This is an ‘**Accepted Manuscript’** of an article published by
Taylor & Francis Group in **Occupational Therapy in Healrth Care**
on 31 December 2021, available online:
https://www.tandfonline.com/doi/abs/10.1080/07380577.2021.2020388

Impact of Lighting Assessment and Optimization on Participation and Quality of Life in Individuals with Vision Loss

T. B. Øien[a]*, A. M. Jacobsen[b], S. T. Tødten[b], T. Ø. Russotti[b], P. Smaakjær[b], and R. S. Rasmussen[b]

[a] *Department of the Built Environment, Aalborg University, Copenhagen, Denmark;*
[b] *Department of Vision, Centre for Special Education (CSU), Slagelse, Denmark*

Turid Borgestrand Øien (cand.arch, PhD) ORCID: 0000-0003-1163-1038
Department of the Built Environment
The Faculty of Engineering and Science
Aalborg University
A.C. Meyers Vænge 15
DK-2450 Copenhagen, Denmark
Tel: 0045-51427368
Email: tuo@build.aau.dk

Anne Mette Jacobsen (OT)
Signe Tornøe Tødten (OT)
Tine Østergaard Russotti (TCH)
Peter Smaakjær (OD) ORCID: 0000-0002-0861-4010
Rune Skovgaard Rasmussen (MSc, PhD) ORCID: 0000-0002-5630-122X

Impact of Lighting Assessment and Optimization on Participation and Quality of Life in Individuals with Vision Loss Abstract

This pilot study was designed to investigate the effects of a holistic lighting intervention on the quality of life for individuals with low vision.

Sixty participants (44 women; median age 69 years) with visual impairment received lighting interventions, including a home visit and consultation in a lighting lab. Assisted by low vision consultants, participants evaluated their performance using the Canadian Occupational Performance Measure (COPM) before and after the intervention. Improvements in visual functioning and quality of life were evaluated using the 39-item *National Eye Institute Visual Function Questionnaire* (NEI VFQ-39), the *Groffman Visual Tracing Test*, and the *Farnsworth Dichotomous Test* (D15).

Following the lighting intervention, scores improved for all activities in the COPM ($p < 0.01$), for near activities and vision-specific role difficulties in the VFQ-39 ($p < 0.05$), and overall in the D15 test ($p < 0.05$). These results suggest the intervention provided an effective method for improving the participants' quality of life and performance.

Keywords: low vision rehabilitation; lighting assessment; domestic lighting; activities of daily life; quality of life

Introduction

In the Western world, people spend more than 85% of their time indoors (Klepeis et al., 2001). For Europeans, the share is 90%, and two thirds of this time is spent at home (WHO, 2014). Lighting has been associated with quality of life in both objective and subjective measures (Brawley, 2009; Stephenson et al., 2012; Sörensen & Brunnström, 1995; Falkenberg et al., 2019). Insufficient domestic lighting can cause falls among seniors (Figueiro, Gras, Rea, Plitnick & Rea, 2012) and the risk of falling is particularly high among people with vision impairment (Carter, 1994). Optimal lighting conditions are essential for visual function in general, and for people experiencing visual impairment in particular, as they can enhance visual acuity and contrast sensitivity (Markowitz, 2006). Since depression and social isolation are prevalent among people with vision impairment (Carter, 1994) optimal lighting is also crucial to support their social interaction, such as being able to perceive and read facial expressions (Lane et al. 2018).

Studies which show that visual function measured in clinical settings is generally better than visual function measured at home stress the relevance of in-home evaluations (Bhorade et al., 2013). The majority of people with visual impairment and blindness are elderly. In Denmark, 77% of those with visual impairment are over 70 years old (Socialstyrelsen, 2019) and this will gradually grow to 82% by 2050 (Statistics Denmark, 2019). As the world's population is ageing the need for low vision rehabilitation is increasing (Perlmutter et al., 2013). Accordingly, lighting assessments are gaining ground in Danish services for people with low vision. However, the initiatives have, by and large, been implemented by individual consultants with varying degrees of lighting expertise, the procedures have been unstructured, and the effects have gone undocumented.

Research on home lighting assessments for people with low vision is rare but includes studies on near-task lighting (Perlmutter et al., 2013), individual lighting prescriptions (Butler et al., 2019), and changes in daily activities and quality of life due to improved domestic lighting (Brunnström et al., 2004). In general, experts have controlled decision-making in these studies, choosing the lighting prescriptions, the locations in the home, and the scope of the assessments (e.g., limiting assessment to a pre-defined category such as everyday activities).

The impact of different lighting levels on objective performance and subjective preferences varies idiosyncratically across individuals, a finding which calls for greater involvement of participants in lighting assessments and prescriptions (Evans et al., 2010). Investigators have expressed a need for studies "that examine the impact of a home-based, client-centered, multifaceted approach to lighting intervention" and explore the "qualitative experience of lighting environments" (Perlmutter et al., 2013, p.680). In line with the rehabilitative turn in health services to more client-centered care and service provision, clients should use their own expertise to co-create the processes of mastery, learning, and change (Lund & Hjortbak, 2017). This client-expertise covers knowledge of their own lives and preferences, their surroundings, and the relationship between these aspects. This move from providing expert-only solutions to facilitating a collaborative process generates a need for "professional and situational reflection work" (Lund & Hjortbak, 2017), where the professional navigates and balances the different types of knowledge at play and relates the rehabilitation to the physical, social, and temporal context of the individual (Wade, 2005). Addtionally, technological developments in lighting have made this home-based and client-centered approach even more relevant as the wide range of manufacturers and products can be difficult for people to navigate. The complexity needs to be translated and "without good advice, people will not make changes" (Butler, 2015, p. 201).

The low vision services in Denmark are organized nationally in two national centers and 23 regional or municipal centers each covering 1–18 municipalities. A majority of the centers are organized as centers for communication or special education, with interdisciplinary teams working in departments covering vision, hearing, and speech. This study investigated how improved lighting conditions affected those in need of low vision rehabilitation.The aim of the study was to measure the effect of a lighting assessment and intervention on occupational performance and the quality of life of the participants.

Methods

Setting from 2017 to 2019, the Vision Department at the Centre for Special Education (CSU) in Slagelse, Denmark, developed and investigated a holistic lighting assessment as part of their services. The pilot project was initiated from a dialogue within the community of practice and the Danish Association of the Blind, and a shared acknowledgement of the need for more knowledge on lighting in low vision rehabilitation. The development process involved an interdisciplinary group of experts from different departments of the organization as well as external consultants, some of whom are authors of the current study.

Participants

All participants were recruited by two occupational therapists working as low vision consultants. Participants were people of all ages who were experiencing issues with performance of activities due to domestic or work-related lighting and who could be supported during the intervention by a relative or a significant other. The inclusion of the relative or significant other was based on the experience that recommendations regarding lighting were more likely to be implemented when the visually impaired citizen was accompanied. Thus, inclusion criteria were broader than the traditional threshold for low vision, defined as reduced visual acuity of less than 0.3 (6/18) in the better-seeing eye that cannot be corrected using eyeglasses, contact lenses, or by medical or surgical interventions. Participants who normally wore glasses were asked to keep and use the same specific pair throughout the intervention.

Participants were excluded if they were considered unable to complete the intervention due to deteriorating health conditions, if they were considered to have profound cognitive problems like dementia, if they were unable to understand instructions due to other circumstances, or if they were unaccompanied. Written informed consent was obtained from all participants.

Procedure

Three stages were included in this study: 1) lighting assessments in participants' home environments, 2) lighting intervention testing different lighting setups in the lighting lab and finding recommendations for optimal lighting for the individual, and 3) follow-up measurements conducted in participants' home environments or by phone to document the changes implemented by the participants themselves.

Baseline Assessment

Visual Function Questionnaire 39 (VFQ-39) (Mangione et al., 2001; Sørensen et al., 2011). Prior to the home visit the VFQ-39 was distributed to the participants by mail or email in order to assess the effect of their visual impairments on their quality of life before and after the intervention (Sørensen et al., 2011). The questionnaire was used to measure participants' perception of daily functioning and quality of life regarding vision. VFQ-39 is an extended version of the VFQ-25 (Mangione et al., 2001), and includes questions focusing on general health and constructs related to vision as well as social functioning, mental health, role difficulties (e.g., difficulty in accomplishing desired tasks, limited endurance, etc.), and dependency on others.

Canadian Occupational Performance Measure (COPM) (Law et al., 1990). In the home of a participant, occupational issues were identified through a narrative interview. The participant described everyday challenges where they experienced difficulties in performance of activities due to visual impairment or nuisance from the lighting conditions, and each participant identified up to three of their most important activities. These activitites were rated using the COPM, an individualized tool for measuring a person's perception of performance of self-identified activities of importance in daily life. Participants identified difficulties in performing daily activities within the categories of *self-care*, *productivity*, and *leisure*. As the participants themselves identified their three activities of greatest concern, the activities that were investigated did not necessarily cover all of the categories. The activities were listed as primary, secondary, and tertiary issues. For example, a list of self-identified difficulties could be: 1) preparing a meal in the kitchen, 2) reading a book in the living room, and 3) finding clothes in the bedroom wardrobe. Each issue was rated from 1 to 10 for importance, performance, and satisfaction with performance, and constituted the primary baseline measurement of the study. The ratings were repeated after the intervention to measure its effect.

Groffman Visual Tracing Test (GVT) (Groffman, 1966) and Farnsworth Dichotomous test (D15) (Farnsworth, 1947).The participant's visual function was measured at the locations of these activities, and wearing their spectacles if this was applicable to the participant's normal practice, using GVT and D15. The GVT is a performance test where the participant visually follow a line of intersecting and overlapping lines from the top to the bottom of a page, where execution time and number of lines recognized are recorded (Groffman, 1966). The D15 is a test used to assess color vision defects, where the participant arranges a panel of 15 different colors, and the measure includes execution time and the order of colors (Farnsworth, 1947). The more errors in this test, the longer the line length when the 15 different colors are placed continuously in the periphery of a circle, and responses are drawn as a continuous line by connecting all colors corresponding to the order chosen by a participant. To calculate D15 Line Length and errors a website tool was used (Török, 2013). Shorter line length and fewer errors indicate better vision performance. The GVT and D15 are quantitative and performance based, yet not dependent on reading or writing skills, or other cognitive skills and therefore applicable to a broad group of participants.

The light (Lux levels and Kelvin degrees) was measured with an LED spectrometer (MK350, UPRtek) at the location of the task investigated, for example at the surface of the dining table or the kitchen-top. If the task was moving through the apartment, it was measured at a height of about 80 cm, which is a pragmatic measure between the typical height of a desk/tabletop and a countertop.

These measurements were supplemented by drawings specifying the light sources and light measurements, and photos of light source locations and the various environments. Throughout the assessment, the low vision consultant informed the participant and relatives about general aspects of lighting and aspects specific to their visual impairment, such as the characteristics of different conditions and expected development, or how an LED works compared to a traditional light bulb.

Prior to the intervention phase, an optometrist measured each participant's visual acuity and contrast sensitivity in the clinic, in order to see if there was an association between visual acuity, diagnosis, and lighting preferences. Visual acuity was measured as baseline characteristics at a distance of three meters from the smallest line without any errors using the standard internal illumination by an internally illuminated computer screen with ETDRS style letters. In the same position and setting, contrast sensitivity was measured using the Topcon Chart 2000 contrast sensitivity chart. The test was conducted binocularly, and subjects requiring vision correction used their eyeglasses or contact lenses. Ultimately, the light threshold, defined as the lowest lighting level needed to obtain the same visual acuity, was measured by an internally illuminated ETDRS style chart in a dark room (5 to 10 Lux). Visual acuity was measured monocularly with habitual correction and the lux level on the chart was measured using a light meter (ISO-TECH ILM 1337).

Intervention

The participants were invited to the clinic to test different lighting options related to the activities identified in the participants' homes. The lighting lab included a 26 m^2 room with a kitchen and dining area, a living room area, and a small play area. The room was further equipped with a closet, a washbasin, and a bathroom mirror to stage bedroom and bathroom settings. Blackout curtains covered the windows and the participant was positioned according to the tested activity. Different lighting, colors, light intensities, lamps, and arrangements were assessed. Starting with a lighting condition resembling participants' home environments, the low vision consultant demonstrated and tested a range of different settings, all of which were continuously compared and assessed by the participant. The goal was to find optimal conditions for each participant in each of their chosen activities (e.g., preparing vegetables at the kitchen worktop) by comparing placements of different light sources. The intervention proceeded by adjusting and observing the interplay between the individual positioned in the activity, the light, and the environment. Information specifying the different bulbs and light (i.e., manufacturer, price, intensity) were provided to participants and their relatives after their preferences for each situation were identified. Different lighting conditions were jointly discussed among the participants and their relatives. Finally, the consultant summarized the lighting prescriptions for each activity and sketched the styles and positions of the suggested lamps, bulbs, and arrangements on a printed photograph of the participants' home environments, which the participants took home.

Follow-up

Follow-up visits were made after approximately four months to repeat outcome measures and document changes made by the participants in their home environments. Photos, corresponding to the ones from the assessment in the first stage, were taken to compare light arrangements at home before and after the intervention, and the changes made were rated by the participants in an endline survey. Participants gave a score from 0 to 10 for the overall range of changes made (0 = no changes made, 10 = all recommended changes made), and gave scores from 1 to 3 to indicate the degree to which they made changes in their environment (1 = none, 2 = partially, 3 = fully) in the following specific categories: Painted; changed the arrangement; acquired new lamps; installed new bulbs. Participants also gave a score from 1 to 3 to indicate the extent to which they received help from others to make these changes. The endline survey also included qualitative feedback regarding the intervention.

Participants who had not made any changes were evaluated by phone and repeated the VFQ-39 and the COPM. However, the Groffman and D15 tests were not repeated, and the endline survey was not conducted.

Statistical analysis

The Wilcoxon signed rank test was used for statistical comparisons of paired data before and after the intervention. Due to the heterogeneous backgrounds of participants and a limited sample size, data was not expected to be normally distributed for all outcome measurements and nonparametric statistics were used. Unless otherwise stated, the results are provided as median values with the corresponding 25th and 75th percentiles in parentheses. All *p* values below 0.05 were considered statistically significant. Participants with missing data were included in the analysis as long as it was possible to measure the primary outcome.

Power and sample size

At the start of the intervention, we expected that participants would reach 30% of the maximum COPM score and that the score would increase to 50% after the intervention. These changes in the COPM were used to calculate the needed sample size. The change from 30 % to 50 % was based on a few pilot observations and may be considered a hypothesis. As the basis for the sample size calculation, we used $\alpha = 0.05$ and power= 0.8, resulting in a sample size of 34 participants. Due to the age of participants and the time-consuming nature of the intervention, we expected 25% of participants to drop out. Thus, we estimated that we needed at least 43 participants.

The results were recorded by consultants and reported for statistical analysis. All analyses were conducted by personnel who were not partaking in the intervention or data collection and who had no competing interests.

Results

The overall intervention was conducted from October 2017 to March 2019. Table 1 summarizes participant's demographic data, the visual diagnoses, and the visual functions measured by the optometrist.

Table 1. Baseline characteristics of the participants in the intervention

Participants (n)	60
Age	69 (45–81) years
Sex, %	
Women	73%
Employment, %	
Retired	55%
Employed	25%
Studying	11%
Other[a]	9%
Accommodation[b], %	
Cohabiting	62%
Living alone	38%
Diagnostics, %	
Age-related Macular Degeneration (AMD)	42%
Retinitis pigmentosa	11%
Cataracts	6%
Glaucoma	4%
Hemianopsia	2%
Other[c]	35%
Visual assessment	
Decimal Acuity[d], Right	0.23 (0.06–0.5)
Decimal Acuity[d], Left	0.18 (0.1–0.4)
Decimal Acuity[d], Binocular	0.28 (0.13–0.66)
Contrast (LogMar)	1.3 (1–1.6)
Baseline threshold value (lux)	300 (190–795)

[a] Prolonged sick leave, attending special courses, or unemployed; [b]Except for one participant living in an assisting living facility, all participants were living in rented or private residences; [c]The category included participants with concussions and rare eye diseases. [d]Decimal Acuity: normal visual acuity is the ability to detect a gap subtending 1 minute of arc, and values below 1.0 are subnormal.

The results from the COPM are shown in Table 2. Participants' primary issues improved for both performance ($p < 0.0001$) and satisfaction ($p < 0.00001$). Similar results were seen for secondary issues; there were improvements in both performance ($p < 0.01$) and satisfaction ($p < 0.0001$). For tertiary issues, both performance and satisfaction improved ($p < 0.001$). Combining the primary, secondary, and tertiary issues into one category, where the maximum score was 30 (3 × 10), both performance and satisfaction improved ($p < 0.001$).

Table 2. Results of the primary and secondary outcomes

	Baseline	After intervention
Canadian Occupational Performance Measure (COPM)		
Primary issues – performance	5 (2.5–6)	**7 (4.5–9)****
Primary issues – satisfaction	4 (2–5.5)	**7 (3.5–9)****
Secondary issues – performance	5 (3–6.75)	**7 (3–8)****
Secondary issues – satisfaction	3 (2–5)	**7 (3–8)****
Tertiary issues – performance	3 (2–5)	**7 (5–8.25)****
Tertiary issues – satisfaction	3 (2–5)	**7 (5–9.25)****
Total (all issues) – performance	12 (8–16)	**20 (15–25)****
Total (all issues) – satisfaction	9 (7–12)	**20 (13–27)****
Groffman Tracing Test		
Number of Points	9 (2–20)	12 (2–21)
Farnsworth D15 (Saturated)		
Total number of errors	26 (16–32)	**23 (13–28)***
Line-length Index	2 (1.25–3)	2 (1–2)
Visual Function Questionnaire 39 (VFQ 25 + Appendix)		
General Health	28 (15–42)	28 (15–42)
General Vision	22 (12–32)	22 (14–32)
Ocular Pain	75 (62–100)	75 (62–100)
Near Activities	29 (21–50)	**38 (25–54)***
Distant Activities	29 (17–56)	27 (17–65)
Vision Specific:		
Social Functioning	58 (38–79)	63 (42–83)
Mental Health	48 (30–70)	53 (30–80)
Role Difficulties	38 (19–50)	**50 (25–69)***
Dependency	62 (38–88)	62 (44–88)
Driving	50 (34–69)	67 (54–79)
Colour vision	75 (50–100)	75 (50–100)
Peripheral vision	50 (25–75)	50 (25–50)

The table shows median values with the 25th and 75th percentiles in parentheses. *$p < 0.05$ and **$p < 0.01$. High scores are best in all tests except the D15. Persons with 20/20 vision and no vision deficits usually score close to 100 in the VFQ-39 items (Clemons Chew, Bressler & McBee, 2003). Groffman scores above 28 are considered normal. For the Farnsworth D15 test, shorter line length and fewer errors indicated better vision performance, the shortest possible line length being 1.0. The COPM reflects primary, secondary, and tertiary issues of daily living instead of areas of self-care, productivity, and leisure.

Comparing improvements of these combined issues, we found that the median performance score changed from 40 to 67 % of the maximum score (from 12/30 to 20/30), while the median satisfaction score changed from 30 to 67 % (from 9/30 to 20/30). Redoing sample size estimations based on these achieved results, this study needed a minimum of only 20 participants, thus there was no indication of the study being underpowered.

Results from the VFQ-39 questionnaire showed that participants experienced improvements for near activities ($p < 0.05$) and achieved a reduction in role difficulties specific to vision ($p < 0.05$). A trend towards improved dependency specific to vision (i.e., less dependency on others) was also observed ($p < 0.08$). No other changes were found with the VFQ-39 questionnaire.

Using the Farnsworth Dichotomous (D-15) color test, participants' total error scores were improved from 26 to 23 ($p < 0.05$). On the line-length index, which indicates the best performance results by the shortest line length, there was a trend of participants improving their performance after the intervention ($p = 0.06$). The endline survey indicated trends of participants primarily having changed lamp fixtures, while other changes like new paint on walls, new bulbs, and other changes in living arrangements were not performed. The qualitative feedback was notanalyzed statistically, but was included in the discussion. No adverse events, including falls, were recorded and the intervention was considered safe for all participants.

Discussion

The results of this study suggest that our lighting intervention provided an effective method for improving quality of life and performance among participants with low vision. The intervention significantly increased clients' perception of their performance and satisfaction with individually selected activities. The participants felt more independent and achieved improved color detection, indicating improved color perception.

The complex workings of vision extend beyond visual acuity, and correction by spectacles only addresses a limited part of the visual experience (Farrall, 1991). Thus, the focus in this investigation was to implement a novel holistic lighting assessment and intervention process. A pivotal aspect of our approach was the narrative interview, which made it possible for participants to take the lead in identifying the most important and pressing activities and performance issues in their home environments. The different elements of the assessment, the detailed assessment of each participant's challenging home activities, lighting measurements, drawings, and photos, provided a basis for the lighting intervention.

Brunnström et al.'s (2004) study bears some resemblance to ours in its examination of types of lighting and use of illuminance and luminance measures in the home environment. However, the prior study differed from ours as it used pre-defined activity categories and locations (kitchen, bathroom, and hall), and lighting adjustments were not client-driven. Perlmutter et al.'s (2013) investigation of a near-task home lighting assessment resembled aspects of the individualized lighting assessment used in our study, and their three-stage design included: 1) descriptions of the lighting environment supported by light measurements and digital photos, 2) light interventions and recommendations, and 3) a follow-up. However, whereas this near-task home lighting assessment was limited to specific activities, our pilot study addressed domestic lighting needs and challenges as experienced by the individual participants.

Drawing on the framework of occupational therapy, our approach acknowledges the physical and social context of each participant by focusing on activities of interest to individual participants, rather than investigating pre-defined activities and controlled environments. Allowing each participant to select and define the most notable issues in their daily life was a source of motivation but also a limitation to the overall measures by causing intervention variation. In tailoring the intervention for each participant, participants received different interventions, which makes the overall assessment and intervention even more comprehensive than the Home Environment Lighting Assessment (Perlmutter et al., 2013) and consequently more dependent on the practice knowledge of the professional.

In addition to more general recommendations on avoiding flicker, glare, and large luminance contrasts, the lighting recommendations regarding specifications of intensity, color temperature, and color rendering, were mainly individual. However, some more general recommendations can be outlined regarding type of lighting, lighting qualities, and environmental aspects, in relation to different activities. Table 3 summarizes some of the more frequently occurring activities listed in relation to self-care, productivity, and leisure.

The main difference of the lighting recommendations is between lighting for near activities (task lighting) and for orientation/movement (general lighting). However, as the participants in their everyday life, were moving between near task activities and orientation/movement in their home environments, the recommendations addressed a combination of the different types of lighting. Furthermore, near activities that included different colors, textures and surfaces, as cooking or handicraft, also required an awareness of the composition and relation between light and shadows on the materials, and consequently recommendations included a flexible lamp.

While the initial lighting assessment in the home was focused on the participants' specific social and physical environment and their individual needs and challenges, the move to the lighting lab facilitated a more explorative approach to lighting. For most participants, the relocation enabled an open investigation of the different lighting options presented, regarding preferences for bulbs and their brightness, color temperature, color rendering, and lamps. Choices for lamps included different manufacturers, types and design properties, locations and orientations, and combinations and distributions. Perhaps most importantly, participants were taught how to test and assess the light themselves.

Table 3. Overview of the most frequentally assessed activities, and the typical associated lighting specifications, including type of lighting, lighting qualities, and environmental aspects.

Activity	**Type**		**Qualities**			**Environmental aspects**				
	Directed lighting	Overall lighting	Balance of light and shadow	Design (shape, material, texture, and surface)	Color rendering	Relation between light zones	Position & direction of light	Position & direction of person	Distribution of light sources	Flexibility of lamp
Self-care										
Looking (at) self in the mirror	x	x	x				x	x		
Finding clothes in the closet	x						x	x		
Eating	x			x	x					
Moving across rooms		x				x			x	
Productivity										
Conducting office work	x	x					x	x		
Cooking	x	x	x	x		x	x			x
Leisure										
Doing handicrafts	x	x	x	x	x		x			x
Reading	x	x		x	x		x			

Contextual aspects such as the role of natural light and direct and reflected glare could also be discussed in this manner. The goal was that these instructions would make the participant able to assess and compare different lighting scenarios themselves. As a way of supporting participants and relatives in their future choice of lamps and light sources, the amount of information provided was adjusted according to the needs of the individual and to the level of interest of both the participant and their relative or significant other.

A similar problem-solving approach to domestic lighting can be seen in Butler (2019), who argued that lighting problems must first be recognized and translated into prescriptions and solutions before these solutions were put into action. However, there are two major differences between Butler's study and the current study. First, low vision rehabilitation in Denmark dates back to the 1950s (Goodrich & Bailey, 2000), while the services in New Zealand are still considered inadequate (Butler, 2019). Second, whereas Butler's lighting prescriptions were based on an expert panel, the prescriptions in our study are co-produced in close collaboration with each participant and a relative or significant other. The involvement of this social relation was an important inclusion criterion as one of the hypotheses of the project was that this attendance was a decisive factor in whether or not the recommendations would be implemented. Active participation in problem identification, testing, prescription, and the acquisition of knowledge about light and how to assess its situational functionalities constituted an encouraging learning process. Relatives gained an understanding of the interplay between lighting and performance of activities for the participant with visual impairment.

The qualitative feedback in the endline survey highlighted various aspects of the intervention that participants found helpful. For instance, some participants emphasized the importance of involving a relative or significant other; one participant noted, "I think involvement of relatives is the alpha and omega." Others described how the intervention had facilitated substantial personal change and learning. One participant explained, "It is great, [it has been] nice to get a gentle push." Another stated, "I have acquired tools to solve my lighting needs." Another said, "Had you not been here, I would have just accepted the terms. It has made a huge difference to my quality of life." One of the participants experienced an effect even though the light had not been changed: "I have not made any changes, but I have myself changed." For some participants, the lighting assessment made no difference, and their vision deteriorated over the time of the study.

Limitations

This pilot study was an open-label longitudinal study, and a major weakness was the lack of a control group. A control group was omitted because all participants expressed a need for help, and we considered it unethical to delay or not provide any help. Despite the limitations, single group studies evaluating outcomes longitudinally are considered an appropriate method and may provide interesting exploratory results (Paulus et al., 2014). In similar future studies, results from participants might be compared to a waitlist control group or a group receiving another type of intervention.

Due to the complex design, it is difficult to determine the impact of different parts of the intervention. Thus, we do not know if similar results could have been achieved without visiting the lighting lab, for example, or whether the adjusted lighting itself or the participants' acquired knowledge of light in daily life made the most impact.

Although the investigation included people of all ages, there was an overrepresentation of elderly people (> 65 years). The majority of participants were retired women who were cohabiting and living in their own homes, and the most frequent diagnosis was age-related macular degeneration. The results may be different among men or younger participants and could differ across different types of diseases and impairments. Limiting such variations was not part of our study's design and may create a bias.

The broad inclusion criteria resulted in a wide variety of visual conditions and functions. Forty-two percent of our participants had age-related macular degeneration (AMD) with central scotomas. Such participants typically do not experience balance problems and difficulty with orientation, especially compared to persons with peripheral visual field defect like glaucoma and retinitis pigmentosa, which were represented in 4% and 11% of the participants.. Limiting the study to a single visual impairment would presumably yield more consistent results. Nevertheless, as many people in this age group experience early vision loss, the lighting assessment can support aging in place for the majority of the population.

All participants were asked to use their spectacles as normal and to keep the same pair of glasses throughout the intervention. During the intervention, we did not assess whether the participant had the appropriate spectacle correction, as our goal was not to measure optimal spectacle correction but to improve lighting conditions. New findings and recommendations for spectacle correction might have caused participants to get new glasses and thereby create a bias in the study.

The positive results obtained by the COPM test could indicate that participants were positively biased by wanting to please the consultants in their subjective ratings. However, the VFQ-39 questionnaire only showed improvements in 2 of the 12 sub-domains, both of which were directly related to near-vision activities, thus participants did not improve on more distant activities on the VFQ-39. A positive bias to please consultants would likely have resulted in significant differences across all of the VFQ-39 sub-domains, which did not happen. Furthermore, the objective measures of the

Farnsworth Dichotomous (D-15) color test also indicated that participants experienced genuine improvements.

Implications for Occupational Therapy Practice

During the course of this study, the interdisciplinary group involved recognized that due to the multiple variables in each individual case—for example, multiple diagnoses or impairments, different levels of coping, complex social or physical contexts—an important part of the rehabilitation was to apply the relevant knowledge to the individual setting. The light measurements collected in the home environments were mainly conducted in order to assess the problem and recreate the lighting conditions in the lighting lab as part of the problem-solving process. Consequently, there is a need for more knowledge regarding the use of lighting assessments in low vision rehabilitation, including practical knowledge of how lighting assessments are conducted and how the knowledge associated with lighting is operationalized. A systematic collection of lighting conditions measured before and after an intervention can however also be a way to assess the quantitative aspects of home lighting environments (Perlmutter et.al, 2013), which can then be analyzed within each specific case or across different cases, according to activity, diagnostics, or specific location.

Locating the intervention phase at the lighting lab enabled a wider range of lamps and set-ups. This supported the participants' learning process by increasing their understanding of the importance of implementing the lighting recommendations. However, in cases of severe cognitive challenges, where learning was limited, or if a visually impaired individual did not have the social support to implement the lighting recommendation, a smaller home intervention would probably be more appropriate. Regarding the follow up, the COPM and VFQ could alternatively have been conducted by phone and telehealth; however we do consider that the Groffman and Farnsworth tests still required our physical presence in order to guide the participants.

The purpose of this investigation was to develop a method for differentiated client-targeted lighting interventions to support independent living among individuals with chronic low vision. Narrative interviews were conducted to gain an understanding of participants' own experiences of challenges in everyday life and to avoid basing interventions solely on professional estimations and suggestions. By focusing on activities of importance to the participants, consultants helped change participants' conceptions of themselves and their surroundings. The participants were open about their challenges, and relating the assessment to activities in their physical and social context was a strength of our approach.

The implication for the practice of occupational therapy and low vision consultants is that lighting assessments for visually impaired individuals can be further improved by the approach and tools of occupational therapy, as exemplified by the assessments and interventions used in this study. In addition, an individualized lighting assessment can be structured to enable and engage people in their social and physical context. Finally, this pilot study established a base of practice knowledge and evidence that can help elevate the existing practice of low vision rehabilitation.

Domestic lighting is an important part of low vision rehabilitation, and the complexity of individuals' needs and challenges calls for a more holistic lighting assessment, addressing both social and physical contexts. This holistic lighting intervention provided an effective method for profoundly improving the quality of life for people experiencing low vision.

Acknowledgments

This work was supported by TrygFonden and Velux Fonden. We would like to thank Professor Marc Fontoynont for his valuable assistance in the development of the lighting assessment.

Declaration of interest statement

The authors declare no competing interests.

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