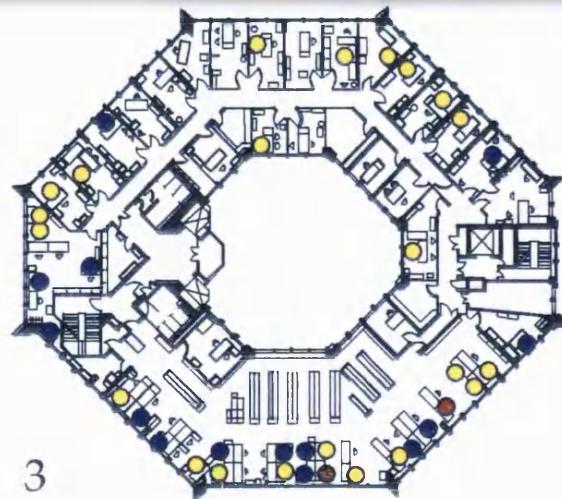
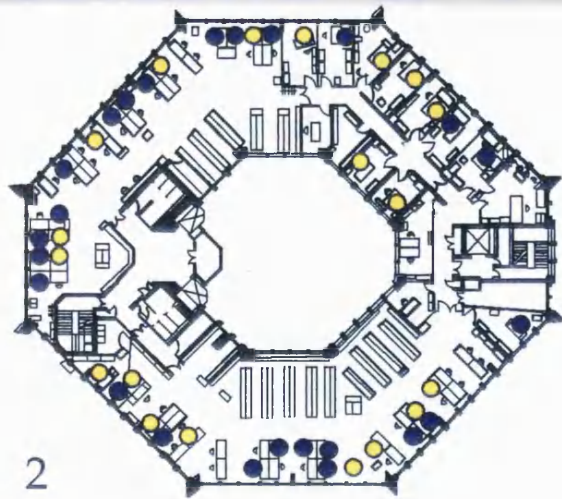


Figure 7.4.1d : Watering eyes occurrence distribution

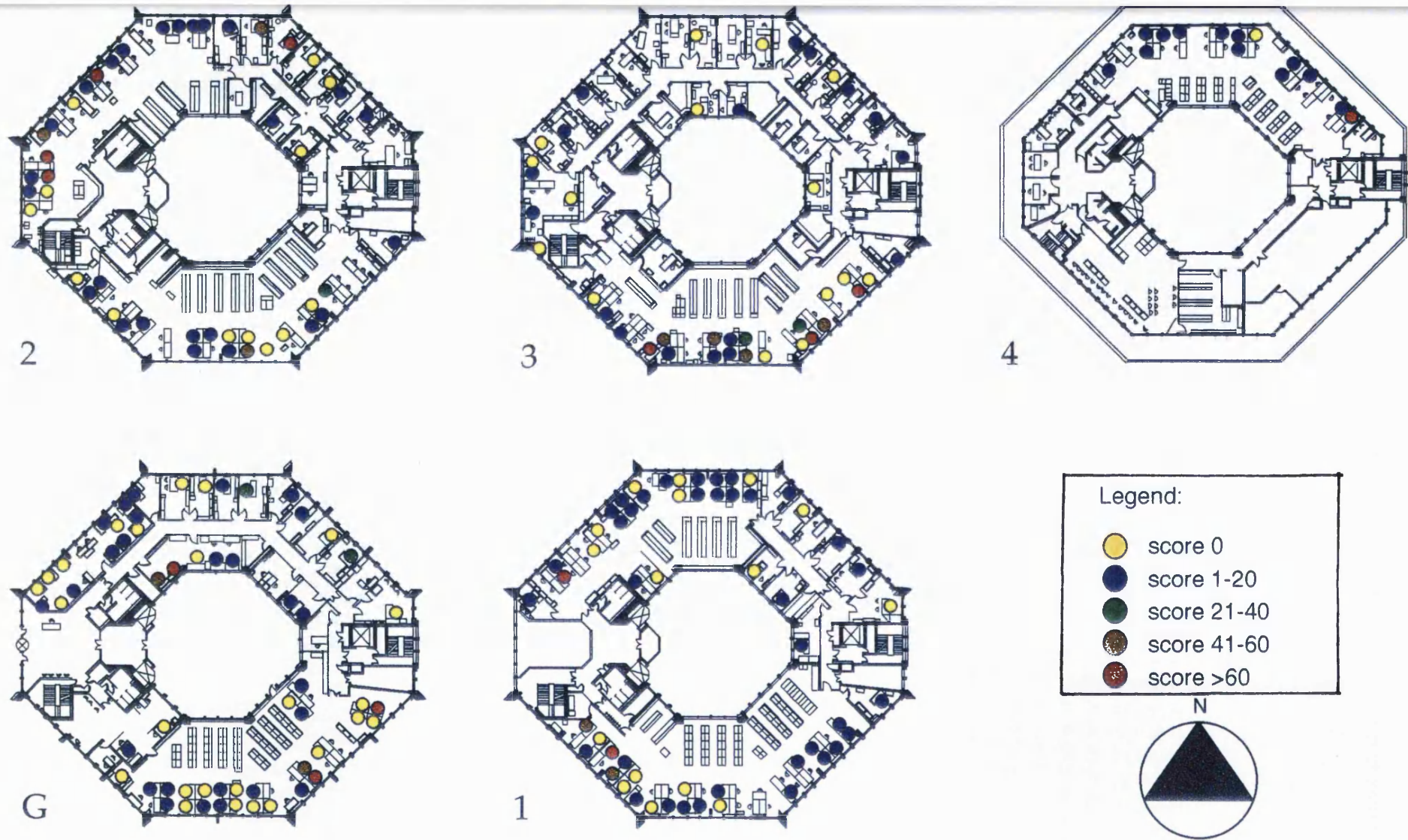


Figure 7.4.1e : Itching Eyes occurrence distribution



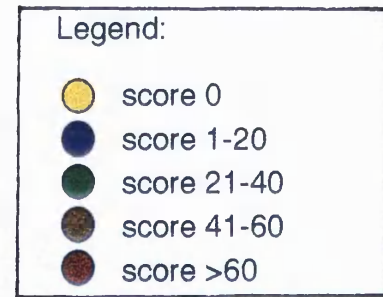
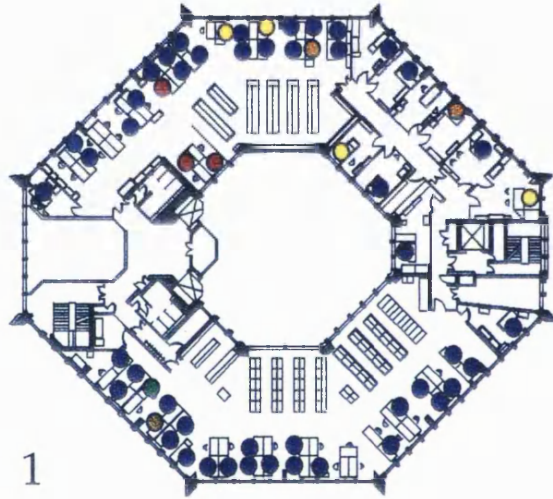
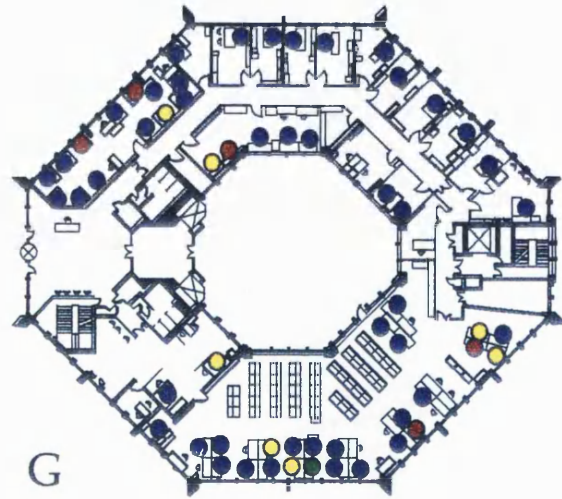
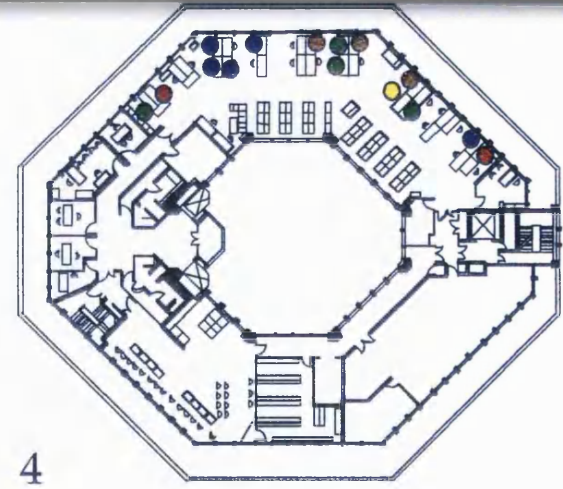
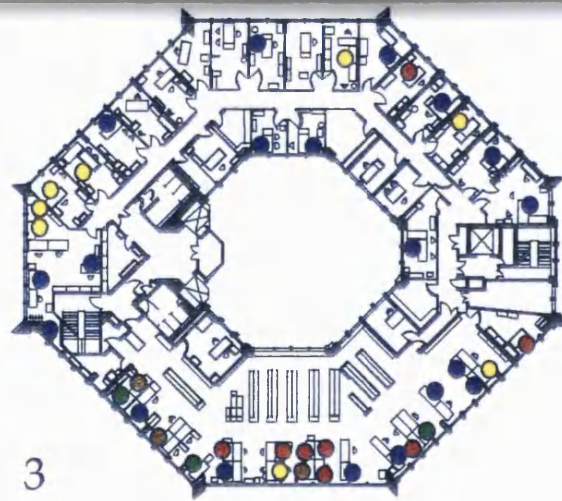
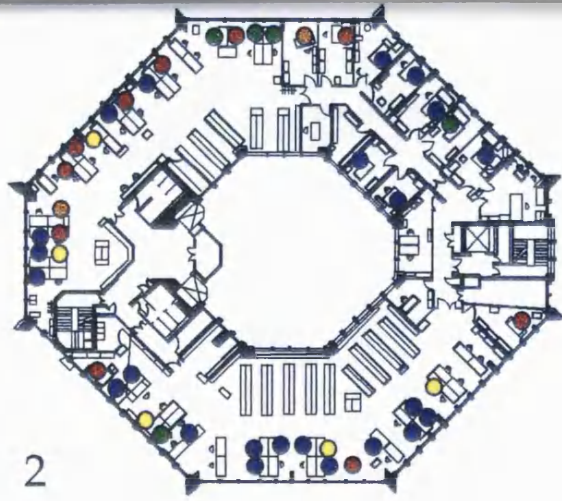
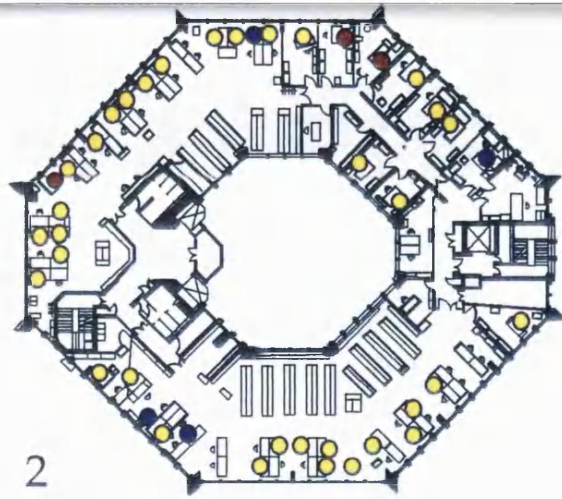
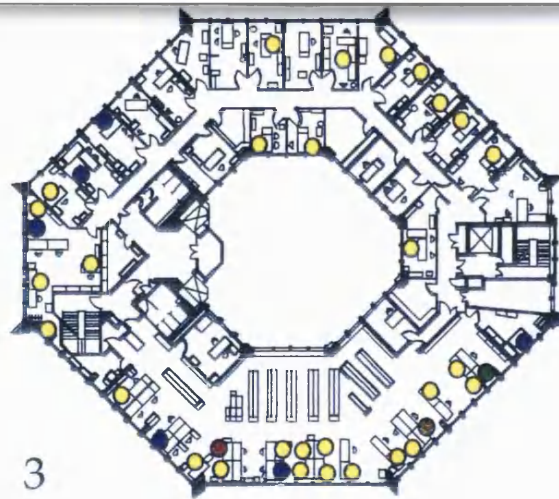


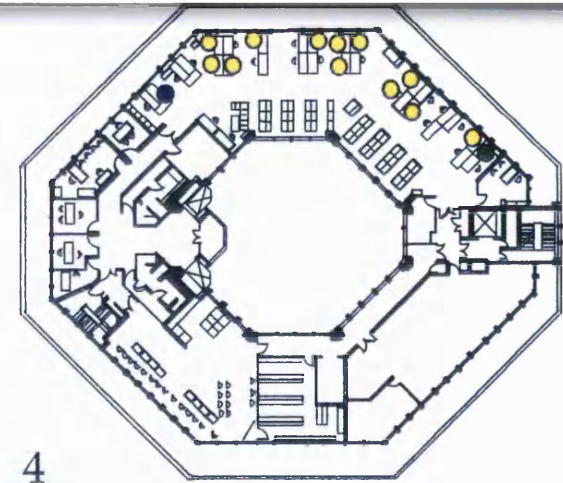
Figure 7.4.1f : Headaches occurrence distribution



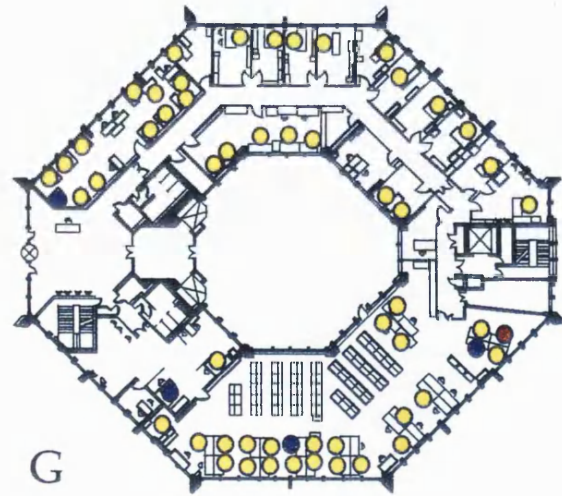
2



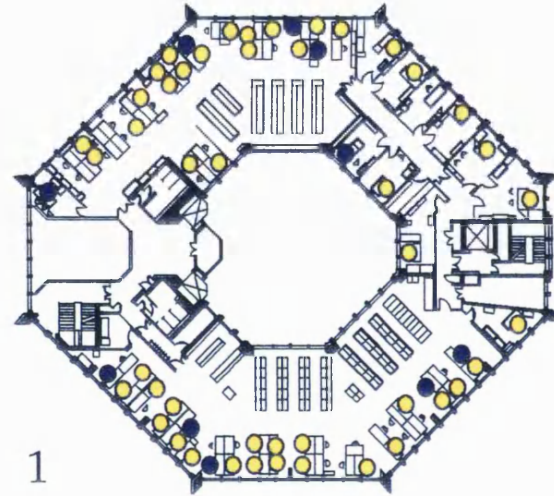
3



4



G



1

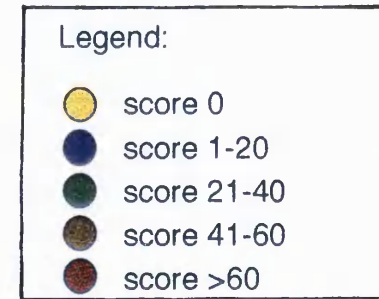


Figure 7.4.1g : occurrence of problem with wearing contact lenses distribution



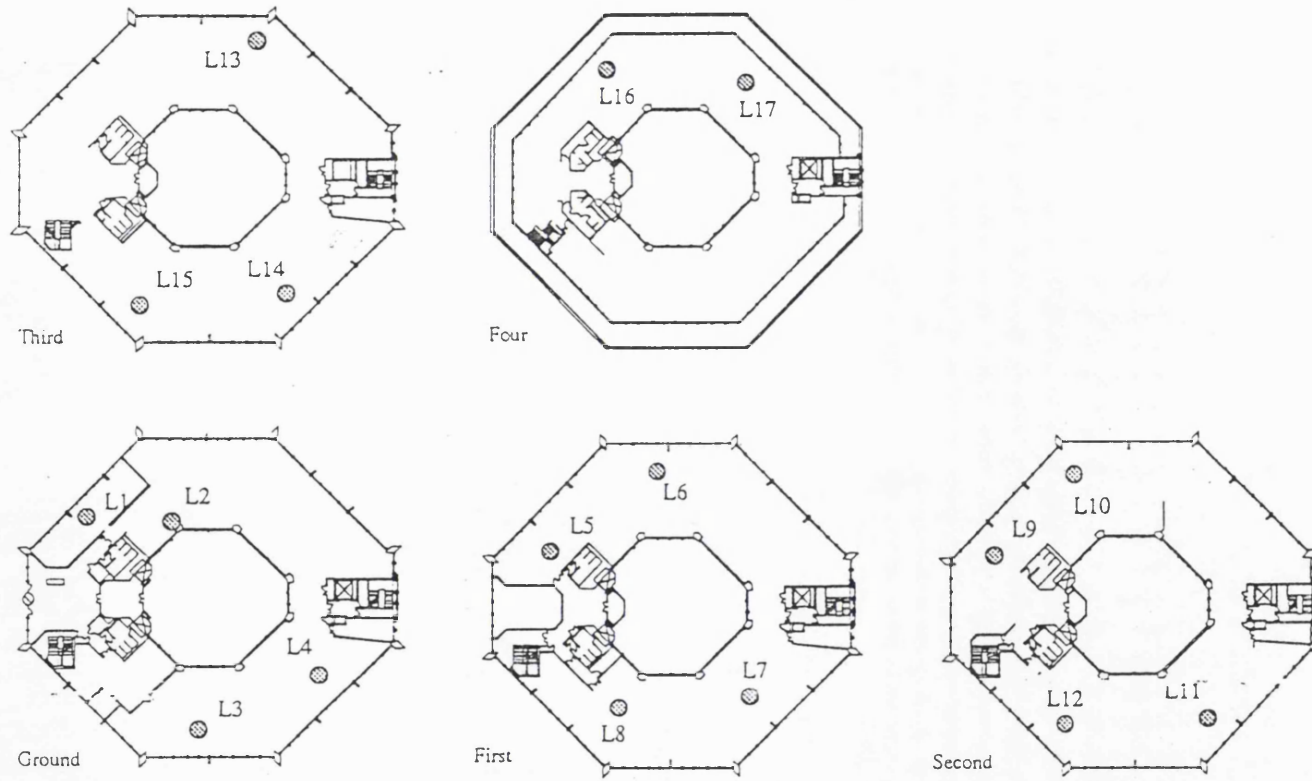


Figure 7.4.2: Link Environmental Monitoring Locations

Table 7.4.2 : Measured thermal, relative humidity and pollutant levels

Floor	cluster	cluster(category)	logger	season	LmeanTemp	LmaxTemp	LMinTemp	LetdTemp	LRHmean	LRHmax	LRHmin	Vel 1.25m	Vel Grad
0	-	-	6.010	Winter	22.2	26.2	16.6	1.2	34.7	47.2	25.6	-	-
0	-	-	6.020	Winter	20.8	23.8	16.8	1.0	34.7	47.2	25.6	-	-
0	-	-	6.040	Winter	20.7	23.2	16.8	1.2	34.7	47.2	25.6	-	-
0	-	-	6.030	Winter	21.3	24.2	16.8	1.1	34.7	47.2	25.6	-	-
1	-	-	6.060	Winter	22.3	23.6	16.6	.7	34.7	47.2	25.6	-	-
1	-	-	6.060	Winter	22.6	23.6	16.2	.6	34.7	47.2	25.6	-	-
1	-	-	6.070	Winter	22.3	23.6	16.6	.7	34.7	47.2	25.6	-	-
1	-	-	6.080	Winter	23.1	26.8	19.4	.8	34.7	47.2	25.6	-	-
2	-	-	6.090	Winter	22.0	23.6	19.2	.8	34.7	47.2	25.6	-	-
2	6.2	eix22	6.100	Winter	23.1	24.8	19.6	.8	34.7	47.2	25.6	.078	7.0E-3
2	6.2	eix22	6.100	Winter	23.1	24.8	19.6	.8	34.7	47.2	25.6	.074	3.4E-2
2	-	-	6.110	Winter	22.7	24.6	19.6	.7	34.7	47.2	25.6	-	-
2	6.2	eix26	-	Winter	-	-	-	-	-	-	-	.162	2.8E-2
2	6.2	eix26	-	Winter	-	-	-	-	-	-	-	.106	-2.4E-2
2	-	-	6.120	Winter	22.8	26.0	19.8	.8	34.7	47.2	25.6	-	-
3	-	-	6.100	Winter	22.2	23.8	16.6	.6	34.7	47.2	25.6	-	-
3	6.3	eix32	-	Winter	-	-	-	-	-	-	-	.107	1.0E-2
3	6.3	eix33	6.140	Winter	21.8	24.6	18.7	1.0	34.7	47.2	25.6	.037	2.6E-2
3	6.3	eix33	-	Winter	-	-	-	-	-	-	-	.098	1.0E-2
3	6.3	eix33	-	Winter	-	-	-	-	-	-	-	.187	-1
4	6.4	eix40	6.160	Winter	22.0	24.6	17.8	1.0	34.7	47.2	25.6	.162	.2
4	6.4	eix40	6.160	Winter	22.0	24.8	17.8	1.0	34.7	47.2	25.6	.124	1.4E-2
4	6.4	eix40	6.160	Winter	22.0	24.8	17.8	1.0	34.7	47.2	25.6	.111	2.8E-2
4	6.4	eix40	-	Winter	-	-	-	-	-	-	-	.188	-1
4	6.4	eix40	-	Winter	-	-	-	-	-	-	-	.262	-1.6E-2
4	-	-	6.170	Winter	21.9	23.6	14.0	.9	34.7	47.2	25.6	-	-

Floor	cluster	cluster(category)	logger	season	Cluster CO2 room mean	Cluster CO2 room max	Cluster CO2 room min	Cluster CO2 room std	Cluster formaldehyde mean	Cluster formaldehyde max	Cluster formaldehyde min	Cluster CO mean	Cluster CO max	Cluster CO min
2	6.2	eix22	6.100	Winter	666.6	1002.0	507.2	64.7	.1	.2	.1	1.6	6.6	.3
2	6.2	eix26	6.110	Winter	684.9	716.0	371.6	71.7	.1	.2	.1	1.4	6.6	.3
3	6.3	eix32	-	Winter	691.1	748.0	386.1	63.7	.2	4.4	.1	1.8	6.6	.2
3	6.3	eix33	6.140	Winter	612.6	712.0	438.8	61.0	.1	1.0	.1	1.8	6.3	.3
4	6.4	eix40	6.160	Winter	784.9	1061.4	672.9	88.7	.1	.4	.1	1.7	4.9	.3

Floor	cluster	cluster(category)	logger	season	Cluster TVOC mean	Cluster TVOC max	Cluster TVOC min	Cluster dust mite/g	Cluster antigen ng/g	Cluster shelf factor	Cluster fleece factor	Cluster respirable dust mg/m3	Cluster max particle size micron
2	6.2	eix22	6.100	Winter	1.6	4.0	.7	-	840.0	.3	.4	2.0E-2	-
2	6.2	eix26	6.110	Winter	1.6	3.0	.6	0.0	-	.3	.4	2.0E-2	-
3	6.3	eix32	-	Winter	4.3	282.0	.1	-	120.0	.2	.4	2.0E-2	-
3	6.3	eix33	6.140	Winter	2.6	53.6	.1	5.0	-	.3	.4	1.0E-2	150.0
4	6.4	eix40	6.160	Winter	2.2	15.7	.1	0.0	1.0	.3	.4	1.6E-2	100.0

Figure 7.4.3a : Distribution of Occupants assessments of Appearance of Work position

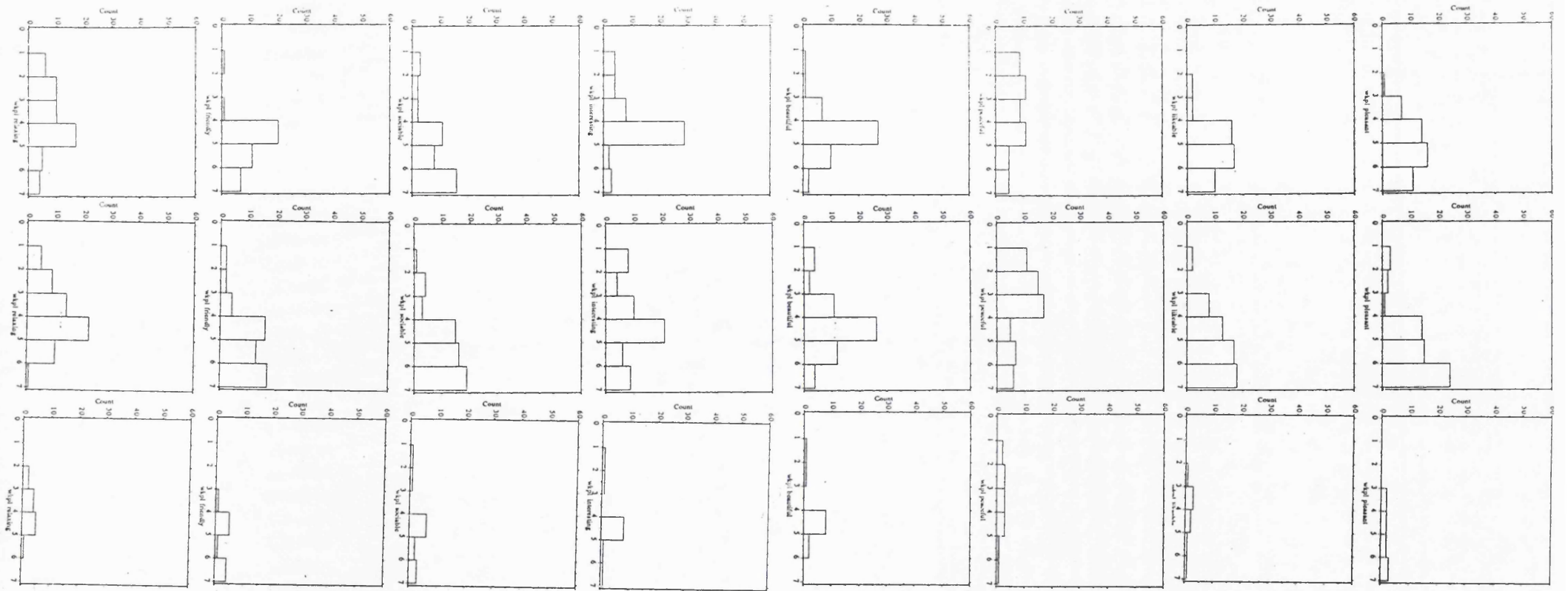


Figure 7.4.3b : Distribution of Occupants assessments of Appearance of Work position

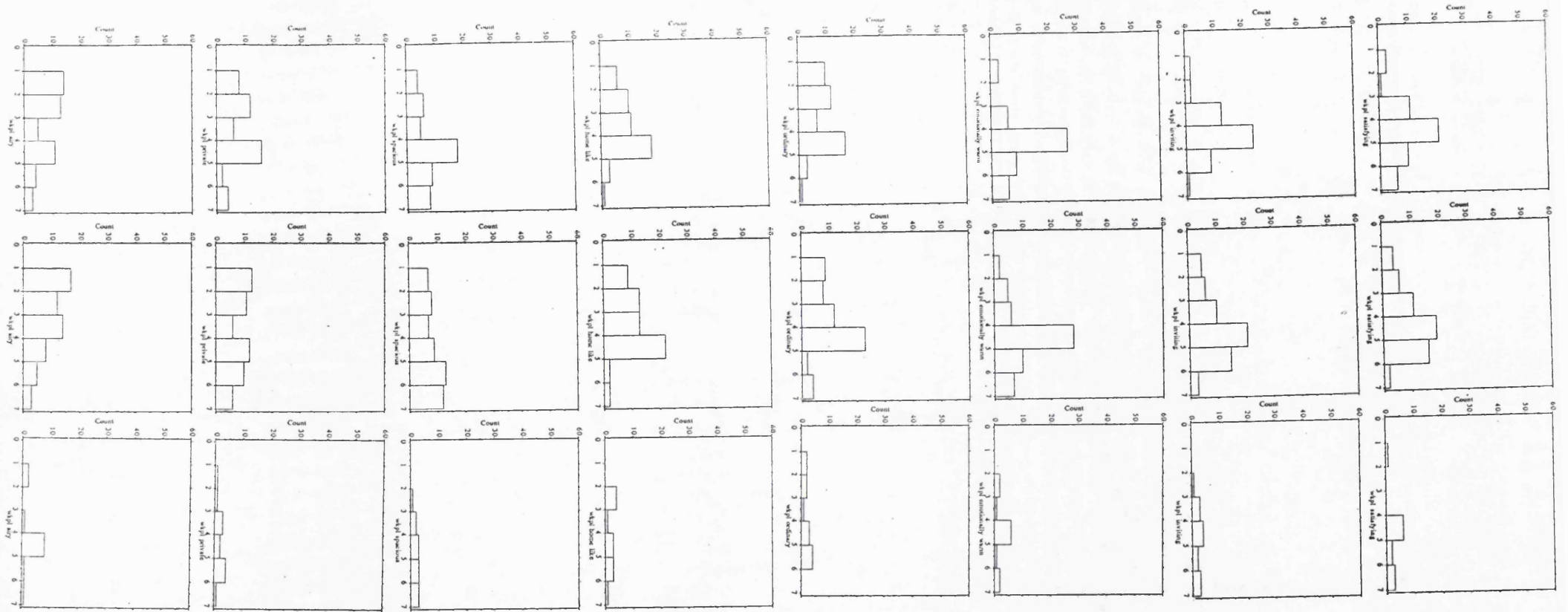
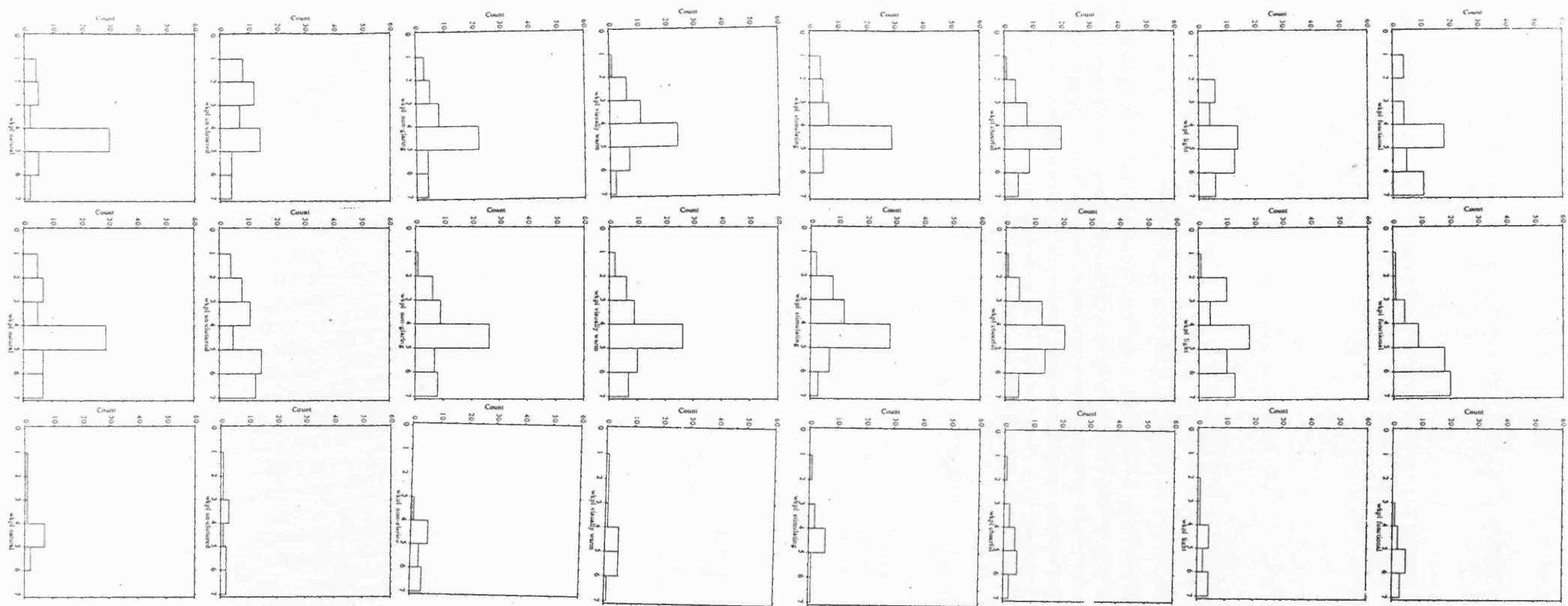


Figure 7.4.3c : Distribution of Occupants assessments of Appearance of Work position



**Table 7.4.4: The range of the measured physical light attributes for the group**

SUBJECTIVE QUALITY	Range of Physical measurements		
	Facing Windows	Siding Windows	Backing Windows
Isoarea (IA)	0.9-132.4	1.7-124.4	0.9-12.6
Win solid <	0-1560	0-690	0-300
Sky solid <	0-1170	0-416.6	0-0
Sky/Win	0-1	0-1	0-0
D ave(L)	21-200	30-154	18-99
D WT(E)	126-928	235-952	358-887
Deye(E)	75-493	83-562	134-321
Dmax(L)	75.7-10080	29.2-3093	75.5-228.3
Dmin(L)	0.3-8.2	0.3-14.7	0.3-12
Dmax/min	33.5-14400	8.3-1009.2	9.1-468

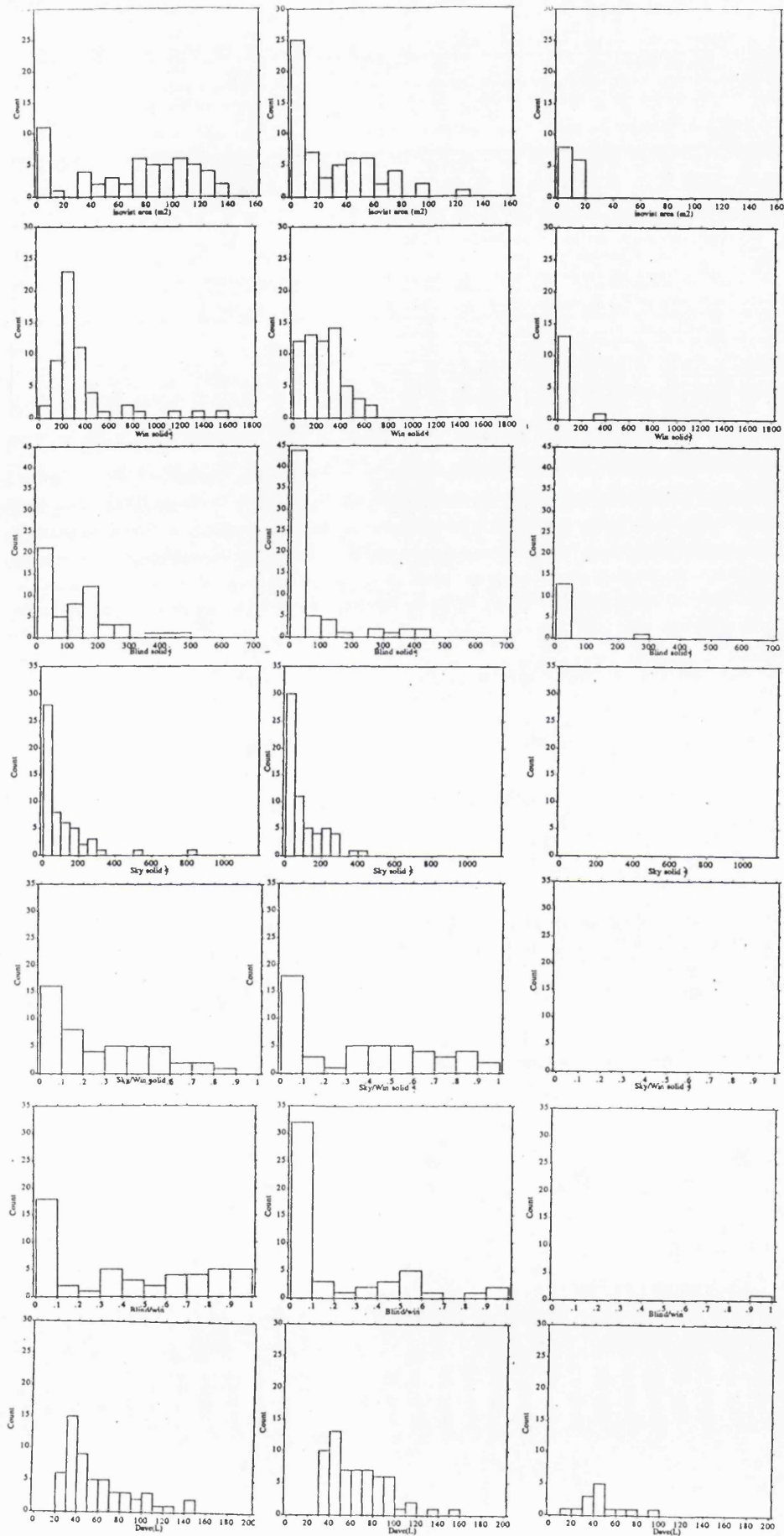


Figure 7.4.4a : The distribution of the measured physical light attributes for the group



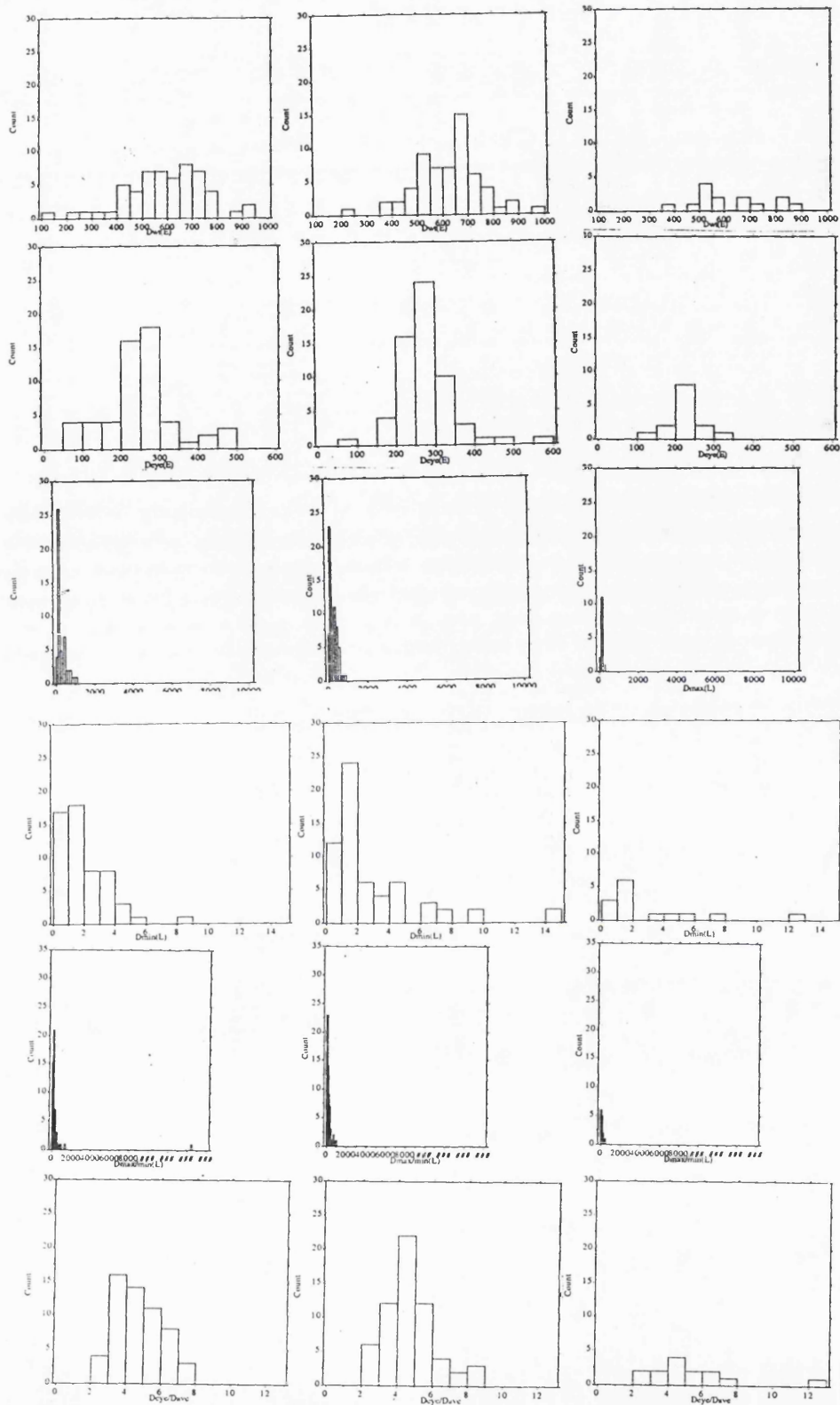


Figure 7.4.4b : The distribution of the measured physical light attributes for the group

Table 7.6a: Difference of symptom occurrence with respect to occupants Location

Symptom	Kruscal-Wallis Analysis		Mean Comparison					
			56		61		14	
	Seat orientation wrt window		Facing Window		Siding Window		Backing Window	
	H	p	Mean	STD	Mean	STD	Mean	STD
Dry Eyes	1.7	0.43	21.6	53.0	16.7	47.5	2.6	5.4
Itching Eyes	3.03	0.22	14.86	36.0	15.1	40.4	3.7	8.5
Watering Eyes	1.68	0.43	2.37	7.3	3.7	9.8	0.9	1.7
Headaches	2.58	0.27	27.86	45.1	19.9	48.17	18.8	41.6
Contact Lense Prob	0.098	0.95	8.9	34.64	2.8	13.37	0.4	1.16

N.B: H indicated is corrected for ties

Table 7.6b: Comparison of Occupants Perception of Work Position Appearance between Seat Orientation

SUBJECTIVE QUALITY	Kruscal-Wallis Analysis		Mean Comparison					
			56		61		14	
	Seat orientation wrt window		Facing Window		Siding Window		Backing Window	
	H	p	Mean	STD	Mean	STD	Mean	STD
Pleasant	4.76	0.09	4.73	1.17	4.90	1.39	5.50	1.51
Likeable	0.04	0.98	4.80	1.13	4.79	1.32	4.83	1.90
Peaceful	0.50	0.78	3.22	1.65	3.00	1.56	3.08	1.50
Beautiful	0.59	0.74	4.10	0.98	3.88	1.19	4.00	1.41
Interesting	1.26	0.53	3.67	1.24	3.85	1.66	4.08	1.50
Sociable	4.48	0.11	5.06	1.66	4.80	1.34	4.23	1.48
Friendly	0.06	0.97	5.02	1.33	4.88	1.45	5.08	1.32
Relaxing	0.12	0.94	3.40	1.48	3.43	1.22	3.42	0.90
Satisfying	3.21	0.20	4.00	1.22	3.90	1.42	4.62	1.50
Inviting	0.96	0.62	3.83	1.08	3.79	1.37	4.23	1.30
Emotionally warm	0.37	0.83	4.23	1.25	4.18	1.34	4.00	1.28
Ordinary	1.70	0.43	3.04	1.55	3.35	1.52	3.42	1.56
Homelike	3.54	0.17	3.18	1.33	3.02	1.27	3.92	1.66
Spacious	0.37	0.83	4.09	1.60	4.13	1.86	4.42	1.31
Private	1.92	0.38	3.38	1.77	3.41	1.86	4.08	1.66
Airy	3.85	0.15	2.98	1.81	2.82	1.66	3.69	1.38
Functional	1.80	0.41	4.79	1.70	5.20	1.29	5.23	1.17
Light	0.85	0.65	4.69	1.54	4.39	1.58	4.58	1.31
Cheerful	1.04	0.59	4.29	1.42	4.07	1.25	4.29	1.33
Stimulating	0.32	0.85	3.59	1.17	3.65	1.12	3.82	1.25
Visually Warm	1.71	0.43	3.83	1.21	4.00	1.28	4.07	1.33
Non-glaring	4.31	0.12	3.94	1.50	4.13	1.35	4.71	1.00
Colourful	1.85	0.39	3.62	1.47	3.48	1.34	4.00	1.08
Quiet	7.50	0.02	3.25	1.52	2.53	1.36	2.85	1.28
Cold	1.16	0.56	4.08	1.67	3.86	1.48	4.31	1.25
Clean	1.93	0.38	4.67	1.55	4.90	1.51	5.31	1.18
Uncluttered	7.23	0.03	3.42	1.78	4.28	1.76	4.33	1.97
Natural	0.02	1.00	3.88	1.40	3.84	1.42	3.92	1.44

N.B: The higher the mean the better the subjective assessment

Table 7.6c: Comparison of Measured Lighting Variables between Seat Orientation

No of Occupants	Kruscal-Wallis Analysis		Mean Comparison					
	Seat orientation wrt window		56		61		14	
SUBJECTIVE QUALITY	H	p	Facing Window		Siding Window		Backing Window	
			Mean	STD	Mean	STD	Mean	STD
Isoarea (IA)	28.84	0.0001	69.55	42.53	29.57	29.03	8.54	3.70
Win solid <	29.80	0.0001	348.68	285.76	242.95	167.91	21.43	80.18
Sky solid <	21.43	0.0001	116.04	200.64	87.01	103.21	0	0
Sky/Win	1.89	0.389	0.32	0.33	0.37	0.343	0	.
D ave(L)	6.11	0.047	60.43	36.34	65.30	27.06	48.64	20.99
D WT(E)	0.61	0.738	591.43	160.79	619.82	130.10	626.50	150.90
Deye(E)	10.23	0.006	251.34	92.00	276.66	73.72	220.93	44.72
Dmax(L)	4.87	0.088	501.61	1333.5	339.63	421.83	155.54	42.99
Dmin(L)	1.71	0.425	1.95	1.54	2.92	3.11	3.09	3.37
Dmax/min	3.08	0.215	493.37	1907.9	212.67	217.96	135.44	124.56

N.B: -H indicated is corrected for ties

## **Chapter 8: Case Study 3**



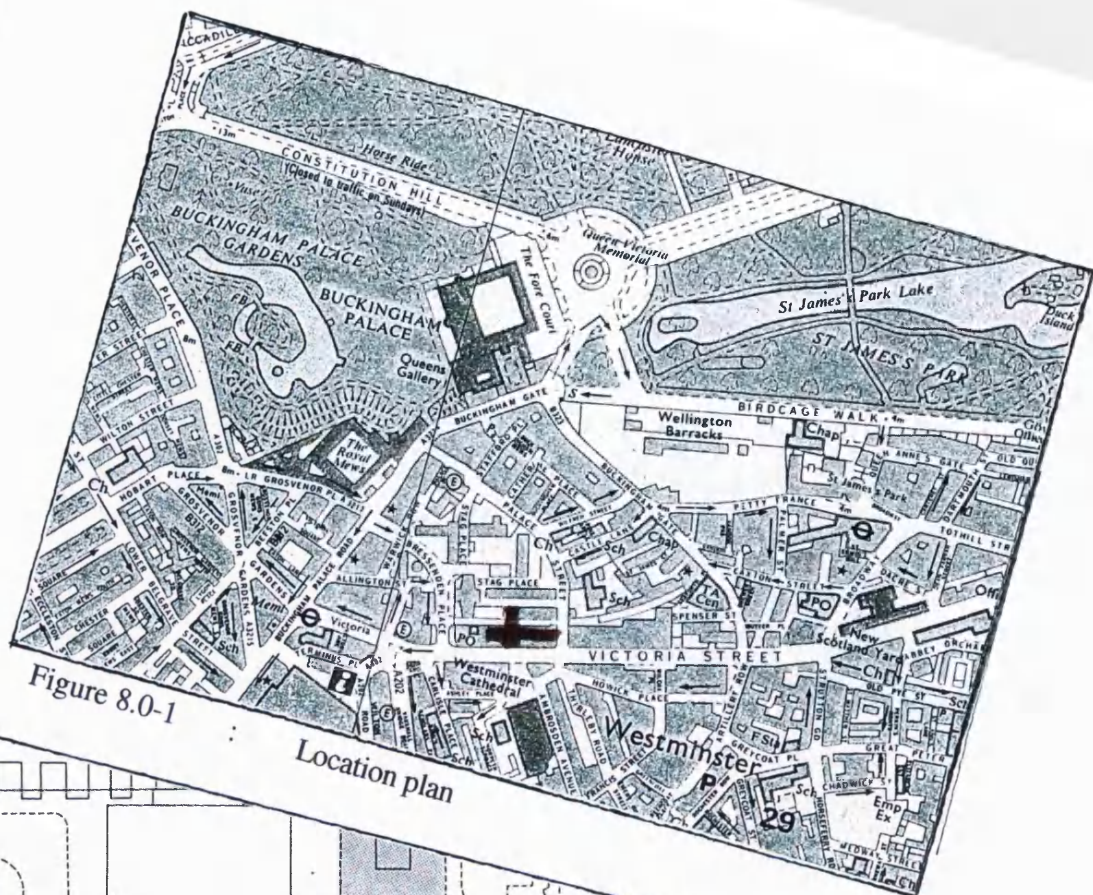


Figure 8.0-1 : Location plan

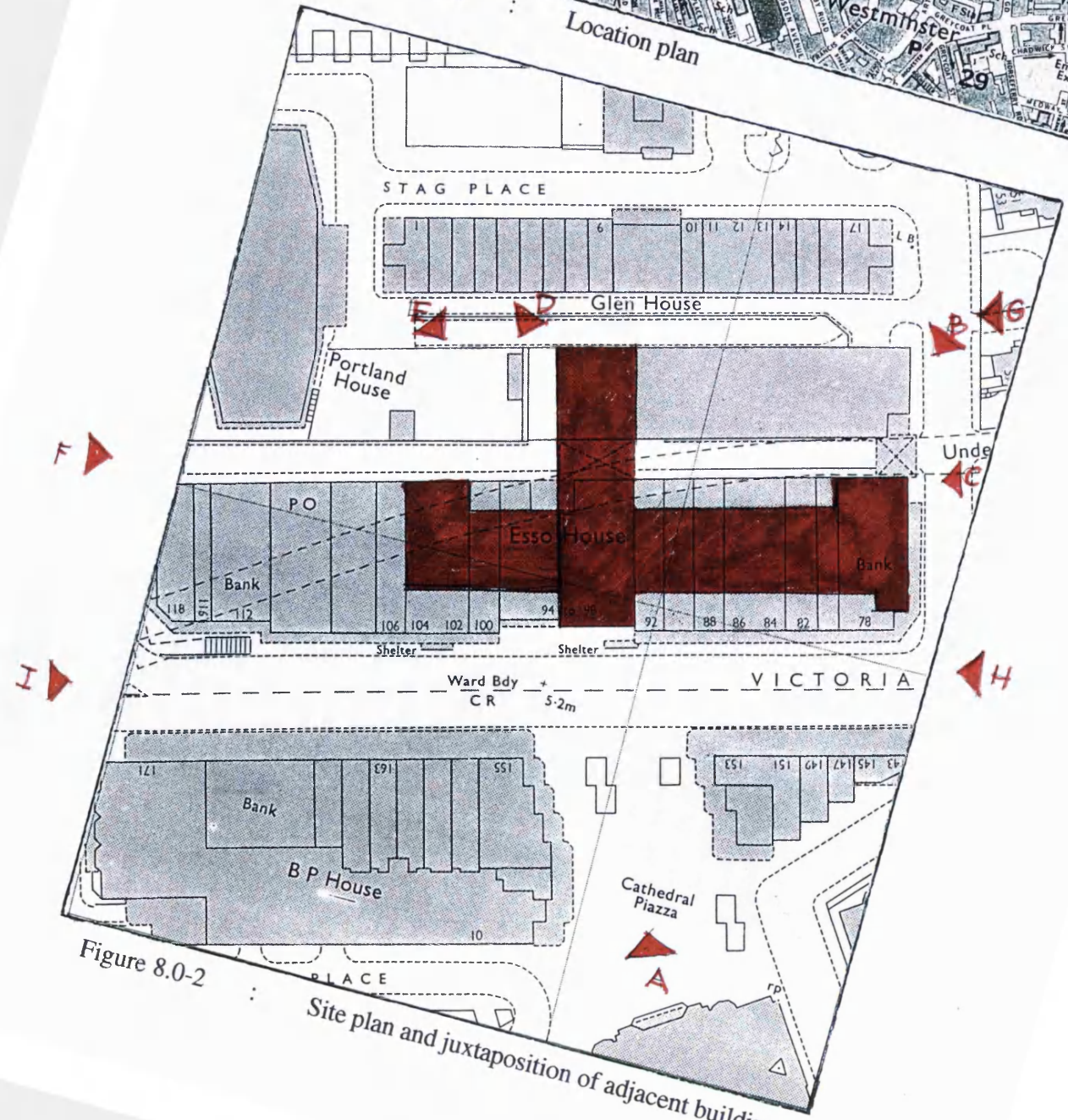


Figure 8.0-2 : Site plan and juxtaposition of adjacent buildings





View A

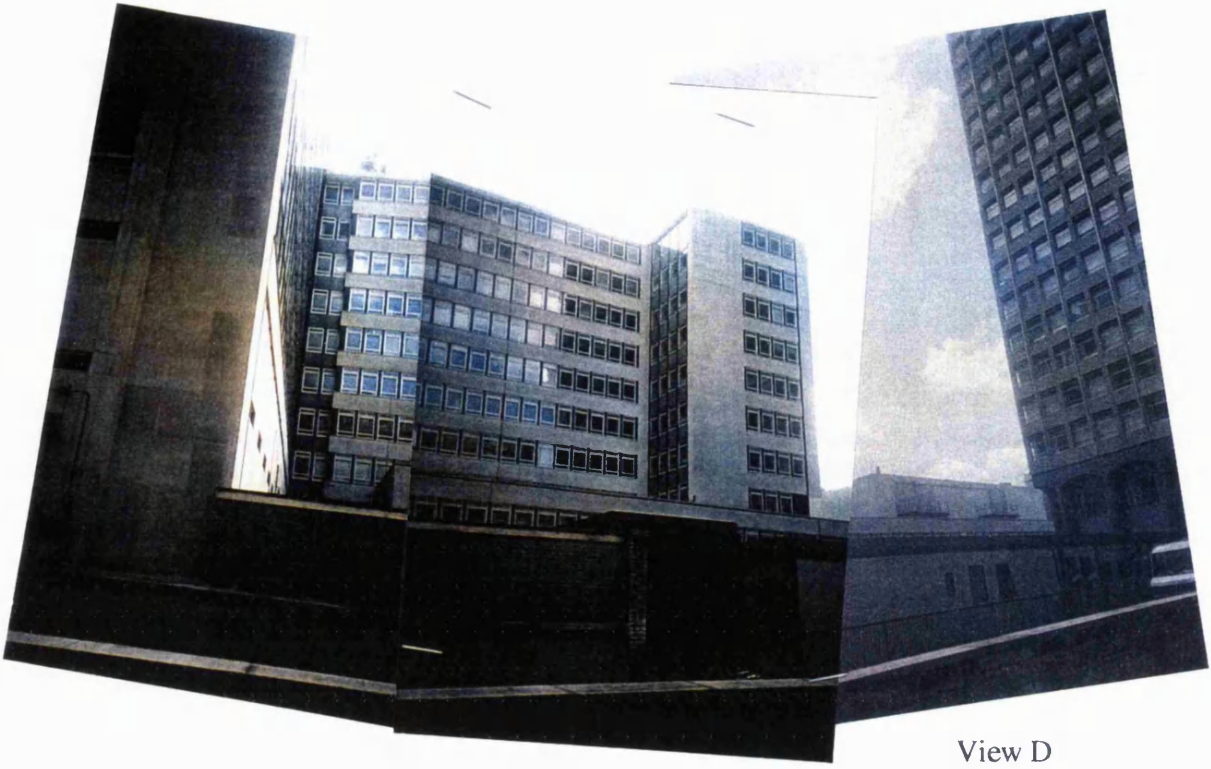
View B



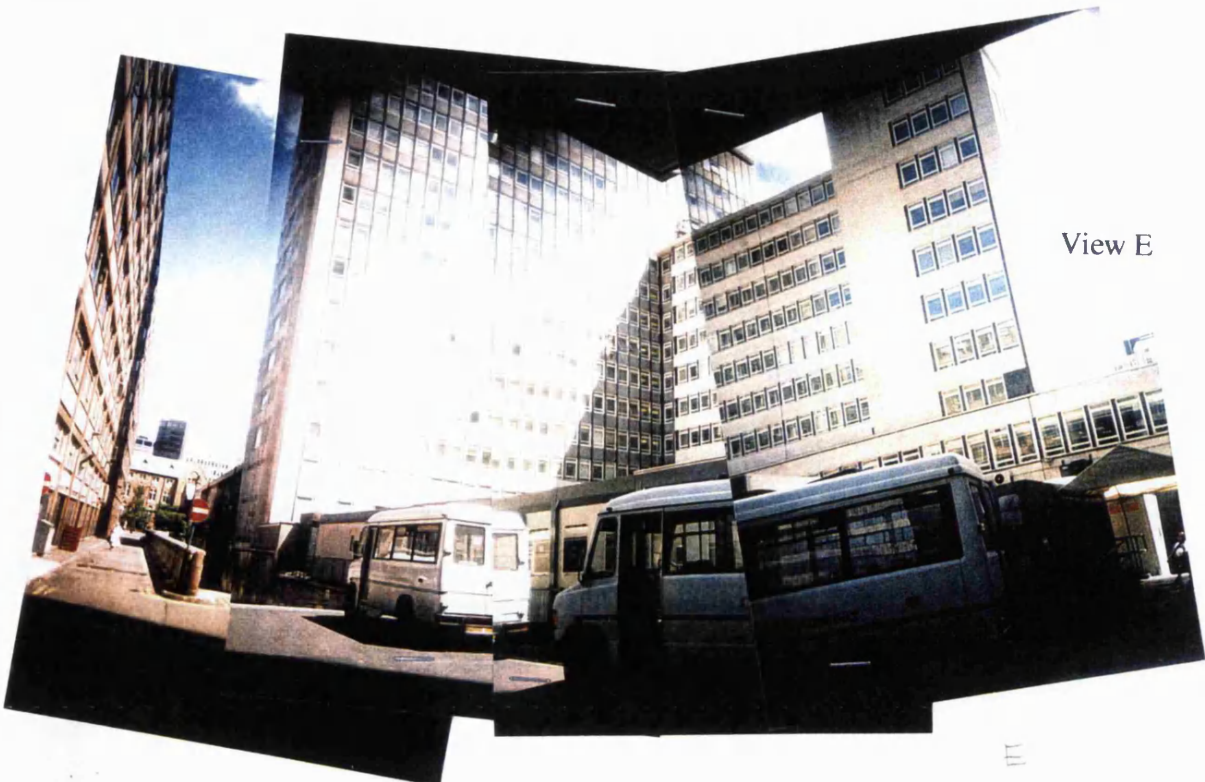
View C



Plate 8.0-1 : Photographs of Pearl assurance Building and the buildings surrounding it.



View D



View E

Plate 8.0-2 : Photographs of Pearl assurance Building and the buildings surrounding it.

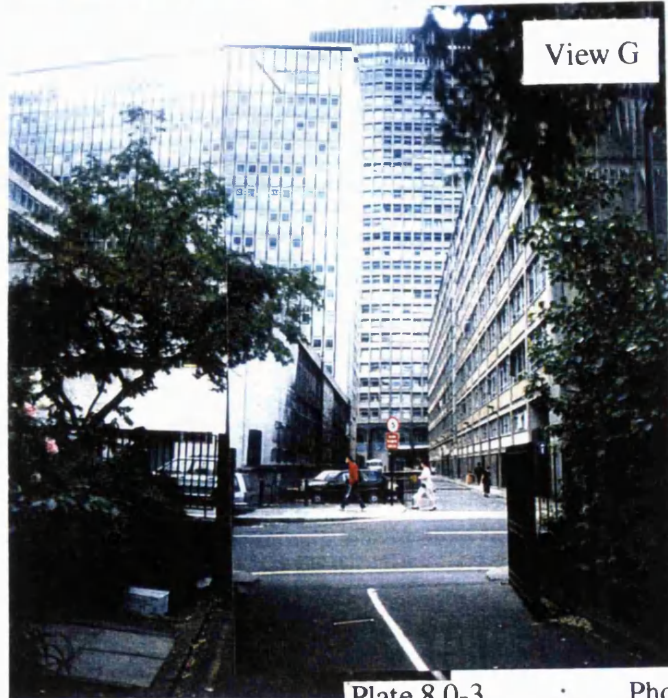




View F



View H



View G



View I

Plate 8.0-3 : Photographs of Pearl assurance Building and the buildings surrounding it.

Table 8.3a: sample job classification

Job category	No of People	Female	Male
Managerial	11	7	4
Clerical	9	3	6
Professional	4	1	3
Technical	0	-	-
Admin	17	4	13
Others	3	3	-

Table 8.3b: Age and gender of sample

Age			16-19	20-29	30-39	40-49	50-65	unspec
Gender	male	26		8	6	5	6	1
	female	18		5	6	1	3	3
No Sample		44		13	12	6	9	4

Table 8.3c: distribution of sample over the floors

Floor	No of Female	No of Male	No of workers
2	5	3	8
3	2	1	3
4	4	11	15
6	7	11	18
Total no of workers	18	26	44



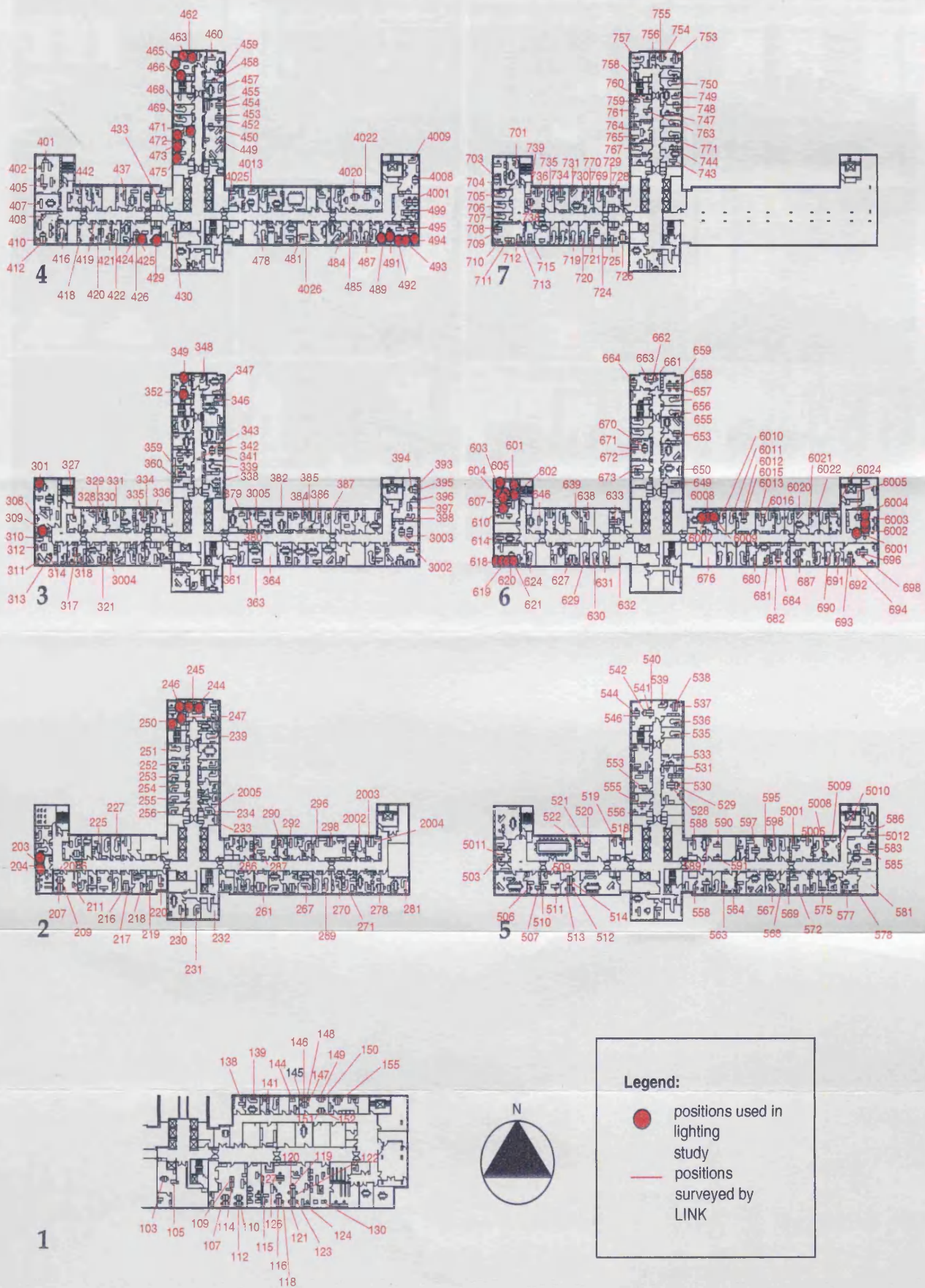


Figure 8.3: The Location of the 44 work positions used in the lighting study and the locations surveyed by LINK





Plate 8.3a : photographs of work positions





Plate 8.3b : photographs of work positions





Plate 8.3c : photographs of work positions





Plate 8.3d : photographs of work positions



Figure 8.4.1a : Distribution of occurrence of eye symptom in the sample (as experienced by occupants)

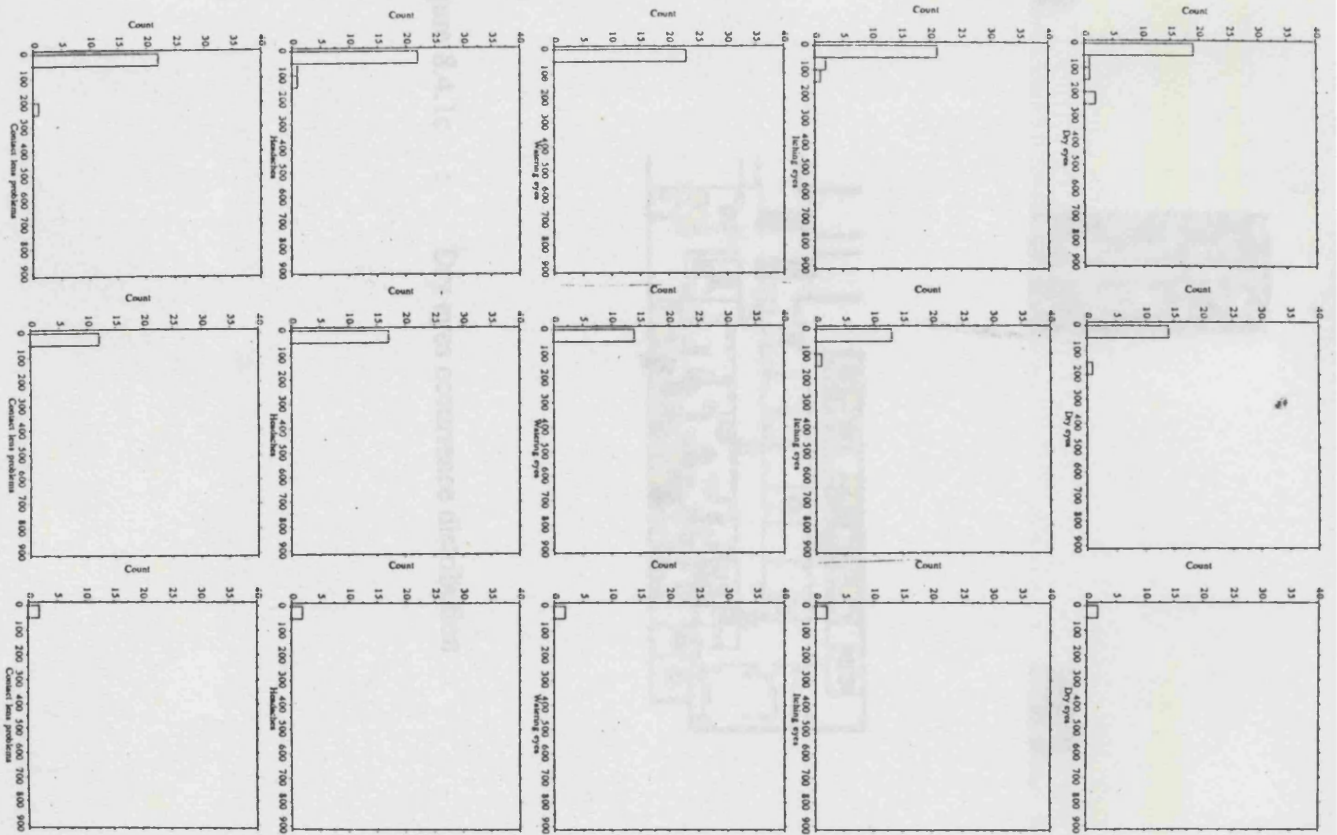
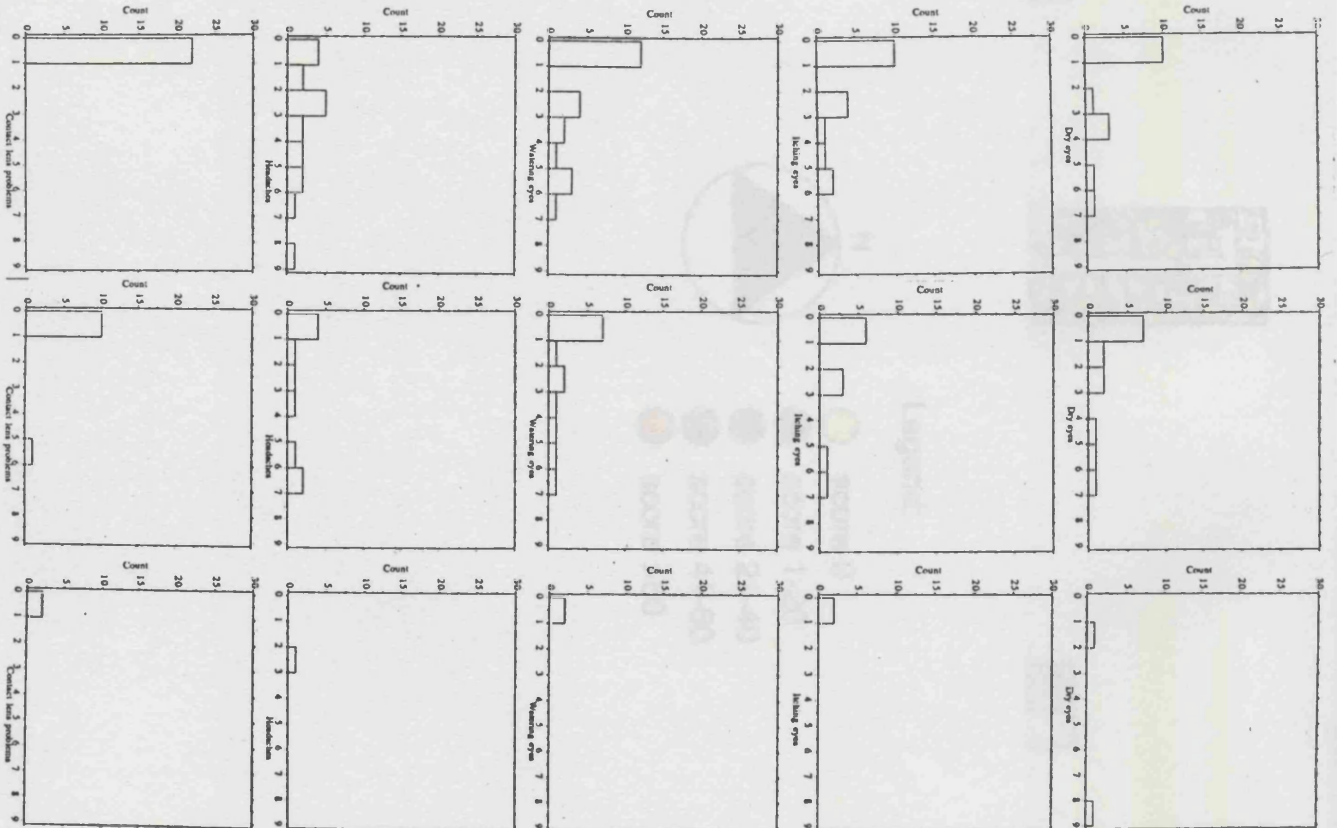
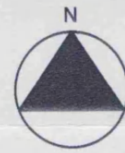
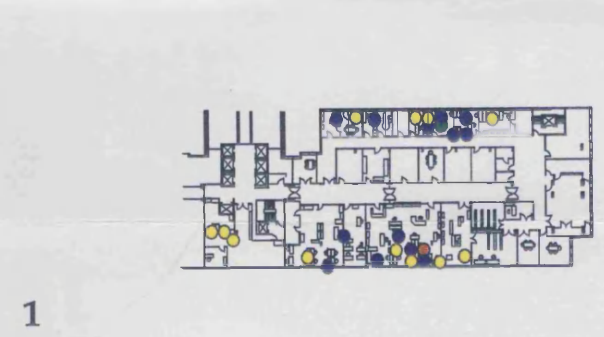
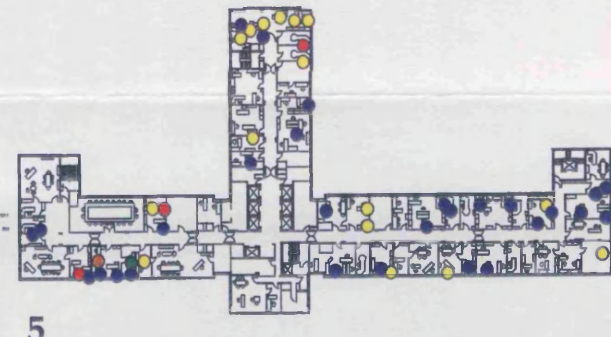
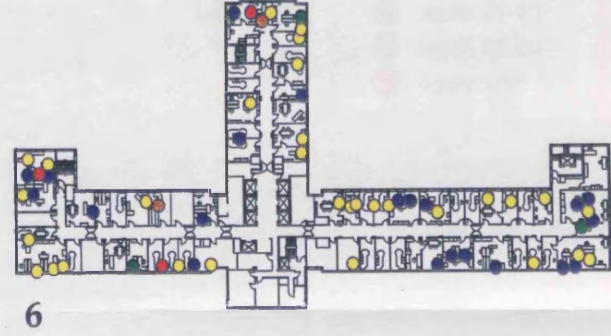
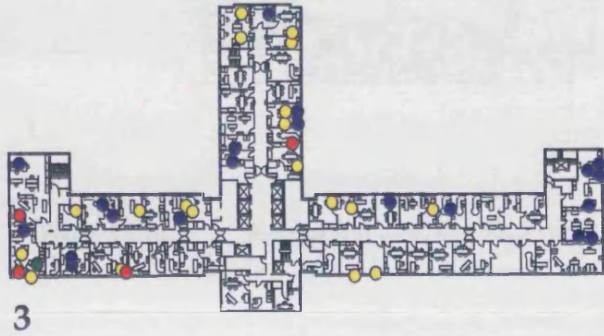
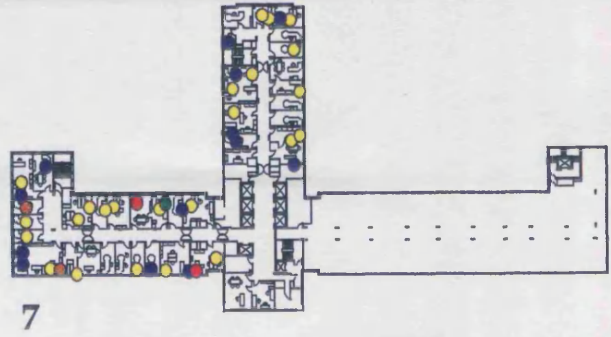
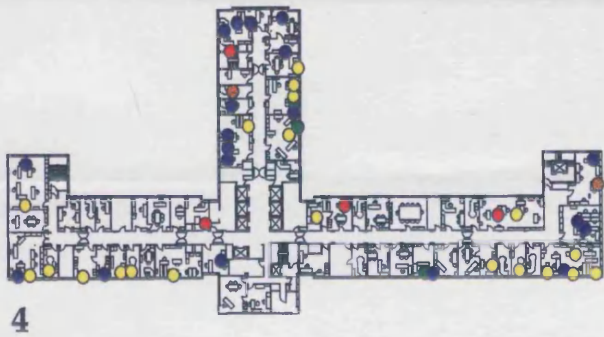


Figure 8.4.1b : Distribution of occurrence of eye symptom in the sample (range 0-50)

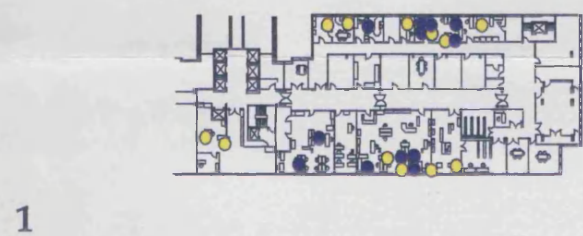
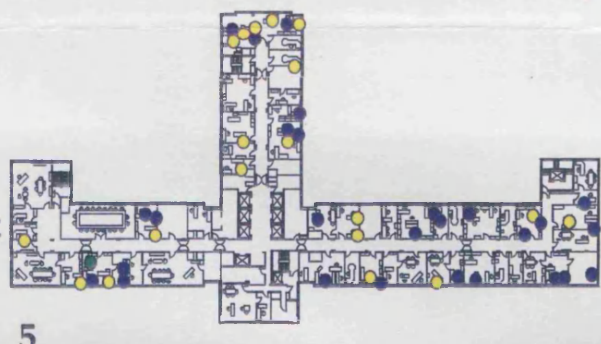
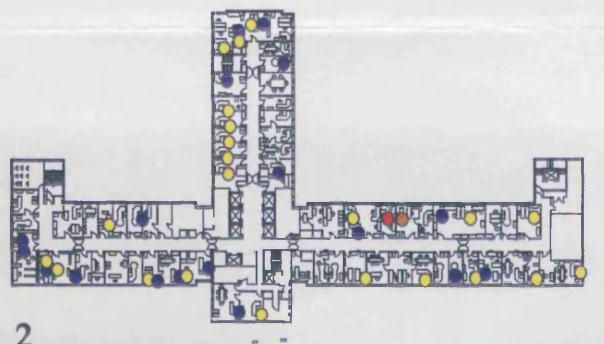
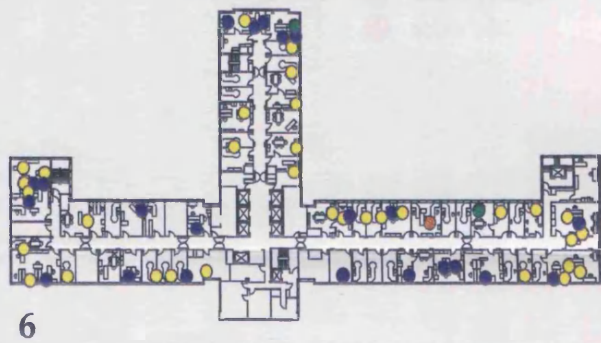
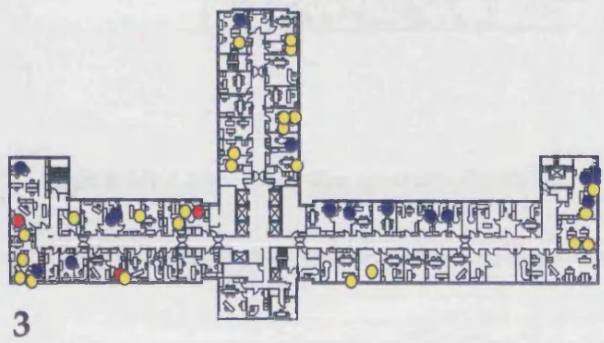
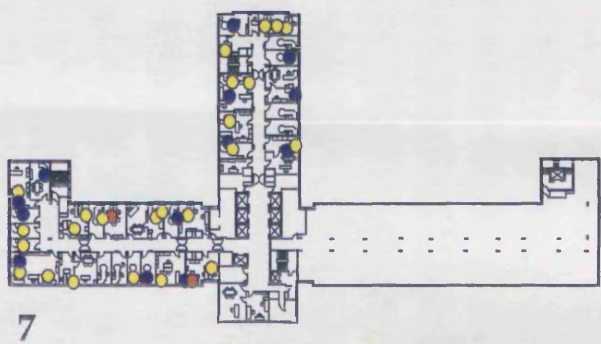
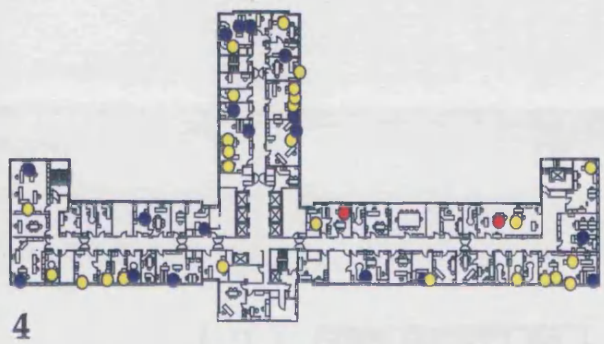




- Legend:
- score 0
  - score 1-20
  - score 21-40
  - score 41-60
  - score >60

Figure 8.4.1c : Dry eyes occurrence distribution





Legend:

- score 0
- score 1-20
- score 21-40
- score 41-60
- score >60

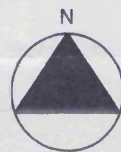
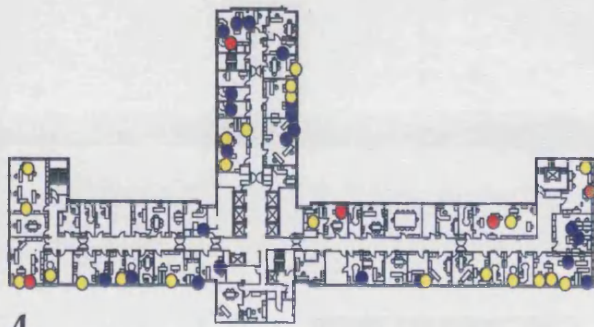
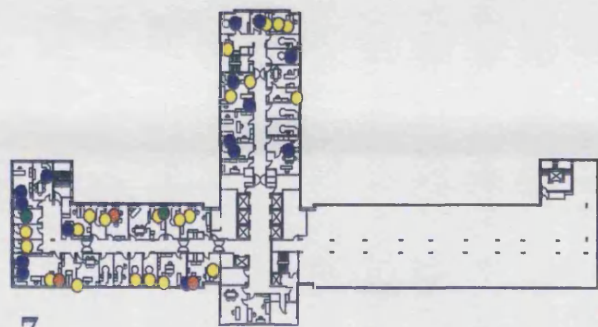


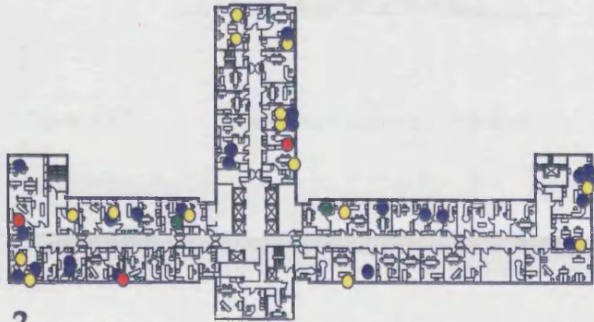
Figure 8.4.1d : Watering eyes occurrence distribution



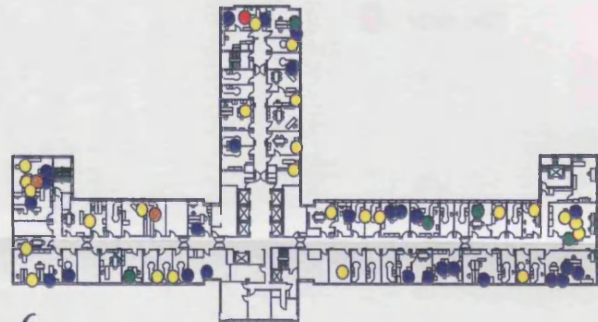
4



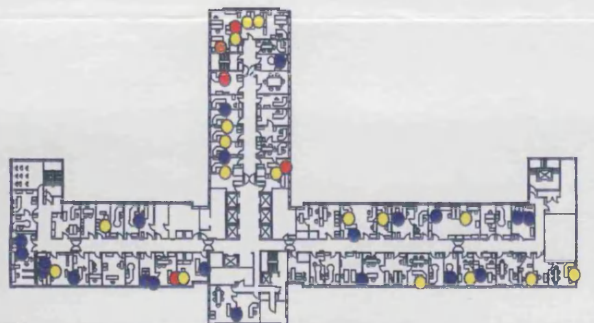
7



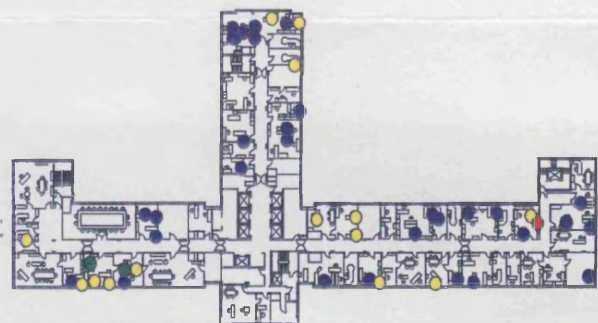
3



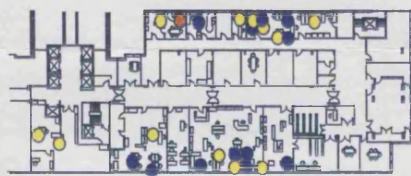
6



2



5



1

Legend:

- score 0
- score 1-20
- score 21-40
- score 41-60
- score >60

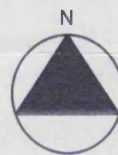
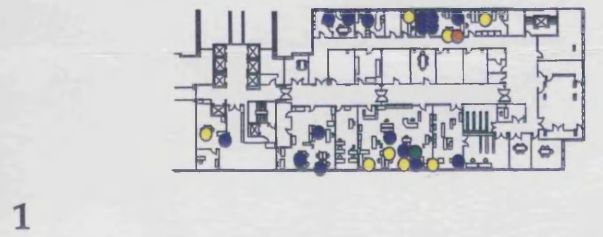
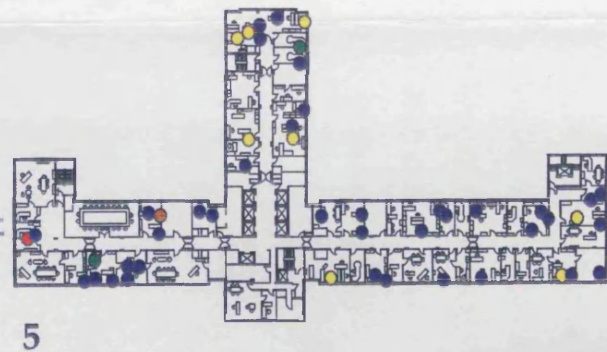
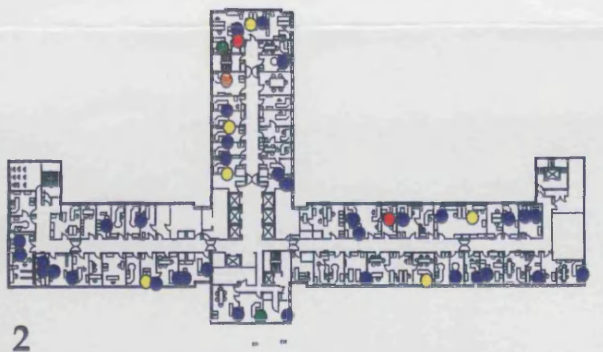
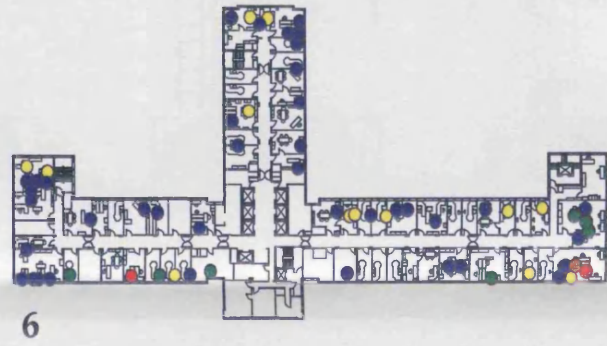
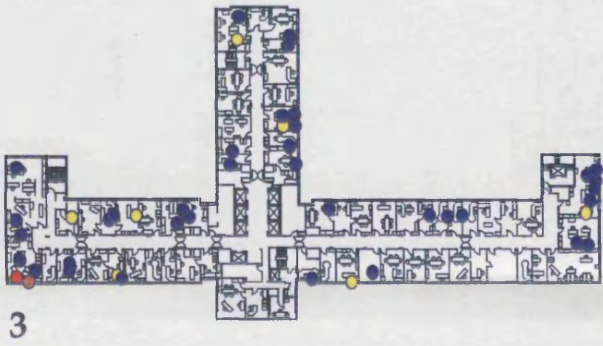
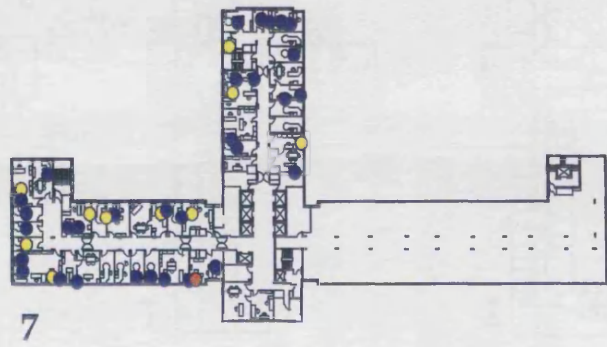
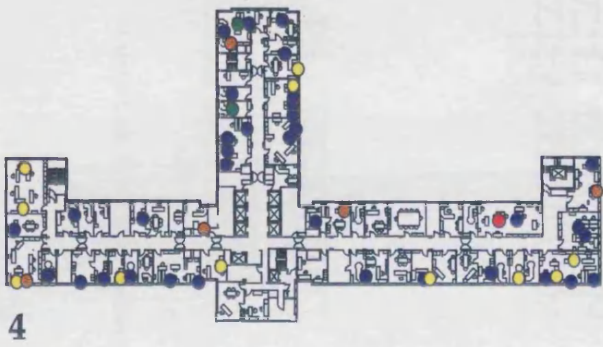


Figure 8.4.1e : Itching Eyes occurrence distribution





- Legend:
- score 0
  - score 1-20
  - score 21-40
  - score 41-60
  - score >60

Figure 8.4.1f : Headaches occurrence distribution

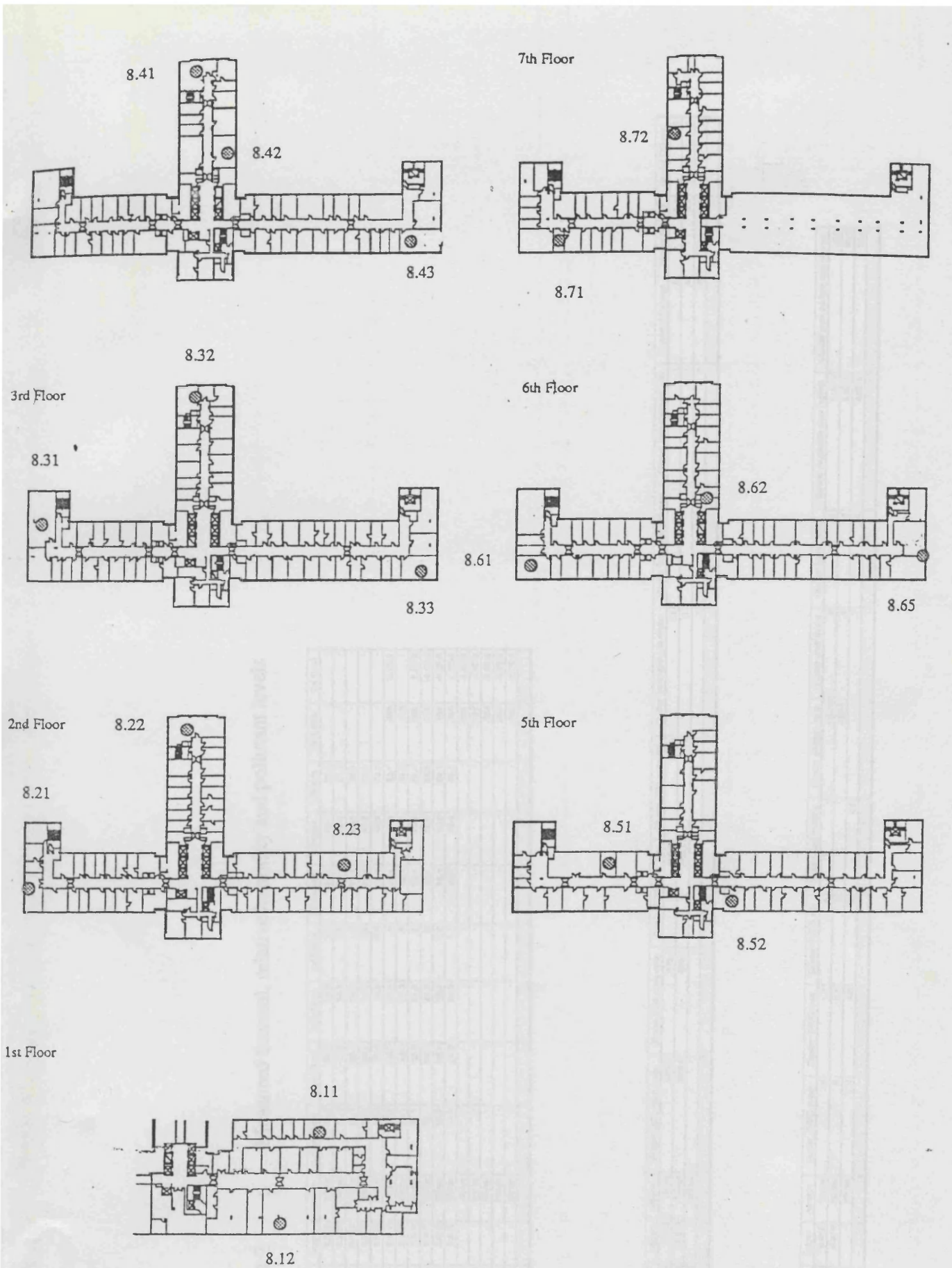


Figure 8.4.2: LINK Environmental Monitoring Location



Table 8.4.2 : Measured thermal, relative humidity and pollutant levels

Floor	cluster	logger	season	LmeanTemp	LmaxTemp	LMinTemp	LstdTemp	LAHmean	LAHmax	LAHmin	Vel 1.25m	Vel Grad
2	*	B.210	Winter	22.2	26.0	18.8	1.3	32.1	40.8	23.1	-	-
2	*	B.220	Winter	21.9	24.5	18.8	1.1	32.1	40.8	23.1	-	-
2	*	B.230	Winter	23.7	26.4	20.0	1.0	32.1	40.8	23.1	-	-
3	*	B.310	Winter	23.2	26.2	19.2	1.2	32.1	40.8	23.1	-	-
3	*	B.320	Winter	24.8	33.8	19.2	2.8	32.1	40.8	23.1	-	-
4	B.4	B.410	Winter	23.1	26.0	21.0	.8	32.1	40.8	23.1	.063	3.6E-2
4	B.4	B.410	Winter	23.1	26.0	21.0	.8	32.1	40.8	23.1	.130	.1
4	B.4	B.410	Winter	23.1	26.0	21.0	.8	32.1	40.8	23.1	.069	2.0E-3
4	B.2	B.410	Winter	23.1	26.0	21.0	.8	32.1	40.8	23.1	.076	-4.1E-2
5	B.6	B.610	Winter	23.9	28.8	20.0	1.2	32.1	40.8	23.1	102	-6.0E-3
5	B.6	B.610	Winter	23.9	28.8	20.0	1.2	32.1	40.8	23.1	199	1.7E-2
6	B.6	*	Winter	-	-	-	-	-	-	-	.063	-3.2E-2
6	B.6	*	Winter	-	-	-	-	-	-	-	.137	4.6E-2
6	*	*	Winter	-	-	-	-	-	-	-	.064	-3.2E-2
6	*	*	Winter	-	-	-	-	-	-	-	.067	-3.3E-2
6	*	*	Winter	-	-	-	-	-	-	-	.064	-2.0E-2

Floor	cluster	logger	season	Cluster CO2 room mean	Cluster CO2 room max	Cluster CO2 room min	Cluster CO2 room std	Cluster formaldehyde mean	Cluster formaldehyde max	Cluster formaldehyde min	Cluster CO mean	Cluster CO max	Cluster CO min
4	B.4	B.410	Winter	480.3	673.7	368.8	63.4	.1	.1	.1	.2	1.8	.2
5	B.6	B.610	Winter	628.6	678.4	360.3	72.9	.1	.1	.1	.3	2.3	.2
6	B.6	*	Winter	-	-	-	-	.1	.1	.1	.3	2.6	.2

Floor	cluster	logger	season	Cluster TVOC mean	Cluster TVOC max	Cluster TVOC min	Cluster dust mites/g	Cluster antigen ng/g	Cluster shelf factor	Cluster fleece factor	Cluster respirable dust mg/m3	Cluster max particle size micron
4	B.4	B.410	Winter	.3	1.7	.1	-	400.0	.6	.6	3.0E-2	36.0
5	B.6	B.610	Winter	.6	6.1	.1	-	600.0	.6	.6	3.0E-2	60.0
6	B.6	*	Winter	1.0	4.3	.1	6.0	-	.7	.6	4.0E-2	36.0

Figure 8.4.3a : Distribution of Occupants assessments of Appearance of Work position

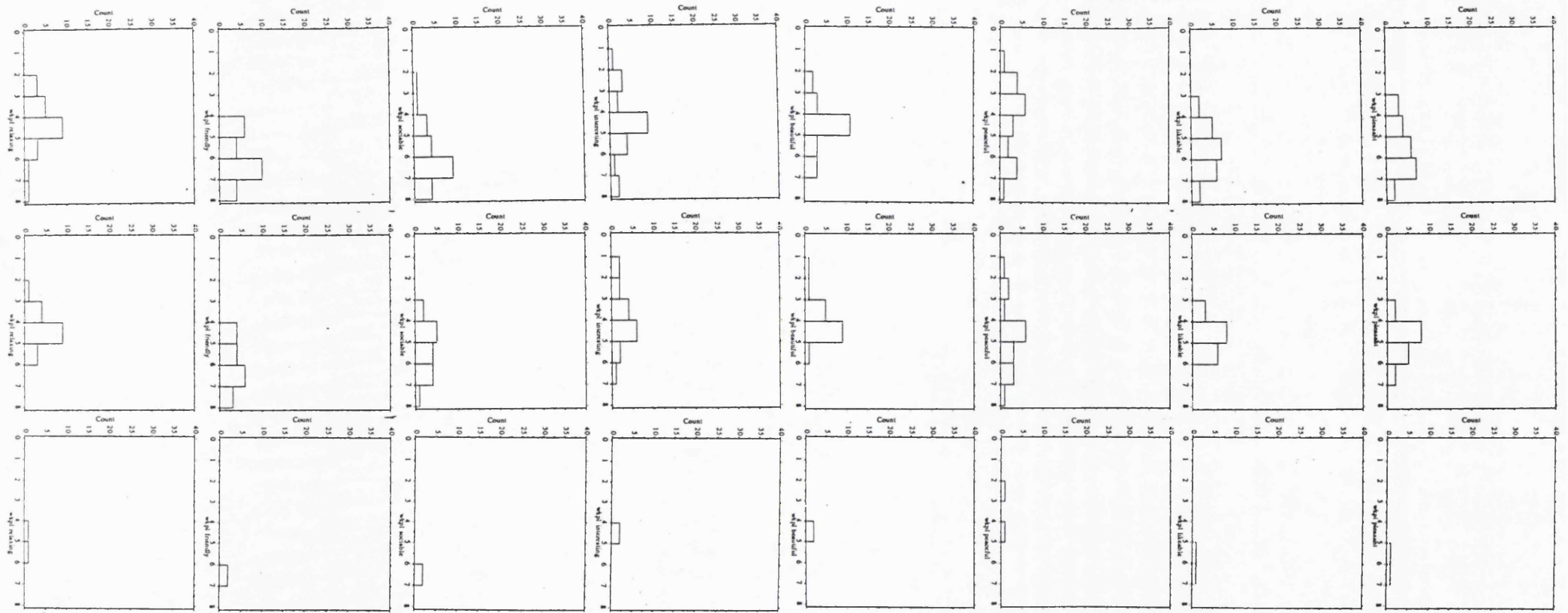


Figure 8.4.3b : Distribution of Occupants assessments of Appearance of Work position

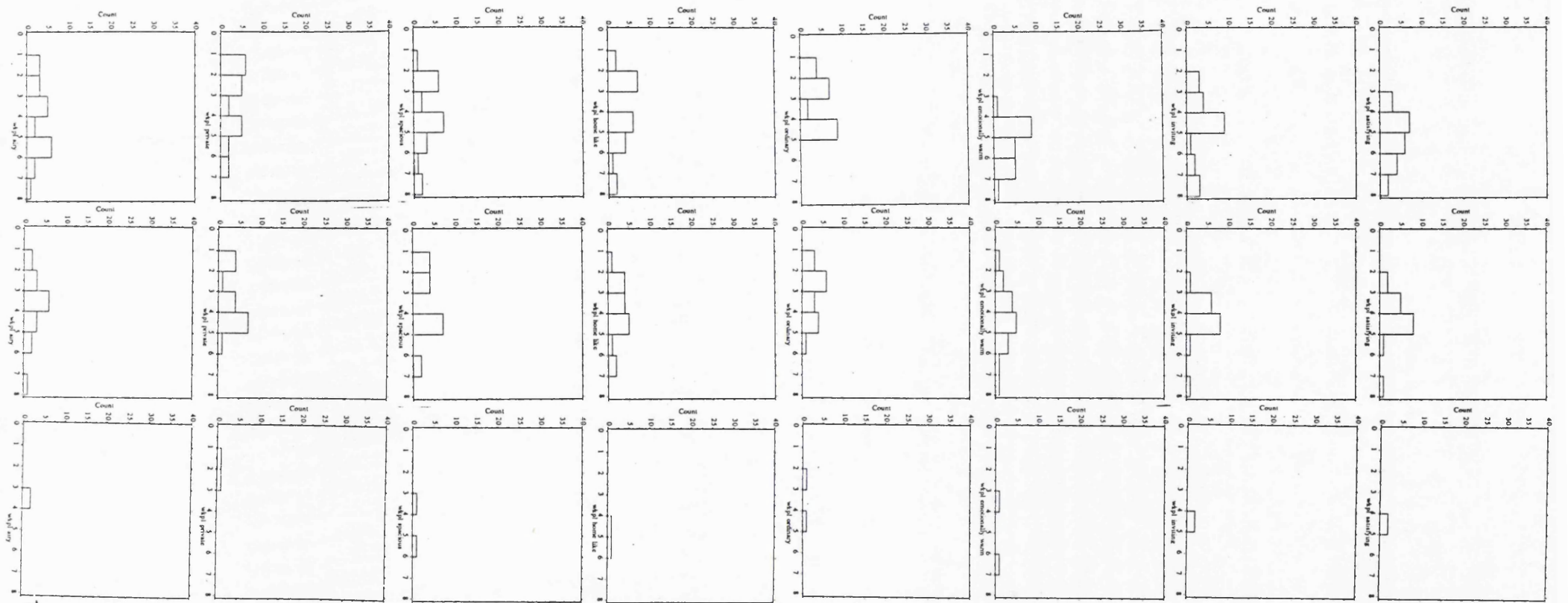


Figure 8.4.3c : Distribution of Occupants assessments of Appearance of Work position

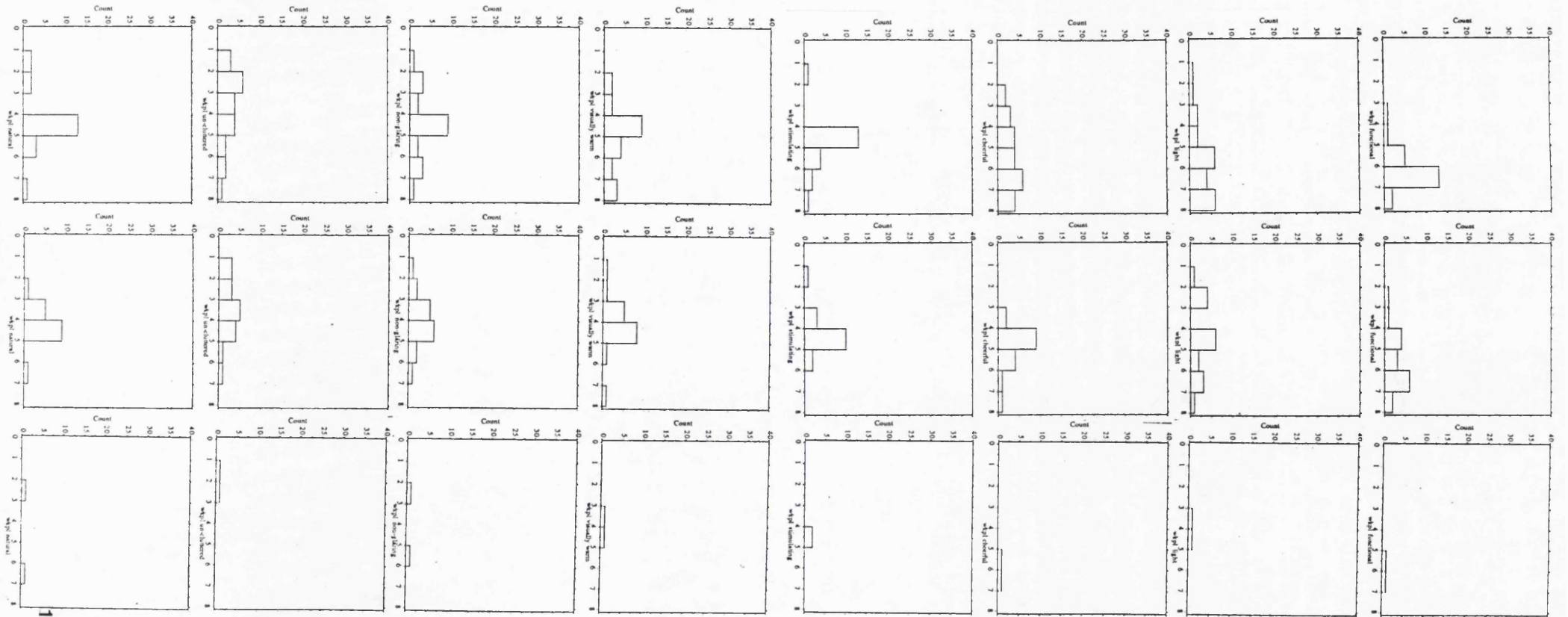


Table 8.4.4: range of physical measurements

SUBJECTIVE QUALITY	Range of Physical measurements		
	Facing Windows	Siding Windows	Backing Windows
Isoarea (IA)	5.1 - 51.5	1.97 - 43.3	14.6 - 24.7
Win solid <	88.2 - 684	0 - 242	0
Sky solid <	0 - 379.8	0 - 117.8	0
Sky/Win	0 - 0.8	0 - 0.9	0
D ave(L)	42 - 287	37 - 387	64 - 65
D WT(E)	134 - 1397	219 - 1380	560 - 590
Deye(E)	111 - 768	97 - 699	358 - 402
Dmax(L)	1.9 - 6873	44.9 - 2246	163.1 - 209.2
Dmin(L)	0.8 - 20.0	0.2 - 13.9	1.7 - 3.8
Dmax/min	0.7 - 3661.1	16.3 - 2495.6	42.9 - 123.1

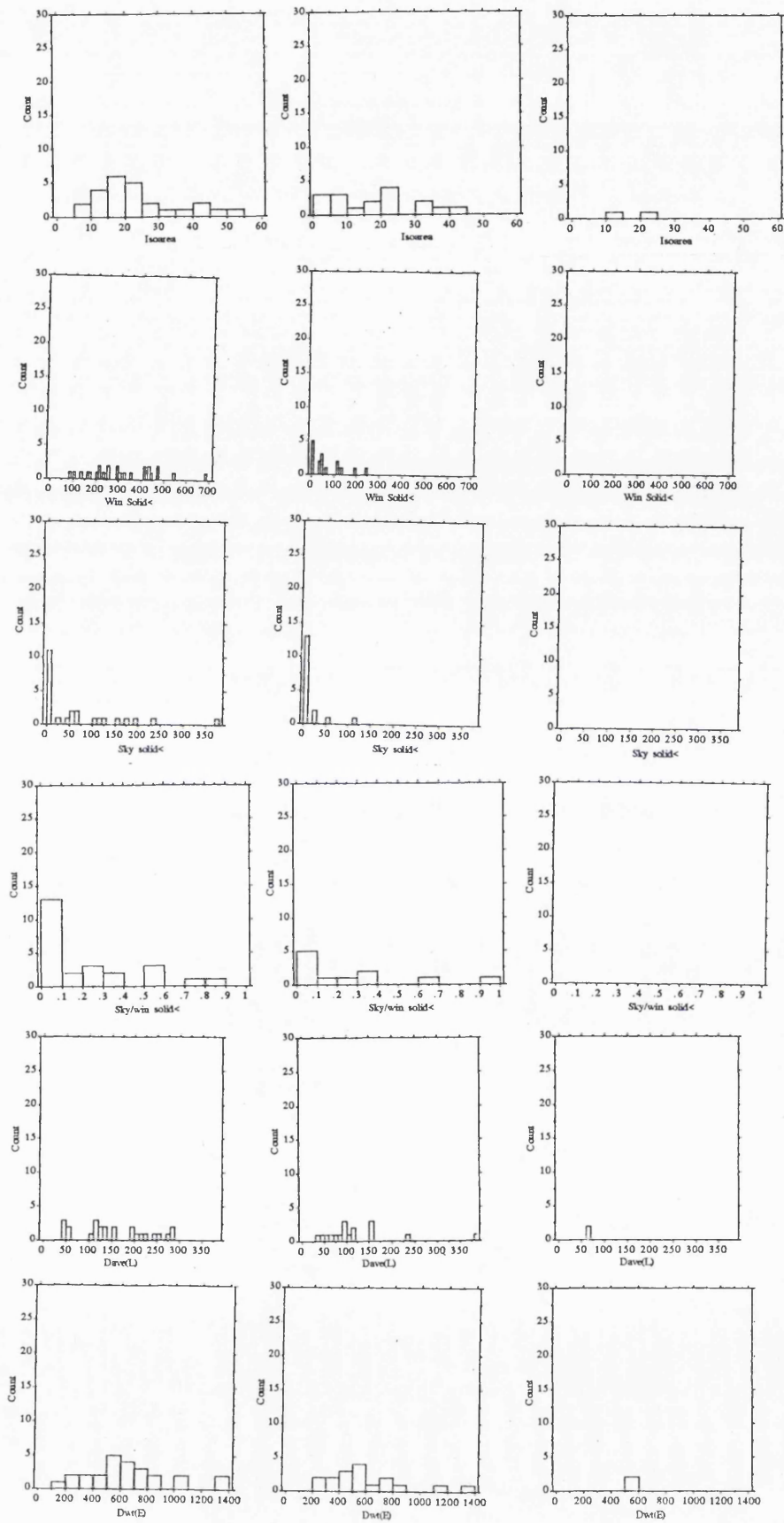


Figure 8.4.4a : The distribution of the measured physical light attributes for the group



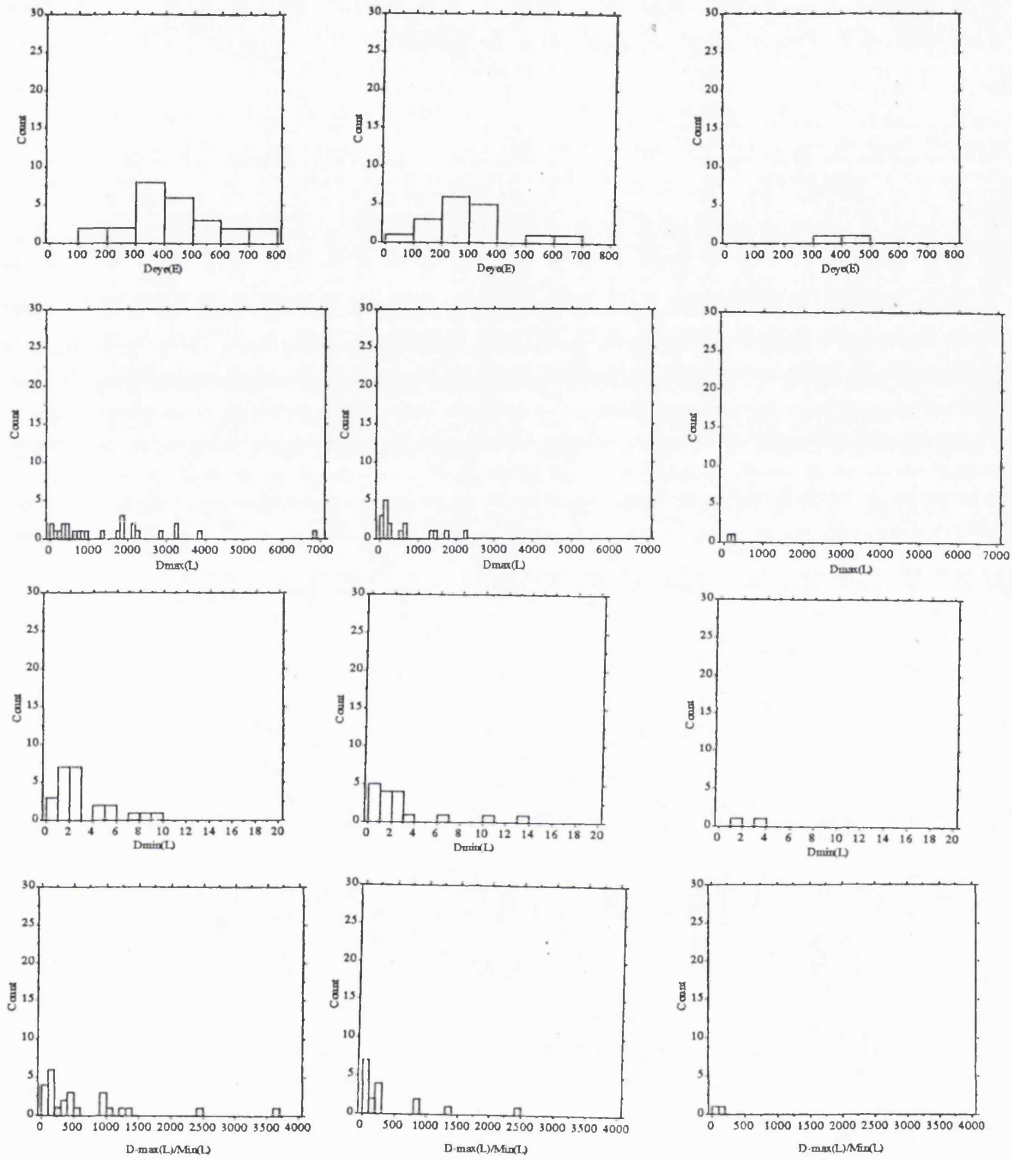


Figure 8.4.4b : The distribution of the measured physical light attributes for the group

Table 8.6a: Difference of symptom occurrence with respect to occupants Location

Symptom	Kruscal-Wallis Analysis		Mean Comparison					
	Seat orientation wrt window		Facing Window		Siding Window		Backing Window	
	H	p	Mean	STD	Mean	STD	Mean	STD
No of occupants			23		15		2	
Dry Eyes	1.46	0.48	29.7	64.4	11.8	39.9	4.5	4.9
Itching Eyes	2.09	0.35	12.1	24.7	10.1	27.3	0	0
Watering Eyes	1.57	0.46	1.7	2.1	1.6	2.1	0	0
Headaches	0.35	0.84	11.2	22.2	9.2	9.4	6	5.6
Contact Lense Prob	1.57	0.46	9.5	45.8	2.6	7.5	0	0

N.B: H indicated is corrected for ties

Table 8.6b: Comparison of Workspace Appearance between Seat Orientation

SUBJECTIVE QUALITY	Kruscal-Wallis Analysis		Mean Comparison					
	Seat orientation wrt window		Facing Window		Siding Window		Backing Window	
	H	p	Mean	STD	Mean	STD	Mean	STD
No of Occupants			24		17		2	
Pleasant	4.3	0.11	5.0	1.2	4.4	0.9	5.5	0.7
Likeable	8.0	0.01	5.0	1.1	4.2	0.7	5.5	0.7
Peaceful	1.6	0.45	3.8	1.7	4.2	1.6	3.0	1.4
Beautiful	3.3	0.19	4.1	1.1	3.5	0.9	4.0	0
Interesting	1.9	0.39	4.0	1.5	3.4	1.4	4.0	0
Sociable	3.7	0.16	5.4	1.3	4.8	1.2	6.0	0
Friendly	0.5	0.79	5.5	1.1	5.5	1.1	6.0	0
Relaxing	1.2	0.55	3.9	1.2	3.8	0.8	4.5	0.7
Satisfying	8.0	0.01	4.8	1.2	3.7	1.2	4.0	0
Inviting	0.8	0.66	4.2	1.6	3.8	1.1	4.0	0
Emotionally warm	4.9	0.09	4.8	1.0	3.8	1.5	4.5	2.1
Unusual	0.2	0.90	2.7	1.2	2.6	1.2	3.0	1.4
Homelike	1.1	0.57	3.6	1.8	3.4	1.4	4.5	0.7
Spacious	1.9	0.39	3.7	1.7	3.1	1.7	4.0	1.4
Private	1.8	0.41	2.9	1.7	3.0	1.3	1.5	0.7
Airy	0.9	0.64	3.7	1.7	3.2	1.5	3.0	0
Functional	1.9	0.39	5.6	0.9	5.0	1.4	5.5	0.7
Light	5.5	0.06	5.1	1.7	4.0	1.7	3.5	0.7
Cheerful	2.6	0.27	4.9	1.6	4.4	1.0	5.5	0.7
Stimulating	4.4	0.11	4.4	1.2	3.7	0.9	4.0	0
Visually Warm	4.7	0.10	4.5	1.4	3.6	1.3	3.5	0.7
Non-glaring	1.1	0.58	4.0	1.5	3.5	1.2	3.5	2.1
Colourful	0.3	0.87	3.7	1.8	3.4	1.2	3.5	0.7
Quiet	3.5	0.17	3.5	1.7	4.1	1.5	3.0	0
Hot	0.02	0.99	4.1	1.5	4.1	1.2	4.0	0
Clean	1.9	0.38	4.8	1.4	4.2	1.2	4.5	0.7
Uncluttered	2.6	0.27	3.3	1.7	3.0	1.4	1.5	0.7
Natural	0.9	0.63	3.8	1.4	3.7	0.9	4.0	2.8
Sat charac & atmosph	2.9	0.23	3.0	0.9	3.1	0.9	4.0	0
Sat visual appearance	2.4	0.30	2.8	0.6	3.1	0.9	3.0	1.4

N.B: The higher the mean the better the subjective assessment

Table 8.6c: Comparison of Measured Lighting Variables between Seat Orientation

	Kruskal-Wallis Analysis		Mean Comparison					
	Seat orientation wrt window		Facing Window		Siding Window		Backing Window	
No of Occupants			24		17		2	
SUBJECTIVE QUALITY	H	p	Mean	STD	Mean	STD	Mean	STD
Isoarea (IA)	1.1	0.57	23.1	12.5	18.6	3.1	19.6	7.1
IP	1.4	0.49	20.0	5.0	17.6	6.7	19.7	3.4
Win solid <	26.9	0.0001	318.9	147.7	69.2	72.6	0	0
Blind solid <	10.5	0.005	68.7	69.0	20.9	36.1	0	0
Sky solid <	7.3	0.02	71.4	95.5	13.4	30.6	0	0
Sky/Win	0.3	0.85	0.2	0.2	0.2	0.3	0	0
Blind/Win			0.3	0.4	0.3	0.3	0	0
D ave(L)	4.7	0.09	155.7	79.2	121.0	83.1	64.5	0.7
D WT(E)	0.5	0.76	648.2	314.3	603.3	304.6	575.0	21.2
Deye(E)	8.0	0.02	426.3	167.5	302.1	147.7	380.0	31.1
Dmax(L)	9.2	0.01	1625.3	1567.0	584.9	683.2	186.2	32.6
Dmin(L)	2.0	0.4	3.9	4.1	3.2	3.8	2.7	1.5
Dmax/min	5.3	0.07	671.7	845.4	423.2	649.4	83.0	56.7
Eye(E)/Ave(L)	4.6	0.10	3.2	1.4	2.8	1.0	5.9	0.4

N.B: H indicated is corrected for ties