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LIGHTING CONDITIONS IN THE HOMES OF OLDER ADULTS: ARE THEY SUITABLE FOR HEALTHY AGING IN PLACE?

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Abstract

Many people in industrialized countries would prefer to remain in their own homes for as long as possible. Remaining healthy while aging in place will depend on maintaining suitable indoor environmental quality. This paper reports preliminary online survey results concerning lighting conditions in the homes of older Canadian adults. Older adults who spend close to 24 hours daily in their homes might not receive the recommended daily light exposure of minimum 250 lx melanopic equivalent daylight illuminance from morning until three hours before bed. Those who spend time outdoors might receive an adequate total exposure if shorter or intermittent very high illuminance exposures are equivalent to long periods at a lower level. Survey participants were generally satisfied with their lighting. Regression analyses revealed small but statistically significant effects of light exposures and satisfaction with lighting on sleep and quality of life, which require validation with light logger data.

Keywords: residential lighting, aging, quality of life, lighting satisfaction, light exposure

1 Introduction

The statistics are clear: The global population distribution is changing such that people older than 60 years of age dominate. Already there are more people in this age group than there are children under 5 (World Health Organization, 2024). By 2050, there will be an estimated 426 million people on Earth older than 80 years. Although aging can bring with it a greater disease burden, some people live healthy lives to a great age. The physical environment in all its dimensions, including lighting, is among the determinants of healthy aging (Sorensen and Brunnstrom, 1995). Older adults who have retired from paid work may be more likely to spend much of their time in their homes – and may wish to continue to live in their own homes – making the lighting in the homes of older adults a necessary research target.

There is limited information about residential lighting environments for any population (young or old), and some of this information is dated. Charness and Dijkstra (1999) surveyed homes of older adults in Florida, finding that the light levels in most homes were lower than the recommendations for reading. Similarly, in the Netherlands, Aarts and Westerlaken (2005) observed lower-than-recommended light levels in the homes of older adults living independently, both for tasks and for daytime light exposures measured vertically at the eye.

The first consensus recommendations for a healthy pattern of daily light and dark exposure are both high during the day (a minimum maintained melanopic equivalent daylight illuminance of 250 lx) and low during the evening (maximum maintained melanopic illuminance of 10 lx) (Brown et al., 2022). Although these recommendations were based on studies of healthy young adults, it bears examining whether older adults experience conditions that might meet these recommendations. If conditions in present-day homes are similar to the older studies, this suggests that older adults do not meet these recommendations, let alone the higher exposures that might be needed to account for age-related changes in the visual system (CIE, 2017).

This paper reports preliminary findings from a study of older adults in Canada and the indoor environmental conditions in their homes. The complete project encompasses several parts, including an online population survey and a 12-month field study, both of which consider the full range of indoor environment conditions (acoustics, lighting, temperature, ventilation) in relation to indoor environmental quality satisfaction, quality of life, and sleep. Here, we report selected light exposure, satisfaction, sleep and quality of life data from the online population survey.

2 Method

The research plan was developed collaboratively by all authors, and revised following review by four Experts by Experience – community members with lived experience relevant to the project. All parts of this project were reviewed and approved by the Research Ethics Boards of the participating institutions.

2.1 Participants

The population survey was launched online on March 6, 2024 and remained open until March 10, 2025. Survey announcements were sent by e-mail to over 450 local community groups, neighbourhood newsletters and newspapers, and national organizations of older adults across Canada for circulation to their networks. Project team members circulated them in their private networks as well as to their institutional colleagues. In addition to the online format, we also offered paper surveys through the mail and telephone interviews. All materials and modes were available in both English and French.

The eligibility criteria were having been born in 1963 or earlier, reporting on living in their personal homes, and resident anywhere in Canada. Caregivers to older adults were also invited to participate. There were 452 valid respondents to the survey (interviews and mail-in surveys were manually added to the online database). We selected those participants with complete data on the light exposure, quality of life, and sleep variables of interest. Six outliers were excluded because they reported fewer than 10 hours per day inside their homes (in one case as low as 3 hours), which we judged to be both unrealistic and not consistent with the purpose of the study, which is to evaluate the home. There were 239 cases included.

Their characteristics are reported in Table 1. The sample was nation-wide, although it was not representative of the population distribution in Canada. For example, the province of Ontario is over-represented; its true proportion of the Canadian population is ~39% as opposed to the 69.9% in the sample. The sample was also not representative of the population in terms of housing type. There is an over-sampling of single detached homes)2021 census data shows ~52% of the population, this sample has 69,0%) and under-sampling of apartments/flats/condominiums (2021 census data shows ~34%, this sample has 16,3%) (Statistics Canada, 2023). The income distribution also includes a much larger proportion of higher incomes than the Canadian population.

2.2 Population survey

2.2.1 General

The survey questions covered all aspects of the respondent's home, the characteristics of their indoor environments (including indoor air quality, acoustics, ventilation, temperature, and lighting); comfort and satisfaction with their environmental conditions; home characteristics; adaptive opportunities to modify environmental conditions; access to nature; community characteristics; quality of life; sleep; demographics, health status, future housing intentions, and fuel affordability. Participants were asked to indicate how many hours per day out of 24 they spent in their homes. Scale responses varied per question, depending on the original source.

The quality of life measure (QoL) was the average of 10 ratings for the quality of various life domains, including physical well-being, social well-being, and spiritual well-being, each rated from 0 (very poor) to 9 (excellent) (Mezzich et al., 2011). Internal consistency reliability for this scale was excellent (Cronbach's alpha = 0.91). Sleep efficiency was calculated as the ratio of time asleep to time in bed, from clock times reported for going to bed, falling asleep, waking, and getting out of bed. Sleep quality and the ease of falling asleep were recorded on seven-point scales from -3 ("very badly" or "very difficult") to +3 ("very well" or "very easy").

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Participants described the amount of light from windows and amount from electric light over the past week on scales from 0 (“far too little”) to 4 (“far too much”), and rated their discomfort from these two sources on scales from 0 (“none”) to 4 (“very uncomfortable”). They rated their overall satisfaction with lighting on a scale from 0 (“very dissatisfied”) to 4 (“very satisfied”).

Table 1 – Characteristics of population survey participants reported here (N=239)

	Age				Sex	
	60-69	70-79	80-89	90 +	Female	Male
N	88	108	40	3	177	62
Valid %	36,8	45,2	16,7	1,3	74,1	25,9

	Education					Location		
	High School	Coll. Dip.	Some Univ.	Bach. Deg.	Grad. or Prof. Deg.	Rural	Suburban	Urban
N	21	29	27	61	101	35	75	129
Valid %	8,8	12,1	11,3	25,5	42,3	14,6	31,4	54,0

	Income								
	< $20k	$20k < $40k	$40k < $60k	$60k < $80k	$80k < $100k	$100k < $150k	$150k +	Don’t know	Missing
N	1	15	19	45	34	66	35	17	7
Valid %	0,4	6,5	8,2	19,4	14,7	28,4	15,1	7,3	

	Housing Type			
	Single Detached	Semi-detached	Row	Apart / Flat / Condo
N	165	11	24	39
Valid %	69,0	4,6	10,0	16,3

	Province of Residence											
	NL	NS	NB	PE	QC	ON	MB	SK	AB	BC	NT, NU, YT	Missing
N	0	17	1	4	6	165	17	3	11	12	0	3
Valid %	0,0	7,2	0,4	1,7	2,5	69,9	7,2	1,3	4,7	5,1	0,0	

Note. Education levels: Coll. Dip. = community college or technical diploma; Some Univ. = university courses; Bach. Deg. = Completed undergraduate (Bachelor’s) degree; Grad. or Prof. Deg = Completed graduate or professional degree. Housing types: Apart = apartment; condo = condominium. Canadian provinces, east to west: NL = Newfoundland & Labrador; NS = Nova Scotia; NB = New Brunswick; PE = Prince Edward Island; QC = Quebec; ON = Ontario; MB = Manitoba; SK = Saskatchewan; AB = Alberta; BC = British Columbia; NW = Northwest Territories; NU = Nunavut; YT = Yukon Territory.

2.2.2 Light exposures

The survey included a modified version of a questionnaire measure of light exposures, as an indirect source of light exposure data (Bajaj et al., 2011). Respondents indicated using a 7-point scale the approximate number of hours per day (1 hour; 1-2 hours;2-4 hours; 4-6 hours; 6-8 hours; 8-12 hours; >12 hours) that they spent being exposed to daylight indoors, daylight outdoors, fluorescent lighting as in an office, incandescent/halogen/LED lighting, a screen in a dark room, and darkness. The categories were converted to the midpoint of each range, then normalized so that no person experienced more than 24 hours in a day.

Table 2 – Approximate corneal illuminances per light source (Bajaj et al. 2011)

Darkness	Screen in Darkness	Halogen/ incandescent/ LED	Fluorescent in an Office	Indoor Daylight	Outdoor Daylight
0,2 lx	10 lx	20 lx	100 lx	200 lx	2000 lx

3 Results

3.1 Light exposure

Table 3 shows the daily time of exposure to various indoor light sources. Using the conversions provided in Table 2, we modified the calculation procedure of Bajaj et al. (2011) to estimate the daytime indoor corneal illuminance dose at home by weighting the hours of exposure to halogen/incandescent/LED lighting (hours * 20 lx) and indoor daylight (hours * 200 lx). The hours of fluorescent light exposure in an office were excluded because these were not at home. The indoor doses per source were summed to form an estimate of indoor light dose at home in lx-hr. We also divided by the number of hours to create an average hourly light exposure at home, in lx. We used the daylight and electric light exposure durations with the corresponding Bajaj corneal illuminance estimates to calculate a total daytime light dose from all sources (indoor and outdoor) and divided this by the number of hours to create an hourly average exposure in lx. (Hours in darkness were not included in this calculation.)

Table 3 – Summary statistics for hours per day exposed to various light sources and resultant light exposures and light dose at home (N=239)

	Dark (hr)	Screen in dark (hr)	Halog/ incan/ LED (hr)	Fluor office (hr)	Indoor dayL (hr)	Time indoors at home (hr)	Indoor light dose at home (lx-hr)	Ave. hourly light exp at home (lx)	Ave daytime hourly light exp - all sources (lx)
Min.	0,5	0,3	0,3	0,2	0,3	10,0	120	26	122
Max.	12,0	10,9	13,2	8,6	18,8	24,0	3765	193	1753
50%ile	6,9	2,6	3,0	0,5	6,9	19,0	1433	146	492
Mean	6,9	2,7	3,2	1,0	7,0	18,5	1472	146	549
SD	2,3	2,1	2,2	1,4	2,4	3,1	471	33	264

Note. Halog = halogen; incan – incandescent; DayL = daylight; Ave. = average; exp = exposure; min – minimum; max = maximum; 50%ile = median; SD = standard deviation.

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3.2 Satisfaction, quality of life, and sleep

Table 4 shows the summary results for their satisfaction with their home lighting, their overall quality of life, and their sleep. Survey participants overall were satisfied with their home lighting (median = 3 out of 4), although there were a few respondents who reported 0 ("very dissatisfied"). The median scores for the amount of light were 2 for both light from windows and electric light, but both the 25th and 75th percentiles were also 2; the majority indicated that the amount of light was "just right". Most respondents indicated no discomfort from glare from either windows or daylight, but a few gave scores high on the scale.

Quality of life and sleep efficacy were both quite good, on average. Both sleep quality and the ease of falling asleep had averages slightly above the scale midpoints, with median values at the "somewhat" well or easy level. The range of responses encompasses the full scale for these variables.

Table 4 – Summary statistics for quality of life (QoL), sleep, and lighting satisfaction (N=239).

	QoL	Sleep			Ltg Satis.	Amount of light		Discomfort from glare	
		Effic.	Quality	Ease		Window	Elec	Window	Elec.
Min.	1	0	-3	-3	0	0	1	0	0
Max.	9	1	3	3	4	4	4	4	3
Median	7,6	0,89	1,0	1,0	3	2	2	0	0
Mean	7,2	0,88	0,7	0,9	2,9	1,9	2,0	0,5	0,2
SD	1,5	0,11	1,4	1,5	0,9	0,5	0,3	0,8	0,6

Note. Effic – efficiency. Ltg satis = lighting satisfaction; Elec = electric lighting.

3.3 Regression analyses

We chose to focus on quality of life and the three aspects of sleep (i.e., efficiency, quality, and ease) as dependent measures that might be influenced by the daily light exposure. The predictor variables were age, sex, the total in-home light exposure in lx-hrs, lighting satisfaction, and the hours per day spent in the home. We also examined the effect of hours inside the home on the average hourly daytime light exposure in lx. All of these regression analyses are shown in Table 5.

Table 5 – Summary of regression analyses, showing the standardized regression weights (β) for the predictors of each outcome, the probability of the model against the null hypothesis of no effects, and the raw and adjusted explained variance.

	QoL (*df* = 5,233)	Sleep (*df* = 5,233)			Average hourly light exposure (lx) (*df* = 3,235)
		Efficiency	Quality	Ease	
β Age	-0,034	0,046	0,063	0,092	0,076
β Sex	-0,071	0,075	0,073	0,079	-0,063
β Indoor light dose at home (lx-hr)	0,030	0,077	0,076	0,147*	na
β Light sat	0,212***	0,116	0,201**	0,079	na
β Hours in home	-0,212***	-0,056	-0,013	-0,091	-0,281***
p	0,00	0,11	0,01	0,03	0,00
R^2	0,095	0,032	0,062	0,05	0,085
R^2adj	0,076	0,011	0,042	0,03	0,073

Note. For β coefficients, * = $p < 0,05$; ** = $p < 0,01$; *** = $p < 0,001$.

4 Discussion

Participants spent a lot of time in their homes: half of the sample spent 19 or more hours per day in their homes. Although the calculated light exposures and associated light doses derived from Bajaj et al. (2011) were necessarily expressed in photopic illuminance (the only quantity available at that time), not the melanopic equivalent daylight illuminances (EDI) recommended in Brown et al. (2022), it is clear from the range of average light exposures that the at-home lighting conditions generally do not deliver the recommended minimum 250 lx continuously during the day. The spectral power distributions of the light sources in these homes are unknowable, but commercially available electric light sources do not have a melanopic daylight equivalency ratio (melanopic DER => 1.71) sufficient to deliver a melanopic illuminance of 250 lx when the average photopic illuminance is 146 lx (Schlangen and Price, 2021). This result is consistent with previous surveys (Charness and Dijkstra, 1999, Aarts and Westerlaken, 2005).

There can be many reasons for spending long hours indoors at home, many of which could contribute to the finding that shorter hours indoors at home each day predicted overall quality of life. Nonetheless, regression analyses revealed (as one would expect) that the lower the hours spent indoors at home each day, the higher the average hourly light exposure from all sources. Whatever the reason for staying indoors, among its consequences is a lower daily light dose, expressed in lx-hr. Brown et al. (2022) recommended 250 lx melanopic EDI throughout the waking day. If one assumes eight hours for sleep and three hours of evening exposure to a maximum of 10 lx melanopic illuminance, then one has 13 hours of daytime light exposure. If it were a continuous exposure to their minimum of 250 lx, one can calculate a target dose of at least 3250 lx-hr, which was reached by only a few participants from indoor lighting alone (see Table 3).

Exposure to daylight, generally outdoors, can enable a sufficient light exposure to meet the Brown et al. (2022) target – at least as estimated here. The calculated average hourly light exposure from all sources did, for many participants, meet or exceed the target: the median of the average hourly light exposure from all sources was 492 lx. However, the recommendation is for the target value to be a minimum exposure continuous throughout the waking hours until three hours before bedtime, not as an intermittent exposure at a much higher level sandwiched between periods of lower exposures. It remains for future research to demonstrate the equivalence of a light dose in lx-hr resulting from varying periods of exposure to a range of melanopic illuminances with an average of at least 250 lx.

This survey analysis does suggest that there may be value in exploring the concept of a target dose. Indoor light dose at home predicted the ease of falling asleep. Although the effect sizes are small in terms of explained variance (R^2) they are notable because of the very large uncertainty in the light exposure and dose quantities. It is remarkable that any interpretable effects were observed with this survey data.

The findings also reinforce what lighting professionals already know: quality and quantity of light share importance as design goals. Regression analyses revealed that lighting appraisal – in this case in the form of lighting satisfaction ratings – also contributed to both quality of life and sleep quality. This is consistent with findings from office environments, where lighting appraisals predicted well-being (Veitch et al., 2008, Veitch et al., 2010).

Despite all the weaknesses of the survey approach, particularly in the imprecision of the light exposure estimates, it has strengths in that a larger and more broadly-based sample could participate than in any experimental or field study. In this instance, the population survey served also as a recruitment tool for a year-long field study now ongoing. Twenty-nine participants from Toronto and Ottawa, Ontario, are taking part in the field study, which includes long-term monitoring of light levels in the principal rooms of the home; two one-week periods with a wearable light logger paired with actigraphy and a sleep log; short-term monitoring of indoor and outdoor sound levels; extensive interviews about opportunities for environmental adaptations; long-term monitoring of thermal and indoor air quality conditions; and questionnaires completed approximately quarterly repeating key parts of the population survey. The lighting components of this field study are expected to validate the population survey findings.

Our aim in this project is to contribute guidance to enable older Canadians to successfully remain resident in their homes as they age. This may take the form of advice to individuals concerning how to live better in one's own home, or it might involve contributions to building codes and application standards that would lead to the creation of spaces that support healthy aging.

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