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Office Lighting for Light-Sensitive Individuals: Summary of a Pilot Test

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Office Lighting for Light-Sensitive Individuals: Summary of a Pilot Test

Background

Documents that specify office lighting requirements are written to provide suitable working conditions for the majority of employees while also balancing the need to be energy efficient. The implementation of those requirements in any particular instance also reflects the need to balance the architectural and interior design features of the space within the budget. The result can be adequate lighting for most public servants, but might not provide a good fit for employees with special requirements, particularly those with light sensitivities of various kinds. With the coming into force of the *Accessible Canada Act*, the need to provide accommodation for this group has been brought into greater focus.

Most workplaces have a fixed grid layout, often of recessed luminaires (light fixtures), with a single on/off control for a large area. This leaves one option for changing the workplace lighting at a given workpoint: to remove the light source from the luminaire directly over the cubicle (fluorescent lamps in the past, LED tubes now) and to rely on the lower level of light received from nearby luminaires. When the luminaire has LED boards integrated into the housing, this option is not available. Other accommodation options for individuals have been to relocate to a place with a different installation or to work from home. Some individuals have made personal modifications such as wearing sunglasses indoors, wearing a hat with a brim to block overhead light, or otherwise shielding the overhead light. None of these is an elegant solution, and few would argue that these solutions meet the mandate established by the *Accessible Canada Act* to provide a safe, accessible, and inclusive workplace.

Testing a new lighting solution

With funding from the Centralized Enabling Workplace Fund, Public Services and Procurement Canada (PSPC) and the National Research Council of Canada (NRC) conducted a pilot test of a new lighting solution in summer-fall 2021. The goal was to identify a lighting system that might serve the needs of both the community of light-sensitive public servants and the larger general population. If successful, this new solution might become a way to provide an inclusive environment for all public servants, reducing the need for individual accommodations.

The joint PSPC-NRC team explored various solutions, learned about lighting innovations elsewhere in the public service, and took guidance from members of the light-sensitive community before settling on a target lighting solution from an Ottawa-based manufacturer. The NRC team contributed its expertise in office lighting quality to narrow down the specifications for the chosen system. Health Canada's Learning Centre in the Brooke Claxton building loaned its space for the pilot test, which made it possible to install the test lighting and compare it to conventional office lighting in an accessible space with suitable security while also following the public health guidance on physical distancing during the COVID-19 pandemic. The pilot test took place in two classrooms that normally would accommodate 12 people each, but for this study during the pandemic only one person occupied each room at a time.

The reference lighting – the typical lighting in many public service offices – consisted of recessed luminaires 1 foot (0.3 m) wide by 4 feet (1.2 m) long, with acrylic lenses with a prismatic ('bumpy') surface designed to spread the light somewhat, while still directing most of the light directly down to the desk surface. The light sources in the luminaires were LED tubes that are in widespread use across Government of Canada offices with a correlated colour temperature (CCT) of 4000 K and colour

rendering index of ~80. This system was not dimmable, and it was designed to deliver ~420 lx on the desk surface. The reference lighting is shown on the left side of Figure 1 and the top of Figure 2.

Figure 1. The view from the front of the Brooke Claxton classrooms, reference lighting left and test lighting right.

The test lighting consisted of recessed luminaires 2 feet (0.6 m) wide by 4 feet (1.2 m) long. These integrated LED luminaires have a proprietary optical design that delivers the light in a more diffuse way, with more light directed to the sides, and less directly down, than the reference lighting. These LEDs had a slightly warmer CCT of 3500 K, and a higher colour rendering index (~90). This means that the lighting appeared less blue and it provided a more accurate colour appearance. The test lighting was dimmable over a range from ~50 lx to ~800 lx. This is a much larger range than would be installed in a regular office, but it was a deliberate choice for this pilot test to enable participants to have a broad choice of lighting conditions to meet their needs. The right side of Figure 1 and the bottom of Figure 2 show the test lighting. By comparing the two rooms one can see the difference in the light distribution. The difference in colour appearance is not accurately shown in these photos.

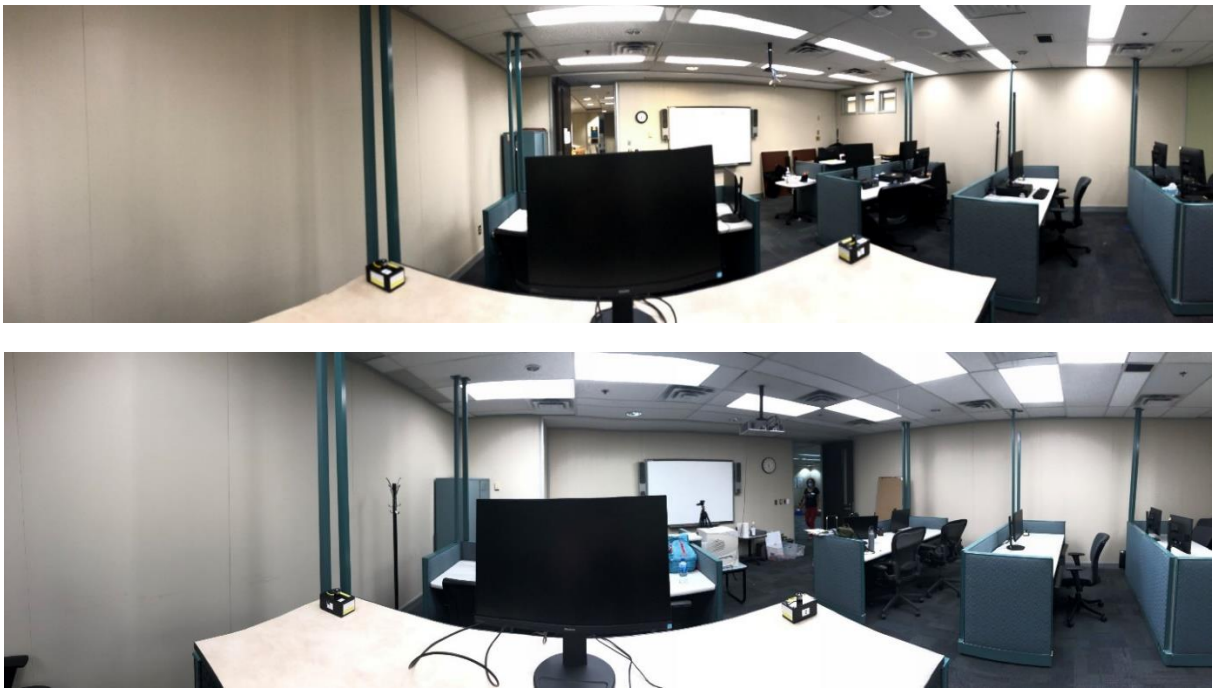

Figure 2. Panoramic views of the two rooms, from the vantage point of the seated occupant. The top photo shows the reference room, and the bottom photo shows the test room. The colour appearance has not been corrected.

How the test proceeded

The research protocol was reviewed and approved by the NRC Research Ethics Board. Research ethics review seeks to ensure that research projects meet Canadian standards of ethics. Knowing that participants might experience adverse effects from the lighting conditions, a dedicated commissionaire with first aid training was present at all times during testing sessions.

Over the summer of 2021 we recruited 14 public servants with light sensitivities who lived in the National Capital Region. The light sensitivities could be either self-identified or from a medical diagnosis. These people heard about the project through the Employment Equity Champions and Chairs Committee (EECCC). In October and November 2021 we recruited another seven participants (NRC employees) from the National Capital Region who did not have light sensitivities. We also had one case study participant who had limited light perception but was legally blind.

We asked participants to spend four workdays in the test office environment, two days in the reference room and two days in the test room. Most people followed this pattern, although schedules prevented some people from completing all four days, and some chose to limit their exposure to the reference room (this will be discussed below). Some people experienced the reference lighting first for two days; others started in the test lighting. The four days were spread over two weeks, always the same two days for any individual (Monday-Tuesday, or Thursday-Friday). Deep cleaning and ventilation on the Wednesday and over the weekend was part of the COVID protocol, as were requirements for physical distancing and the wearing of an NRC-supplied mask at all times.

One NRC researcher was present for each participant testing day, to ensure that things went smoothly. For most of the time participants did their own work on their own laptops, alone at an assigned location in one room or the other, where there was a sit-stand desk, a monitor, a keyboard and a mouse provided for their use. They also were permitted to bring their own peripheral devices, if preferred. Participants could choose between using WiFi and a network cable for Internet access. At three times each day (8:45, 11:30, and 15:30), an off-site NRC team member sent an e-mail invitation to each participant, asking them to complete a questionnaire about their feelings, their judgements about the lighting and the room, and their experience of visual and physical health symptoms. The questionnaires used validated scales from prior research. These repeated questionnaires allowed us to observe any developments over the workday. In the mornings we also asked about their sleep on the preceding night. There was an additional questionnaire invitation sent on the morning of the third day in each sequence (i.e., the Wednesday or the Saturday after each two-day visit to the test site). These morning questionnaires allowed us to see whether there were any aftereffects from working under one lighting type or another.

During the testing days, lighting conditions and the height of the sit-stand desks were monitored in both rooms. This made it possible to see whether or not the lighting controls had been used, and what light levels were chosen, and verified that the levels were stable in the reference lighting room. Before the start of testing in July, and after its conclusion in December, NRC researchers conducted extensive physical measurements of both lighting conditions.

What did we find?

The focus of this pilot test was on the effects of the lighting on the light sensitive participants, with the hypothesis being that the test lighting system, which was designed to be a good-practice solution based on scientific evidence, would result in better ratings of the lighting, better mood, and fewer physical and visual health problems. The aim for the general population participants was to verify that the test lighting did not cause any unintended ill effects for the general population. This Executive Summary

focuses on the lighting comparisons, rather than on effects of the time of day or day in the study (which were few in any case). The results reported here are statistically significant effects from linear mixed models analyses (with a few exceptions, noted below).

Use of lighting controls

The light-sensitive participants were somewhat more likely to use the lighting controls, and they dimmed the lighting down from the high starting level in the test lighting room to a level that was in many cases lower than the level in the reference room (Table 1). This resulted in the test lighting room being, on average, lit to a higher level for the general population group than the light sensitive group and it was higher for many people in both groups than would be typical of electric lighting in public service offices. People who used the controls in both groups tended to make a choice in the morning and not to change it throughout the day.

Table 1. Average lighting levels and lighting choices for the light sensitive and general population groups.

	Light-Sensitive N=12 Photopic illuminance (lx)	General Population N=7 Photopic illuminance (lx)
Reference lighting		
Desk surface	404	404
Vertical, seated eye height	222	222
Test lighting		
# of controls users	8/12	3/7
Desk surface (measured)		
Mean	485	657
St. Dev.	280	186
Median	353	783
Maximum	795	785
Minimum	62	254
Vertical, seated eye height (calculated from pretest measurements)		
Mean	371	499
St. Dev.	209	138
Median	272	593
Maximum	602	595
Minimum	55	198

Office Lighting Survey judgements

One of the judgements about the lighting in the two rooms involved agree/disagree statements for which normative data exist. The normative data (from offices in the northeastern United States with similar lighting to the reference room in this study), tell us what percentage of office workers can be expected to agree with each question. Tables 2 and 3 summarize the answers to these statements after people had experienced each room for up to two days, at the end of the day. The light-sensitive participants agreed that “the light fixtures are too bright” in both rooms, to a higher degree than the normative sample, and that the reference (old) lighting was uncomfortably bright for their tasks (Table 2). A higher-than-normative percentage of the light-sensitive participants judged the test lighting to be better than the lighting in most workplaces (Table 3).

The general population group also agreed that ‘the light fixtures are too bright’ to a higher degree than the normative sample (Table 2), even though the light level from those luminaires was lower in the reference room than the test room. They also agreed more than expected with the statement “my skin is an unnatural tone under the lighting” in the reference room (Table 1), where the colour rendering index was lower. Their judgements of whether the room lighting was worse, the same, or better than in other places did not differ from the normative sample (Table 3).

Table 2. Office Lighting Survey responses in the afternoon of the second testing day for agree/disagree statements.

Item	Norm	Light Sensitive - Day 2 Reference N = 9	Light Sensitive - Day 2 Test N = 11	General Population -Day 2 Reference N = 6	General Population -Day 2 Test N = 7
	Agree %	Agree %	Agree %	Agree %	Agree %
1. Overall, the lighting is comfortable.	69	67	82	83	86
2. The lighting is uncomfortably bright for the tasks that I perform.	16	44*	36	33	29
3. The lighting is uncomfortably dim for the tasks that I perform.	14	22	0	0	0
4. The lighting is poorly distributed here.	25	11	9	17	0
5. The lighting causes deep shadows.	15	11	0	33	14
6. Reflections from the light fixtures hinder my work.	19	22	0	0	0
7. The light fixtures are too bright.	14	44**	36*	67***	29
8. My skin is an unnatural tone under the lighting.	9	11	0	33*	29
9. The lights flicker throughout the day.	4	0	0	17	0

Note. * p<.05, **p<.01, *** p<.001 for comparisons between that group and normative North American data.

Table 3. Office Lighting Survey responses in the afternoon of the second testing day for worse/same/better statement.

Item			N	Worse %	Same %	Better %
		Norm (%)		19	60	22
10. How does the lighting compare to similar workplaces in other buildings?	Light Sensitive	Reference Day 2	9	11	78	11
		Test Day 2	11	9	36	55*
	General Population	Reference Day 2	6	33	50	17
		Test Day 2	7	14	57	29

Note. *p<.05 for comparisons between that group and normative North American data.

Lighting quality and room appearance appraisals

This category includes seven measurements: lighting quality (1-5), bothersome glare (1-5), room brightness (0-100), room clarity (0-100), room attractiveness (0-100), room colourfulness (0-100), and personal appearance (0-100). Personal appearance was judged after looking at one's own image in a mirror provided for the purpose; given the need to remain alone in the room, this was a good proxy for judging how other people might look under the lighting. We have focused on the assessments made in the afternoon of each testing day.

Both groups had large, statistically-significant effects for lighting quality and personal appearance (Figure 3). The test lighting was rated as having better lighting quality for both the light-sensitive and general population samples, and it gave a better personal appearance as well. The general population group also rated the test lighting as giving a brighter room appearance (consistent with the light level measurements) and being more attractive.

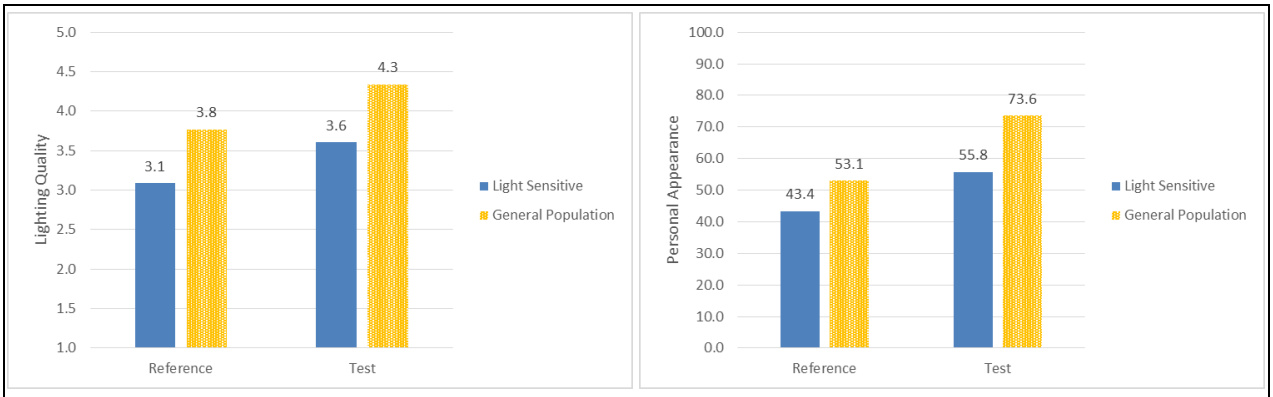

Figure 3. Lighting quality and personal appearance judgements were higher in the test lighting for both the light-sensitive and general population groups.

At-work mood and health

At three times daily, participants answered the same questions about mood (pleasure and arousal, each scored 1-9), average visual health symptom intensity (smarting, itchy, or aching eyes; sensitivity to light; teary eyes; dry eyes, scored 0-4), and average physical health symptom intensity (sore back, wrists or arms; excessive fatigue; headache; difficulty thinking; emotionally upset; anxious; hypersensitivity to stimulation, scored 0-4). The morning responses were taken as the baseline, and we examined the change from this state at lunchtime and at the end of the day.

Figure 4. This shows the average change (from the morning baseline) in visual symptom scores following exposure to the lighting conditions.

The light-sensitive group showed a statistically significant, medium-sized effect for visual symptoms (Figure 4). The light-sensitive group had started the testing days with an average visual symptom score of 0.8 (on a scale from 0-4), and the general population group started the days with an average of 0.2. Averaged over the whole exposure (all times, both days), visual health symptoms tended to increase slightly in the reference lighting and to decrease slightly in the test lighting for the light-sensitive group, but the general population showed the same small increase in visual symptoms in both lighting conditions.

Carryover effects on sleep, mood, and health

In addition to the mood (pleasure and arousal) and health symptoms (visual and physical), in the mornings we also inquired about the previous night's sleep: the ease of falling asleep, sleep quality, and sleep duration. These were tested for differences between the rooms on the mornings following each day under the reference and test lighting conditions, to see whether there were after-effects of the lighting exposures. Only the visual health symptoms showed a difference, and only for the light-sensitive group (Figure 5): on days after the test lighting, their visual health symptoms were lower than on days following the reference lighting.

Another indicator of the different effects of the lighting on the light-sensitive group was participation. Four participants of 13 chose not to return for a second day in the reference lighting, citing that they had felt unwell after the first day. One of these withdrew from the study completely. Everyone scheduled for a second day in the test lighting returned.

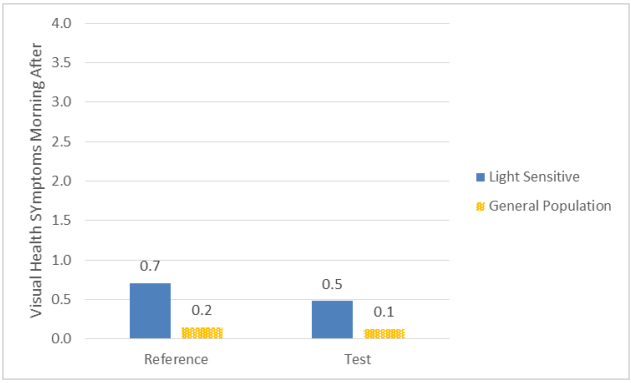

Figure 5. After-effects of light exposures on visual health symptoms.

Case study

The case study participant was an individual who is legally blind, but perceives some light in the peripheral field of view and experiences discomfort from glare in some places. Scheduling limitations meant that this individual experienced each lighting condition for one day only, with the reference lighting first and the test lighting second. This individual did choose to lower the light level in the test lighting, making it similar to the reference lighting. The NRC experimenter assisted with questionnaire responses; those that required vision were excluded (e.g., personal appearance judgements). The case study participant agreed that the test lighting was comfortable, judged the test lighting to be better than in most workplaces, and gave it a higher score for lighting quality than the reference lighting. This participant experienced a slight increase in visual health symptoms over the day in the reference lighting, and a very small decrease in the test lighting.

Personal light recipes

At the end of each person's participation, we asked for their personal light recipes: The lighting they would have if they had free choice over their office lighting. Both the light-sensitive and general population groups emphasized the importance of daylight and the ability to personally adjust the light level. Among both groups, between 1/3 and 1/2 expressed a preference for a warmer colour to the light and half mentioned the importance of the location of overhead lights in preventing discomfort from glare.

Conclusions and next steps

The purpose of this pilot test was to determine whether this novel lighting solution might prove to be an inclusive solution to the office lighting needs of light-sensitive individuals. In this, it succeeded. The test lighting reduced the incidence of visual health symptoms for the light-sensitive participants both during the workday and for the carryover effects on the following day. Both the light-sensitive participants and those from the general population judged the test lighting to have higher lighting quality than the reference lighting.

This was a short-term test with a small number of participants, which has limitations. Some elements of the test lighting would be difficult to implement in the field, particularly the individual control over the wide range of light levels. The next step for this test is to implement a more realistic installation of the test lighting over a whole floor of an office building, where public servants doing their regular work can experience this lighting for longer periods. By monitoring lighting energy use as well as regularly surveying the occupants, it will be possible to evaluate the long-term potential of this lighting solution under more realistic conditions. Such a test is currently being planned.

Acknowledgements

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