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Citation for published version (APA):

van Duijnhoven, J., Aarts, M. P. J., Rosemann, A. L. P., & Kort, H. S. M. (2017). Office lighting characteristics determining occupant's satisfaction and health. In M. Kobav (Ed.), *Lighting for modern society: proceedings of the Lux Europa 2017* (pp. 384-388). Lighting Engineering Society of Slovenia.

Document status and date:

Published: 20/09/2017

Document Version:

Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

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Office lighting characteristics determining occupant's satisfaction and health

J. van Duijnhoven, M.P.J. Aarts, A.L.P. Rosemann, H.S.M. Kort

Department of the Built Environment
Eindhoven University of Technology
Eindhoven, the Netherlands
j.v.duijnhoven1@tue.nl

H.S.M. Kort

Research Centre for Innovations in Health Care
University of Applied Sciences Utrecht
Utrecht, the Netherlands

Abstract—Light beneficially influences human health directly, but moreover, indirectly via occupant's satisfaction with lighting. This study identified parameters influencing occupant's satisfaction with lighting. During a five-day study, 46 office workers evaluated their office lighting conditions once a day using the Office Lighting Survey. The significant correlations between satisfaction with lighting and the lighting statements in the OLS indicated that the aspects 'brightness', 'distribution', and 'reflections' are of importance. These aspects relate to the lighting parameters 'illuminance', 'uniformity', 'luminance distribution', 'glare', and 'luminance'. The significant correlations between general health and the lighting descriptors became not significant when the correlation was controlled for satisfaction with lighting. This research shows the relevance of investigating satisfaction with lighting and its possible (beneficial) aftereffects. Including this knowledge in the lighting design process is important as office workers' satisfaction with lighting and their health will clearly be determined by the overall lighting situation provided at their workplace.

Index Terms— Field study, Occupational Health, Office landscape, Office Lighting Survey (OLS), Visual comfort

I. INTRODUCTION

Office environments have recently evolved from individual offices to shared office landscapes. A general lighting design in combination with central lighting control reduces the office workers' ability to set the lighting conditions in accordance with their individual needs, desires, and preferences. In order to apply the preferred lighting conditions per individual office worker, it is necessary to control lighting conditions per individual. Moreover, it is essential to know which aspects influence these individual needs and preferences as well as the impact of light on their satisfaction with lighting and their general health in order to design and control the lighting conditions.

Light influences human health via the circadian timing system [1] and via environmental satisfaction [2]. In order to assess occupant's satisfaction with lighting, Boyce and Eklund developed an Office Lighting Survey (OLS) in 1995 [3]. This questionnaire is often used in light effect studies to determine people's experiences and evaluations regarding office lighting [4],[5],[6].

The objective of this study was to identify parameters which relate to the overall satisfaction with lighting of office workers within office landscapes. These parameters are expected to contain several office lighting characteristics, but other environmental or personal aspects may also play a role in determining office workers' satisfaction with lighting.

II. METHOD

The five-day study was performed in May 2016 in an office building in the Netherlands. This office building consisted of two floors mainly designed as office landscapes. The office featured in total 83 workplaces equipped with computers and all had a view to the outside.

A. Lighting conditions

The weather conditions varied throughout the study period from overcast sky on Monday to clear sky on Friday. The windows on the ground floor did not contain a blind system, whereas at the first floor an automatic blind system was installed. The office landscapes were lit by dimmable suspended luminaires (Prolicht, Glorius, Ø1400 7x14//24W

DALI) and dimmable LED spots (Quadro LED reflector 31W 2100lm 3000K or Quadro LED Reflector 53W 2400lm), see Fig. 1 and Fig. 2.



Figure 1: Suspended luminaires (Prolicht, Glorius)



Figure 2. LED spots (Quadro led reflectors)

B. Participants

Forty-six office workers (22 male and 24 female) participated in this research. The participants all voluntarily participated and signed an informed consent form. The majority of the participants fell in the age category '25-34 years' and reported that their most performed task was 'using the computer'.

C. Procedure

The participants were asked to fill in the Office Lighting Survey (OLS) (27 items) at the end of their workday (\pm 16:00h) regarding the lighting conditions at the workplace they were working at that moment. Each participant completed at least one questionnaire and at most five questionnaires. In total, 113 questionnaires were collected and included in the data analyses. Overall satisfaction with lighting, assessed via the OLS, was rated on a 5-point scale from (1) 'very satisfied' to (5) 'not at all satisfied'. One of the 27 questions was regarding their self-reported general health.

D. Data analysis

All questionnaire data were analysed in IBM SPSS Statistics 23. Normality tests showed that all data was not normally distributed; therefore, non-parametric tests were applied to analyse the data. Kendall's tau correlation coefficients were calculated to identify correlations and the Mann-Whitney test was applied to investigate differences between two groups. All tests were performed two-sided since it was expected that there were relations between external explicators and satisfaction with lighting, no direction was predicted. The significance level of 0.05 was used to identify statistical significance.

III. RESULTS

This section provides the results separately for satisfaction with lighting and self-reported general health.

A. Satisfaction with lighting

Satisfaction with lighting was analysed in relation to the environmental aspects (the location of the office worker and the lighting descriptors from the OLS questionnaire) and in relation to personal aspects (the user characteristics of the office workers).

1) Environmental explanations for satisfaction with lighting

The office policy included flexible workplaces so the office workers were able to choose their own workplace each day. However, the office workers did not choose different workplaces across the two floors. They were working either

at the ground floor or at the first floor. Office workers working at the first floor (69 questionnaires) reported to be equally satisfied with the lighting conditions compared to the office workers at the ground floor (44 questionnaires). The difference between both floors was not significant ($U=1433.5$, $p=.585$).

Many significant correlations were found within the lighting descriptors of the OLS itself (see Table 1). The overall satisfaction with lighting correlated significantly with six statements (i.e., S1: Overall the lighting is comfortable, S2: The lighting is uncomfortably bright for the tasks that I perform, S3: The lighting is uncomfortably dim for the tasks that I perform, S4: The lighting is poorly distributed here, S6: Reflections from the light fixtures hinder my work, and S7: The light fixtures are too bright). All statements but statement 1 correlated negatively with the satisfaction with lighting. This indicated that the absence of uncomfortably bright or dim lighting, a poor lighting distribution, reflections from light fixtures, and too bright light fixtures led to a higher satisfaction with lighting. In addition to statements 2 and 3, it was found that the tasks of the participants played a role in determining occupant's satisfaction with lighting. Significant correlations were found between the overall satisfaction with lighting and the rating of lighting for different office tasks (i.e., reading from paper, reading from computer, writing on paper, typing on computer, drawing on paper, and drawing on computer). There was also a significant correlation between the overall satisfaction with lighting and the evaluation of the amount of light for the work that was performed at that moment ($\tau=0.554$, $p=.000$).

The lighting conditions were described in three attributes in the questionnaire: electrical lighting (i.e., (1) bad to (5) good), the brightness of the lights (i.e., (1) too much light to (5) does not get too bright), and glare from the lights (i.e., (1) high glare to (5) no glare). The overall satisfaction with lighting correlated significantly and negatively with all three attributes. The correlation between the brightness of the lights and the overall satisfaction suggests that people rather prefer too much light compared to a lighting situation in which the lighting does not get too bright.

In the questionnaire, the glare aspect was subdivided into five categories (i.e., reflected glare from work surface, glare from ceiling lights, glare from task lights/desk lamps, bright lights in workspace, and glare reflected in computer screen). The strongest correlation of these five was between overall satisfaction and the bright lights in the workspace ($\tau=0.454$, $p=.000$).

The last significant correlation within the OLS was found between overall satisfaction and the appearance of lighting compared to similar workplaces.

2) *Personal explanations for satisfaction with lighting*

Male participants reported to be statistically less satisfied with the lighting compared to female participants ($U=1023$, $p=.001$). There was no significant differences in overall satisfaction with lighting between office workers younger than 35 and office workers equal or older than 35 years ($U=1440$, $p=.673$) and between office workers with or without glasses or contacts ($U=1454$, $p=.812$).

Office workers who reported that their most performed task was not computer-related reported a higher overall satisfaction with lighting compared to the office workers who said their most performed task was using a computer. However, this difference was not significant (Mean Rank no comp= 53.04, Mean Rank comp=57.47, $U=558.5$, $p=.627$).

B. *General health*

General health was assessed on a five-point scale from (1) excellent to (5) poor. Self-reported general health (Mean=2.08, $SD=0.734$) correlated significantly with the overall satisfaction with lighting, five lighting statements (i.e., S1,S2,S4,S6,S7), the three attributes, five of the six tasks (task 5 not significant), four of the five glare cases (glare case 5 not significant), the amount of work, and the evaluation of the amount of light for the work that is performed. A significant correlation was also found between general health and the overall satisfaction with lighting of the office workers ($\tau=0.398$, $p=.000$). People who reported a higher satisfaction with lighting also reported a higher general health. When the correlations between the lighting descriptors and general health were controlled for overall satisfaction with lighting, all correlations became not significant.

TABLE I. CORRELATION COEFFICIENTS BETWEEN OVERALL SATISFACTION WITH LIGHTING AND SUBJECTIVE LIGHTING DESCRIPTORS WITHIN THE OFFICE LIGHTING SURVEY (τ = KENDALL'S TAU CORRELATIONS, P=SIGNIFICANCE LEVEL, TWO-SIDED TEST, * INDICATES SIGNIFICANCE (P<0.05))

Subjective OLS Items	Overall satisfaction with lighting
S1: Overall the lighting is comfortable (agree – disagree)	$\tau = 0.740, p=.000^*$
S2: The lighting is uncomfortably bright for the tasks that I perform (agree – disagree)	$\tau = -0.672, p=.000^*$
S3: The lighting is uncomfortably dim for the tasks that I perform (agree – disagree)	$\tau = -0.250, p=.005^*$
S4: The lighting is poorly distributed here (agree – disagree)	$\tau = -0.481, p=.000^*$
S5: The lighting causes deep shadow (agree – disagree)	$\tau = -0.094, p=.287$
S6: Reflections from the light fixtures hinder my work (agree – disagree)	$\tau = -0.394, p=.000^*$
S7: The light fixtures are too bright (agree – disagree)	$\tau = -0.515, p=.000^*$
S8: My skin is an unnatural tone under the lighting (agree – disagree)	$\tau = -0.061, p=.488$
S9: The lights flicker throughout the day (agree – disagree)	$\tau = -0.164, p=.062$
How does light appear compared to other buildings (Worse – about the same – better – I don't know)	$\tau = -0.255, p=.002^*$
Attribute 1: Electrical lighting (Bad 1 2 3 4 5 Good)	$\tau = -0.557, p=.000^*$
Attribute 2: How bright are the lights? (Too much light 1 2 3 4 5 Does not get too bright)	$\tau = -0.356, p=.000^*$
Attribute 3: Glare from lights (High glare 1 2 3 4 5 No glare)	$\tau = -.367, p=.000^*$
Task 1: Reading from paper (Excellent - Pretty good – Neutral – Not very good – Poor – Not applicable)	$\tau = 0.324, p=.000^*$
Task 2: Reading from computer (Excellent - Pretty good – Neutral – Not very good – Poor – Not applicable)	$\tau = 0.580, p=.000^*$
Task 3: Writing on paper (Excellent - Pretty good – Neutral – Not very good – Poor – Not applicable)	$\tau = 0.347, p=.000^*$
Task 4: Typing on computer (Excellent - Pretty good – Neutral – Not very good – Poor – Not applicable)	$\tau = 0.578, p=.000^*$
Task 5: Drawing on paper (Excellent - Pretty good – Neutral – Not very good – Poor – Not applicable)	$\tau = 0.181, p=.026^*$
Task 6: Drawing on computer (Excellent - Pretty good – Neutral – Not very good – Poor – Not applicable)	$\tau = 0.385, p=.000^*$
How would you describe the amount of light (Much too bright – A bit too bright – Just about right – A bit too dim – Much too dim)	$\tau = -0.467, p=.000^*$
Glare case 1: Reflected glare from work surface (Not at all bothersome – Not very bothersome – Fairly bothersome – Bothersome – Not applicable)	$\tau = 0.290, p=.000^*$
Glare case 2: Glare from ceiling lights (Not at all bothersome – Not very bothersome – Fairly bothersome – Bothersome – Not applicable)	$\tau = 0.378, p=.000^*$
Glare case 3: Glare from task lights/desk lamps (Not at all bothersome – Not very bothersome – Fairly bothersome – Bothersome – Not applicable)	$\tau = 0.361, p=.000^*$
Glare case 4: Bright lights in workspace (Not at all bothersome – Not very bothersome – Fairly bothersome – Bothersome – Not applicable)	$\tau = 0.454, p=.000^*$
Glare case 5: Glare reflected in computer screen (Not at all bothersome – Not very bothersome – Fairly bothersome – Bothersome – Not applicable)	$\tau = 0.308, p=.000^*$
Would you say that the amount of light for the work you do is (excellent – good – fair – poor)	$\tau = 0.554, p=.000^*$

IV. DISCUSSION

The significant correlations between overall satisfaction with lighting and the lighting statements indicated that the aspects 'brightness', 'distribution', and 'reflections' are considered as relevant. These aspects can be determined with the lighting parameters 'illuminance', 'uniformity', 'luminance distribution', 'glare', and 'luminance'. It is notable that statement 8 (i.e., my skin is an unnatural tone under the lighting) did not correlate significantly with overall satisfaction with lighting. This may be explained by the fact that only two questionnaires were filled in with 'agree' and therefore no significant correlation was found. The lighting conditions may have differed too less to get more discrepancy in the answers on this statement.

Based on the separate glare cases within the OLS, it was found that glare from bright lights influenced the overall satisfaction with lighting the most. Reflected glare from the work surface influenced overall satisfaction the least (i.e.,

the lowest correlation coefficient). All desks within the office space were white coated but were covered by a black desk pad. This black surface may have caused less reflections from the work surface.

All significant correlations between general health and the lighting descriptors disappeared when the correlation was controlled for overall satisfaction with lighting. This demonstrates the importance of people's satisfaction with lighting regarding their general health. Former studies also demonstrated this link between environmental satisfaction or satisfaction with lighting and self-reported general health [2][7].

The current study demonstrated that multiple subjective lighting characteristics influence overall satisfaction with lighting. Although The International Commission on Illumination (CIE) recommends researchers to investigate a wide variety of behavioral and health outcomes that might reasonably be affected by light exposure [8], often only one or a few lighting parameters were investigated in light effect studies. The CIE mentions that it is not impossible to write recommendations for healthful lighting; however, there should be a cautious and conservative approach in which the recommendations describe the total lit environment and not individual elements within it [8].

V. CONCLUSION

The office workers' satisfaction with lighting was significantly related to almost all OLS questions (except three statements including lighting descriptors). The large number of correlations within the OLS highlights that satisfaction with lighting concerns a combination of multiple lighting descriptors. Therefore, it is recommended to include a large variety of lighting characteristics (e.g., illuminance, uniformity, luminance distribution, glare, and luminance) when investigating occupant's satisfaction with lighting and/or occupant's general health.

This research shows the relevance of investigating overall satisfaction with lighting and its possible (beneficial) aftereffects. Including this knowledge in the lighting design process is important as office workers' satisfaction with lighting and their health will clearly be determined by the overall lighting situation provided at their workplace.

ACKNOWLEDGEMENT

We would like to thank the company Bolidt (Hendrik-Ido-Ambacht, the Netherlands) and its employees for granting the opportunity to perform this study in their office building. This research was performed within the framework of the strategic joint research program on Intelligent Lighting between TU/e and Koninklijke Philips N.V. and the Impuls II SPARK program.

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