University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

The Effects of Biophilic Lighting on Student Comfort and Productivity

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Prepared for:

Course Code: PSYC 421

University of British Columbia

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April 14th, 2022

Prepared for:
PSYC 421
Penny Martyn, UBC Green Buildings Manager

Executive Summary

In this study, we aimed to investigate the optimal lighting choice for UBC to incorporate into campus buildings to support UBC students' productivity and comfort levels. We did this by testing the effects of different biophilic lighting options in workspaces with limited access to natural daylight. We anticipated that integrating methods to mimic lighting that follows a circadian rhythm has a more positive effect overall than mimicking daylight or artificial lighting. Using a Qualtrics online survey, we presented participants (N=95) with pictures that represent three different timestamped lighting conditions that show: (1) artificial lighting, (2) mimicked natural daylight, and (3) mimicked lighting that follows a circadian rhythm. We examined the data collected from the Likert scale, PEECE scale and a productivity scale in which participants rated their perceived productivity and comfort among the three conditions.

According to the results, a significantly better effect in comfort is found in lighting that follows our circadian rhythm than in other conditions. The results also proved our prediction that mimicking natural light conditions through either biophilic lighting option can improve productivity and comfort compared to traditional artificial lighting.

Introduction

Literature Review and Knowledge Gaps

Research has found that workspaces with access to natural daylight can elevate productivity and promote a sense of comfort when working in such an environment (Di Trapani, 2015; Freeman, 2018). In the absence of natural daylight, 'biophilic lighting' options that mimic natural sunlight are beginning to be explored as alternatives (Terrapin Bright Green, 2014; Guzowski, 2020). Researchers have studied the effects of daylight compared to conventional artificial lighting (Borisuit et al., 2015), but there are still gaps in understanding the psychological effects of biophilic lighting designs and how they compare to each other. In particular, there are options which either mimic constant daylight conditions or that follow the circadian rhythm and change throughout the day. Further, there are gaps in knowledge about how these biophilic lighting options impact people in spaces without access to natural daylight. Our research seeks to fill in these gaps by studying the effects of circadian and static daylight biophilic lighting options on people's comfort and productivity in basement workspaces where natural daylight is not a viable option.

As it is challenging to provide access to natural sunlight in these spaces, biophilic lighting may provide a more naturalistic and beneficial environment for UBC students to engage in their daily activities. Examining this possibility could position UBC as a leading institution in incorporating biophilic lighting elements in their buildings to promote student wellbeing and success.

Driving and Restraining Forces

Reasons for promoting the incorporation of biophilic lighting into basement workspaces have been based on benefits related to visual comfort and a possible increase in mood from naturalistic elements (Guzowski, 2020). These unique features cater to the ideal design of office and study spaces which can provide people indoors with a sense of connection to nature. Whereas, we should also minimize the effect of restraining forces. Include but are not limited to possible lack of access to biophilic lighting options and unawareness of its advantages. The expenditure of incorporating biophilic lighting is another restraining force, as less costly lighting options will be preferred by UBC Building Operations.

Research Question and Hypothesis

This study aims to discover how biophilic lighting elements influence student comfort and productivity compared to traditional lighting in basement workspaces. There are three predictions within our study. Our first prediction is that incorporating methods to mimic natural daylight in a basement will have a more positive effect on comfort and productivity levels compared to artificial lighting. Moreover, in our second prediction we believe that integrating methods to mimic lighting that follows our circadian rhythm in a basement will have a more positive effect on comfort and productivity levels compared to lighting that mimics natural daylight. Lastly, in our third prediction we concluded that implementing lighting that follows a circadian rhythm in a basement will have a more positive effect on comfort and productivity levels compared to artificial lighting.

Methods

Participants

A total number of 162 participants needed to be recruited according to the power analysis (see Appendix A), while only 95 valid responses (all questions are answered) were recorded. Our participants were recruited within the UBC campus and also through online channels (e.g., links spread around the social media, direct messaging). We presented these participants (24 male, 67 female, 4 unreported gender) with pictures of all three lighting conditions through the Qualtrics online survey. Participants ranged from 18-42 years of age (*M=22.6, SD=22.8*). The majority of participants were UBC students (69.5%) with the other 14.7% being students outside of UBC and 15.8% not being students at all. All of the participants that were previously exposed to the stimulus or already know what our study is about are excluded (i.e., students in PSYC 421 class).

Conditions

We conducted a within-subjects experiment in which we presented all participants with a control condition and two treatment conditions. For each condition, participants were shown photos of different lighting conditions within a basement workspace. Each condition had its own lighting element and changed through four different time stamps; 10am, 2pm, 6pm, and 10pm (see Appendix B, C, and D). The time-stamped photos allowed us to show participants how the lighting conditions would stay the same or change with the passage of time. The control condition consisted of artificial lighting, in which the artificial light was constant through all time stamps. In treatment condition 1, we mimicked natural daylight in the basement workspace photo and kept the conditions constant throughout all time stamps. Lastly, for treatment condition 2, we mimicked lighting that follows our circadian rhythm, where the lighting of the basement workspace changes according to its time stamp. These three conditions formulated the independent variables of this study to assess whether biophilic lighting elements influence student comfort and productivity compared to artificial lighting. All photos were taken in Woodward library in UBC Vancouver campus and edited through PhotoScape X (see Appendix H and I for more editing details).

Measures and Procedures

The survey was created by using Qualtrics and introduced three different conditions to participants who took the survey. In addition, the structure of these three conditions were randomized on a within-subjects design, followed by several questions for assessment on comfort and productivity (see Appendix A). For each condition, participants were asked to rate their levels of comfort and productivity on a Likert Scale. A score of 1 corresponded to "strongly disagree" for assessing comfort and "very unproductive" for assessing productivity. Meanwhile, a score of 7 corresponded to "strongly agree" for assessing comfort and "very productive" for productivity. In addition, we assessed participants' comfort levels by using a validated scale known as the PEECE scale, in which it measures the "emotional comfort in relation to patient experience and participation" (Willams et al., 2017). Moreover, we defined student wellbeing in study spaces as high levels of comfort and productivity. These questions for assessing comfort and productivity were the dependent variables for this study, as we expected responses to vary between conditions. Furthermore, questions were utilized to discover how different lighting conditions translated to measures of comfort and productivity. Survey responses were collected virtually and anonymously through Qualtrics, while having all ethical protocols underway, as we included a consent form in the beginning of the survey (see Appendix O). The survey was open to collect responses from participants for four weeks, which served as the primary data for this study.

Results

Data was collected from March 8th to April 10th, 2022. Of the 209 participants that completed the survey, 20 (9.56%) participants were excluded from our final analysis for not meeting our criteria of being a student. Out of the remaining 189 participants, 65 (31.1%) of them failed to complete the survey and were excluded. Data from an additional 27 (12.9%) participants was removed because they did not answer the attention check question correctly (see Appendix O, p. 27). For another two participants, data was lost due to processing errors. This resulted in our final analysis being based on 95 participant responses. To run our analysis, JASP statistical software was used to determine all of our results.

To assess whether biophilic lighting conditions increase comfort and productivity in a basement workspace, we quantified both comfort and productivity using a PEECE scale and ran a within- subject, repeated measures ANOVA. For each participant, average comfort and average productivity was calculated under each condition. The individual participant averages were then aggregated into group averages for both comfort and productivity under the control, daylight and circadian conditions.

For comfort, the circadian group average was the largest (M = 4.722, SD = .248, SEM = .025), compared to the daylight group average (M = 4.480, SD = .265, SEM = .027), and the control group average (M = 4.061, SD = .368, SEM = .038). These results are consistent with our hypotheses. For productivity, the daylight group average was the largest (M = 5.232, SD = 1.267, SEM = .130) compared to the circadian group average (M = 5.147, SD = 1.288, SEM = .132) and the control group average (M = 4.611, SD = 1.424, SEM = .146). Refer to Appendix J, figure 1.1 and Appendix L, figure 1.1 for descriptive tables.

Consistent with our three hypotheses, we found a statistically significant difference between comfort according to lighting conditions (f(1) = 88.755, p < .001). A Holm Post-Hoc test revealed significant pairwise differences between all three conditions. Between the control conditions and daylight conditions, an average difference of -.419 (p < .001) was found. Between the control conditions and circadian conditions, an average difference of -.661 (p < 0.001) was found and finally, between the daylight conditions and circadian conditions, an average difference of -.242 (p < .001) was recorded. Refer to Appendix J, figure 1.3 for sum of squares values for comfort.

We found a statistically significant difference between productivity according to lighting conditions as well (f(2) = 10.796, p < .001). Hyun-Feldt sphericity corrections were performed to correct violations. Consistent with hypothesis 1 and 3, a Holm Post-Hoc test revealed significant pairwise differences between control and daylight conditions, with an average difference of -.621 (p < .001), and between control and circadian conditions with an average difference of -.537 (p < .001). A significant pairwise difference was not found between daylight and circadian conditions, with an average difference of 0.084 (p < .562). Refer to Appendix L, figure 1.3 for sum of square values for productivity.

On average, post-secondary students in Vancouver, Canada reported that they felt most comfortable in study spaces with circadian lighting. Compared to control conditions, circadian lighting had a large effect size for comfort, Cohen's d = 1.8, 95% CI. Compared to daylight conditions, circadian lighting had a medium effect size for comfort, Cohen's d = .66, 95% CI. Daylight conditions in study spaces also had a large effect size, Cohen's d = 1.1, 95% CI. These findings are consistent with our three hypotheses (see Appendix N for calculation process, and Appendix J, figure 1.3 for partial eta-squared values).

For productivity, participants reported that they felt most productive in study spaces with daylight lighting. Compared to control conditions, daylight lighting had a small effect size for productivity, Cohen's d = .44, 95% CI. Compared to circadian conditions, daylight lighting also had a small effect size for productivity, Cohen's d = .06, 95% CI. Finally, compared to control conditions, circadian lighting had a small effect size for productivity as well, Cohen's d = .38, 95% CI. See Appendix L, figure 1.3 for partial eta-squared values.

Discussion

This study demonstrates the importance of lighting on human wellbeing in study areas, especially when we are implementing more basement study areas on campus. The results suggest that there should be improvements and adaptation of lighting in these basement study areas to foster healthier campus spaces. The lighting has a statistically significant impact on students' mental health, wellbeing, and productivity. The results support that the different effects of lighting, especially with lighting that follows our circadian rhythm, is worthy of the university's attention with regards to promoting student wellbeing. With regards to productivity, it is thought that there would not be a huge difference between implementing the light mimicking natural daylight and the light following our circadian rhythm. However, the current artificial lighting should be replaced by either of them.

Although most of our hypotheses were supported, this study has some limitations. First, the participants did not get to experience the realistic set of the three conditions. As this study was done through an online survey, participants had to imagine themselves in each room, unable to be present in the room and incapable of experiencing lighting that follows our circadian rhythm according to its respective time stamps.

Conducting an online survey also means that the participants were not in the same environment when taking the survey. For example, the locations where participants took the survey were not controllable. This could impact the results because participants might look around and compare given conditions with the room they are in. Also, individual settings of screens were not controlled either, which means that the tone we tried to present might not have been presented the same. For example, we tried to keep the tone to 12pm daylight according to Vestralux. (n.d.), but the participants' perception can still be very subjective as some people have blue light blocking filters on their laptop screens which present the content more yellow than the default.

Most importantly, we only reached slightly more than half of our targeted number of participants. This decreases the statistical significance dramatically, leading to an inability for our results to represent the whole campus population. It also gives us a larger margin of error, not being able to identify anomalies.

These limitations could be overcome in future research. Without COVID restrictions and with a longer period of research time and more funding, researchers would be able to run this study with real in-person conditions, having the participants in a well-designed lab to study and measure their real-time comfort and productivity levels.

For the lighting that mimics natural daylight, it would be relatively easy to install because the light remains constant throughout the day; it would be just the light bulbs and locations of lighting installed in existing buildings. However, lighting that follows a circadian rhythm needs to be programmed to follow the 24-hour time pattern of a day. It may also be advantageous for the lighting to change throughout different seasons. Thus, it would be more challenging to install, and require more time and effort on time to manage the lighting regularly. It might also consume more energy to keep the lights running, so further research and pilot studies should be conducted to assess efficiency.

Recommendations

Our research project has discovered that the results of our study have been predominantly consistent throughout our three individual hypotheses. We found that both natural daylight and circadian rhythm lighting elements increase levels of comfort and productivity over artificial lighting under a basement workspace setting. In addition to this finding, mimicking lighting elements that follow our circadian rhythm tend to produce higher levels of comfort, and to some extent productivity, over mimicking the effects of natural daylight. For future research, we recommend conducting the same experiment but under real conditions on campus instead of virtually. In addition, we would also recommend studying a larger pool ($n > 162$), with more diverse age groups, and focusing on the more practical aspects of installing biophilic lighting such as energy efficiency and cost. In regards to more future studies, a correlational study on productivity and comfort could be done in order to discover if productivity is closely related to comfort. Additionally, future research could be done in other spaces on campus that rely solely on artificial lighting, such as lecture halls without windows or skylights. To do this, the same experiment could be conducted in lecture halls instead of basement workspaces to measure student's productivity and comfort levels.

Considering the limitations of our study for our client, UBC Green Buildings Manager Penny Martyn, we highly recommend three key actions. For the short term, we suggest our client runs in-person pilot studies on the effects of biophilic lighting with upcoming SEEDS student research groups taking PSYC 421. This would include working with SEEDS and Professor Zhao to create a project brief for students; identifying key brands and securing a set of light bulbs for the study; and identifying priority areas on campus to set as a test location. Furthermore, we recommend finding ways to support these student research projects during their data collection phase to maximize participants and analyze the results to come up with a future action plan moving forward.

Over the medium term, we recommended replacing conventional lighting with the appropriate biophilic lighting option in priority study spaces on campus. The plan would be to utilize the results from SEEDS student research to identify the most promising biophilic lighting option available. In addition, this would lead to collaboration with UBC Energy and Water Services to conduct a review of other practical aspects such as energy efficiency and cost of the lighting. Furthermore, this would require collaborations with other UBC Building Operations units and Custodial Services to replace existing light bulbs in the identified locations.

Lastly, for the long term we suggest collaborating with other UBC Building Operations units to install biophilic lighting in all new buildings on campus. The first step would be to develop guidelines for determining where biophilic lighting will be installed in new buildings. Moreover, the next step would be to collaborate with relevant UBC Building Operations units to ensure continuous supply and installation of biophilic lighting in new buildings on campus. Eventually, we hope replacing artificial lighting with biophilic lighting in priority areas on campus will increase student comfort and productivity at UBC.

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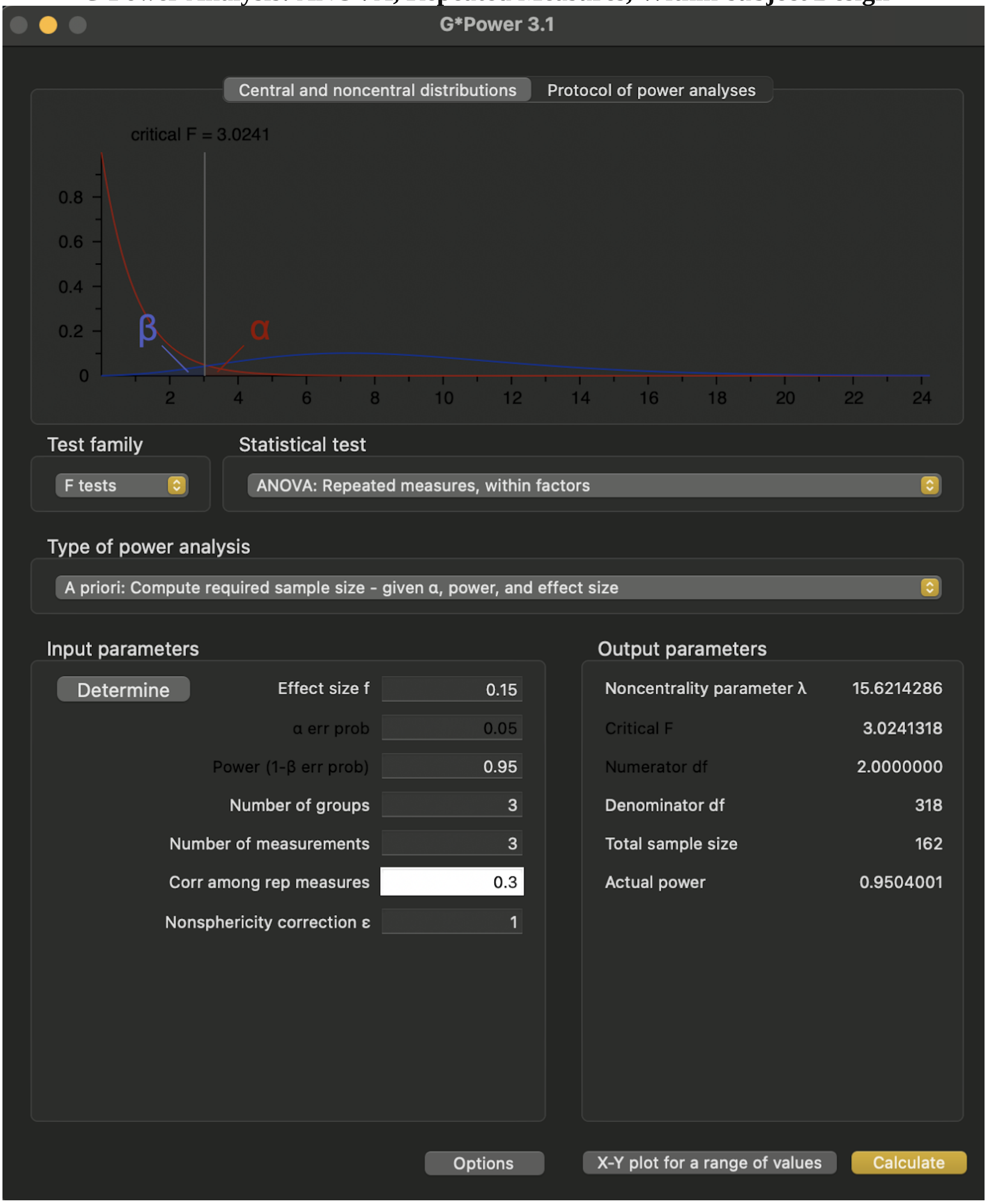
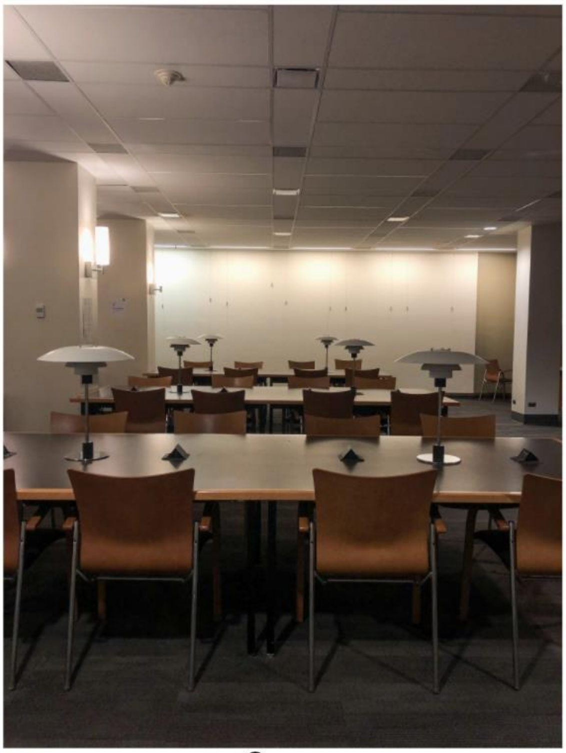
Appendix A

G Power Analysis: ANOVA, Repeated Measures, Within-subject Design



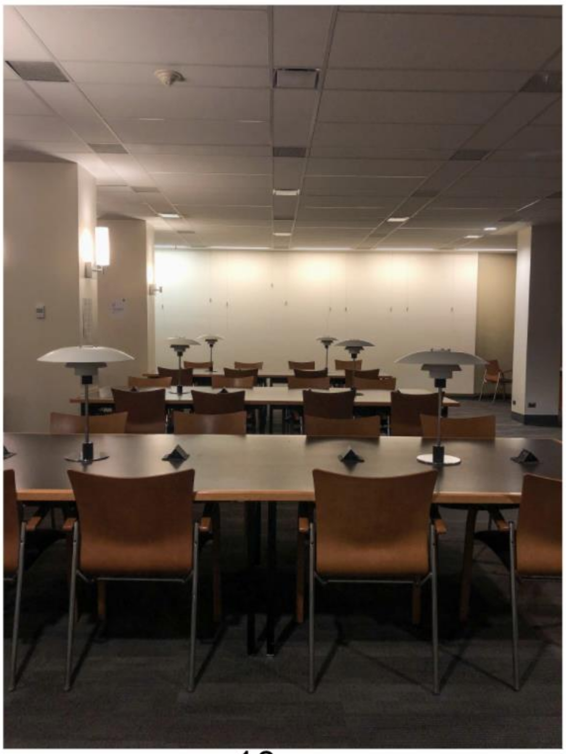
Appendix B
Control Condition: Artificial Lighting

10am



2pm

6pm



10pm

Appendix C
Condition 1: Mimicking Daylight

10am

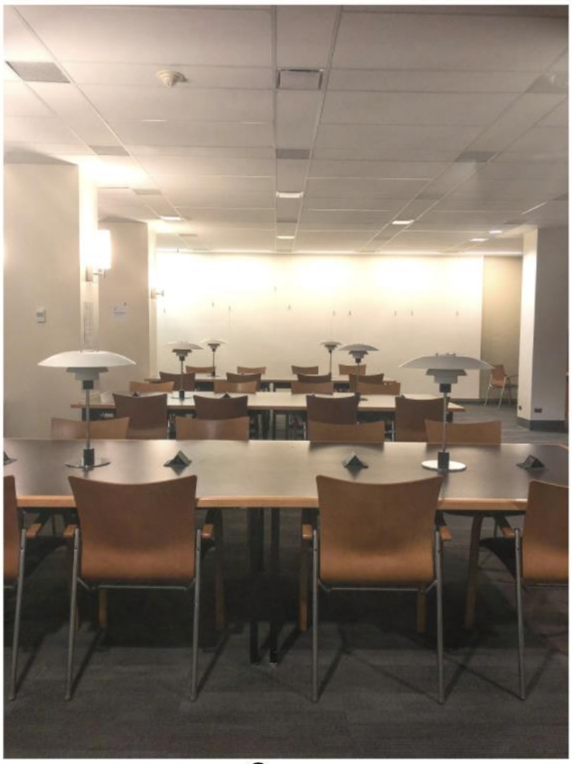
2pm

6pm

10pm

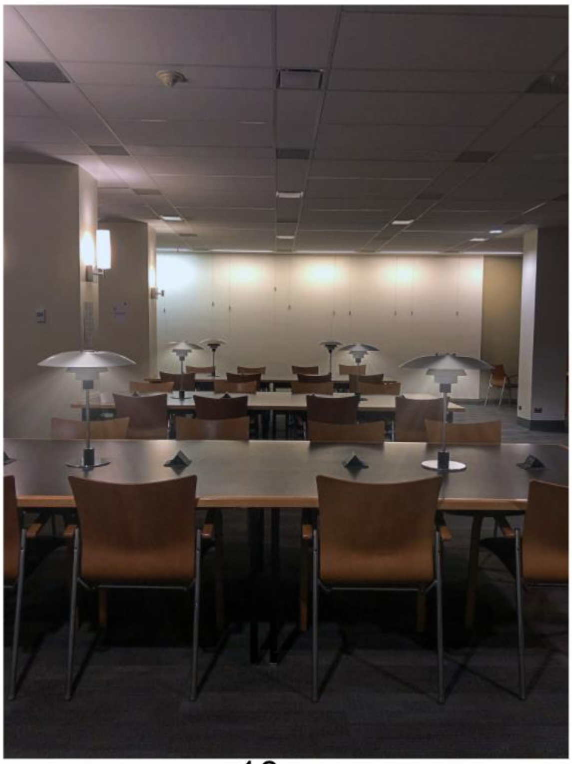
Appendix D
Condition 2: Circadian Lighting

10am



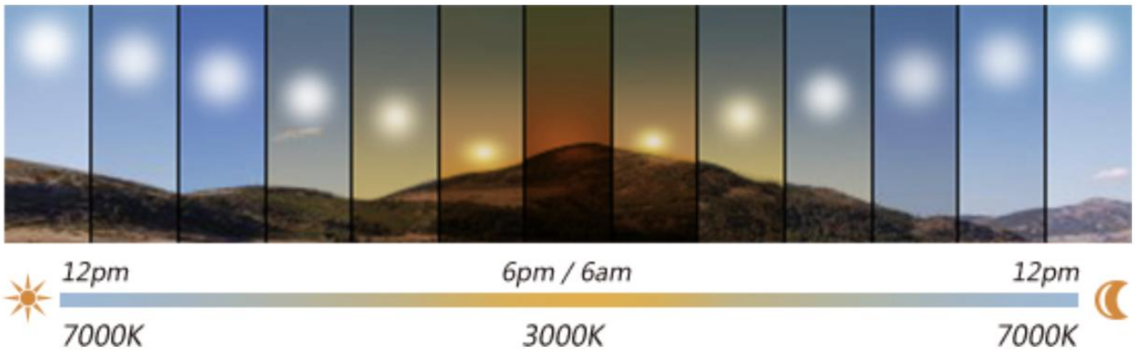
2pm

6pm



10pm

Appendix E
Reference Image of Lighting Conditions (Vestralux, n.d.)



Appendix F
The 12 Items of the PEECE Scale (Williams et al., 2017)

Subscale	Item	Factor loading	Skewness	Kurtosis	Corrected item-total correlation	Cronbach's α if item deleted
Positive emotions	Q4 Calm	0.858	−0.600	0.276	0.732	0.847
	Q6 At ease	0.802	−0.557	0.267	0.707	0.850
	Q9 Content	0.792	−0.458	−0.135	0.700	0.850
	Q1 Relaxed	0.789	−0.531	0.608	0.668	0.856
	Q10 In control	0.714	−0.293	−0.720	0.625	0.862
	Q7 Smiling	0.684	−0.402	−0.305	0.563	0.869
	Q8 Energised	0.674	0.063	−0.342	0.616	0.862
Perceived meaning	Q5 Cared for	0.816	−1.025	1.546	0.666	0.745
	Q2 Valued	0.770	−0.672	0.656	0.643	0.748
	Q11 Informed	0.728	−0.652	−0.032	0.591	0.767
	Q3 Safe	0.677	−1.101	1.473	0.534	0.781
	Q12 Thankful	0.628	−1.381	2.214	0.524	0.786

Appendix G
Question for Productivity Assessment

Estimate your productivity level in this room. How productive do you expect yourself to be here?

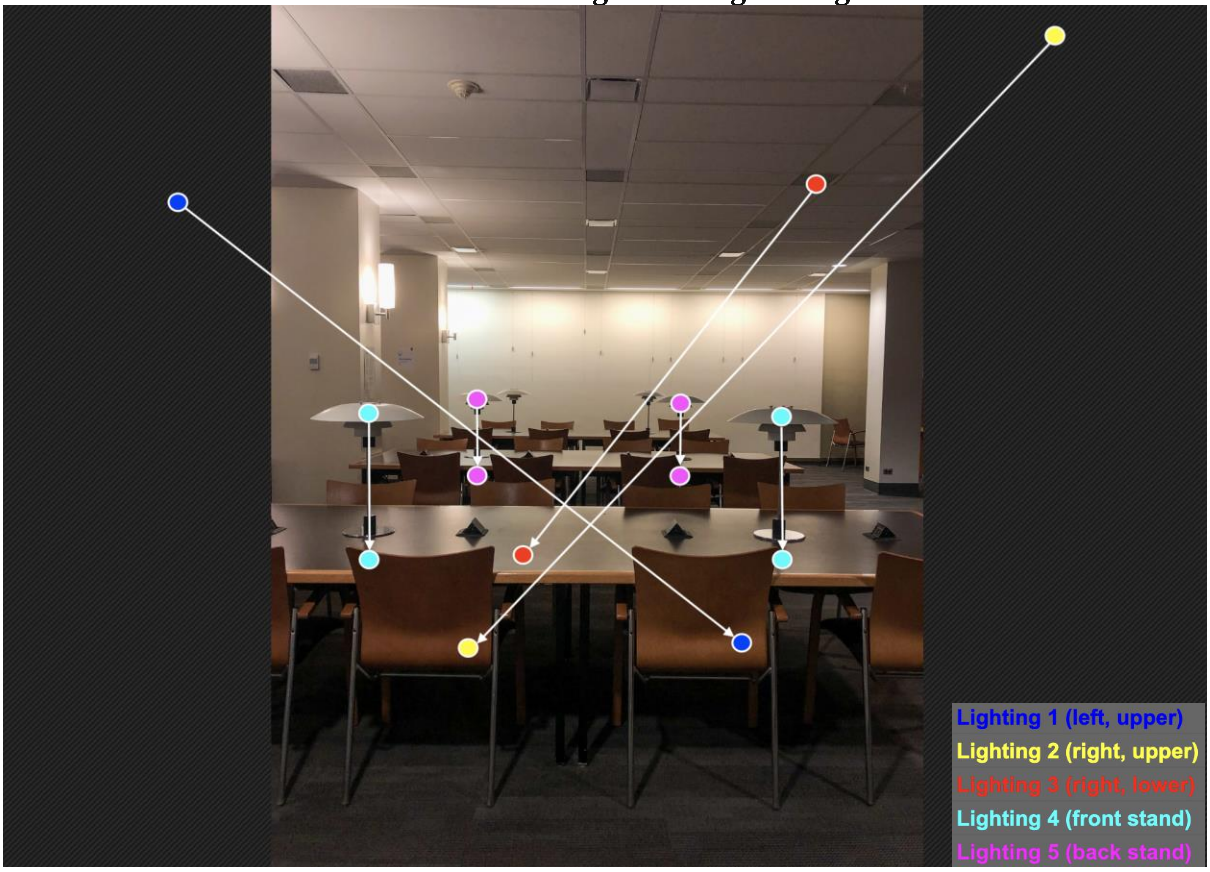
- ○ Very productive
- ○ Productive
- ○ Somewhat productive
- ○ I don't know
- ○ Somewhat unproductive
- ○ Unproductive
- ○ Very unproductive

Appendix H
PhotoScape X Photo Editing Settings

Lighting conditions - Edits through PhotoScape X					
Control: Artificial lighting (steady)			No further editing done from the original photo taken		
T1: Artificial lighting mimicking daylight					
Time					
12:00		**Lighting 1 (left, upper)**	**Lighting 2 (right, upper)**	**Lighting 3 (right, lower)**	
	color:	#ffffff	#ffffff	#ffffff	
	arc:	0.15	0.15	0.02	
	brightness:	-55	-65	-90	
	scale:	100	100	25	
	angle:	0	0	0	
	aspect ratio:	100	100	80	
T2: Artificial lighting that mimicks the circadian-rhythm lighting pattern (4 lighting situations)					
Time					Additional notes:
10:00		**Lighting 1 (left, upper)**	**Lighting 2 (right, upper)**	**Lighting 3 (right, lower)**	
	Color:	#ffe6f0ff	#ffe6f0ff	#ffe6f0ff	Bluer tone than T1
	Arc:	0.15	0.15	0.02	
	Brightness:	-55	-65	-90	
	Scale:	100	100	25	
	Angle:	0	0	0	
	Aspect ratio:	100	100	80	
14:00		**Lighting 1 (left, upper)**	**Lighting 2 (right, upper)**	**Lighting 3 (right, lower)**	
	Color:	#ffffffe6	#ffffffe6	#ffffffe6	Yellower tone than 10am
	Arc:	0.15	0.15	0.02	
	Brightness:	-60	-65	-90	
	Scale:	100	100	25	
	Angle:	0	0	0	
	Aspect ratio:	100	100	80	
18:00		**Lighting 1 (left, upper)**	**Lighting 2 (right, upper)**	**Lighting 3 (right, lower)**	
	Color:	#ffff7c11	#ffff7c11	#ffff7c11	Assumption: sun sets around 6pm
	Arc:	0.15	0.15	0.02	Additional: Darken highlight 80 (default 0)
	Brightness:	-60	-65	-90	
	Scale:	100	100	25	
	Angle:	0	0	0	
	Aspect ratio:	100	100	80	
22:00		Lighting 4 (front stand)	Lighting 5 (back stand)		Dimmed a lot, bluer tone, stands on
	Color:	#ffffff	#ffffff		
	Arc:	0.15	0.15		Lighten shadows -15 (default 0)
	Brightness:	-65	-70		Darken highlights 70 (default 0)
	Scale:	25	10		Temperature 8170 (default 6500)
	Angle:	0	0		Black vignette 7 (default 0)
	Aspect ratio:	90	90		

Appendix I

Presentation of Light Editing Settings



Appendix J

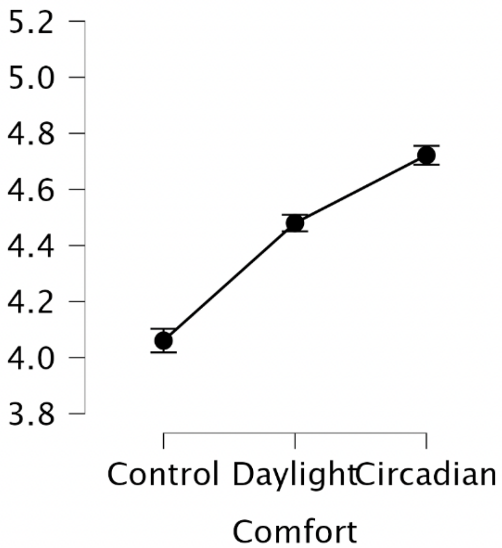
Within-subject Repeated Measures ANOVA with Descriptive Statistics and Plots: Comfort

Descriptives

Descriptives

Comfort	Mean	SD	N
Control	4.061	0.368	12
Daylight	4.480	0.265	12
Circadian	4.722	0.248	12

Descriptives plots



<u>Figure 1.1 (table) & 1.2 (graph) : Descriptives for Comfort</u>

Repeated Measures ANOVA

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2	η^2_p
Comfort	2.686	2	1.343	88.755	< .001	0.890	0.890
Residuals	0.333	22	0.015				

Note. Type III Sum of Squares

<u>Figure 1.3: Repeated Measures ANOVA,</u> *<u>f(1) value</u>*

Note: The N here refers to individual questions within the PEECE scale (i.e. 12 items within the questionnaire); it represents 95 participants.

Appendix K

Post Hoc Tests: Comfort

Post Hoc Tests

Post Hoc Comparisons - Comfort

		Mean Difference	SE	t	p_{holm}
Control	Daylight	−0.419	0.050	−8.350	< .001
	Circadian	−0.661	0.050	−13.166	< .001
Daylight	Circadian	−0.242	0.050	−4.817	< .001

Note. P-value adjusted for comparing a family of 3

Figure 1.0: Post Hoc Tests for Comfort

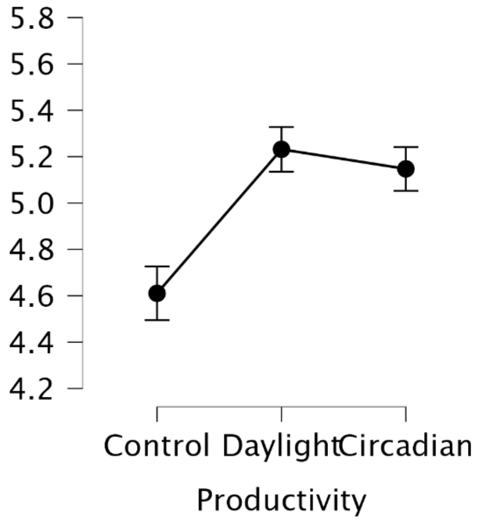
Appendix L
Within-subject Repeated Measures ANOVA with Descriptive Statistics and Plots: Productivity

Descriptives ▼

Descriptives

Productivity	Mean	SD	N
Control	4.611	1.424	95
Daylight	5.232	1.267	95
Circadian	5.147	1.288	95

Descriptives plots



<u>Figure 1.1 (table) & 1.2 (graph) : Descriptives for Productivity</u>

Repeated Measures ANOVA ▼

Within Subjects Effects

Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	η^2_p
Productivity	None	21.565[a]	2.000[a]	10.782[a]	10.796[a]	< .001[a]	0.103
	Huynh-Feldt	21.565	1.901	11.345	10.796	< .001	0.103
Residuals	None	187.768	188.000	0.999			
	Huynh-Feldt	187.768	178.685	1.051			

Note. Type III Sum of Squares

[a] Mauchly's test of sphericity indicates that the assumption of sphericity is violated (p < .05).

<u>Figure 1.3: Repeated Measures ANOVA for Productivity,</u> *<u>see f(2) values.</u>*

Appendix M
Post Hoc Tests: Productivity

Post Hoc Tests

Post Hoc Comparisons - Productivity

		Mean Difference	SE	t	p_{holm}
Control	Daylight	−0.621	0.145	−4.283	< .001
	Circadian	−0.537	0.145	−3.702	< .001
Daylight	Circadian	0.084	0.145	0.581	0.562

Note. P-value adjusted for comparing a family of 3

Figure 1.0: Post Hoc Tests for Productivity

Appendix N
Sample Calculations

Standard Error of the Mean (SEM):

SEM = SD/(sqrt(n))

Productivity, daylight condition *SEM* Calculation:

SEM = 1.267 / (sqrt(95)) = **.1299**

Cohen's d:

$d = x_1 - x_2 / S_{control}$

Comfort, circadian compared to control group Cohen's *d* Calculation:

$d = x_{circadian} - x_{control} / S_{control}$
d = 4.722 – 4.061/ .368
d = **1.796**

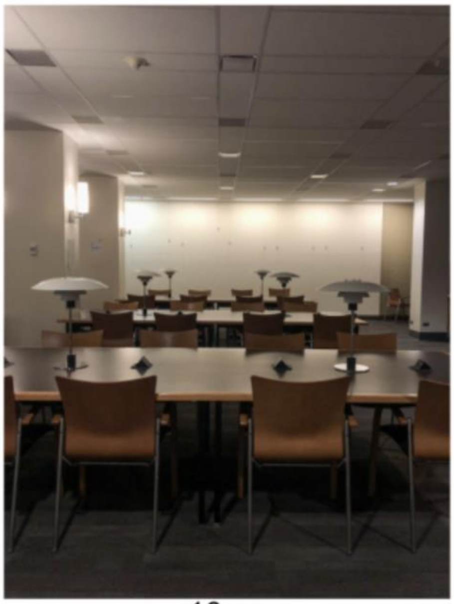
Note: Standard deviation of the control group was used to calculate all Cohen's *d* values due to the nature of our study including both control and experimental group(s).

Appendix O

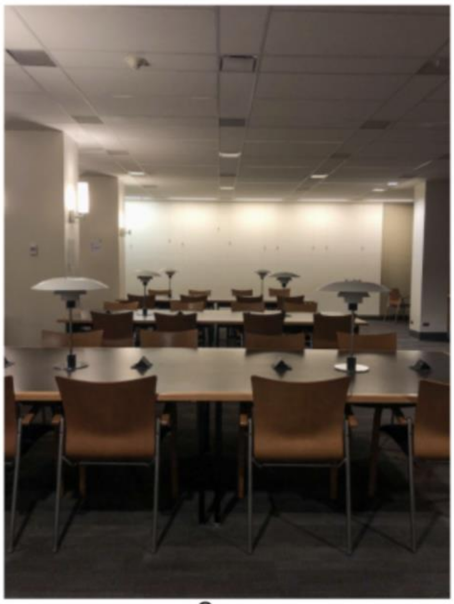
Survey Question Screenshots in Order of Control - Condition 1 - Condition 2

THE UNIVERSITY OF BRITISH COLUMBIA

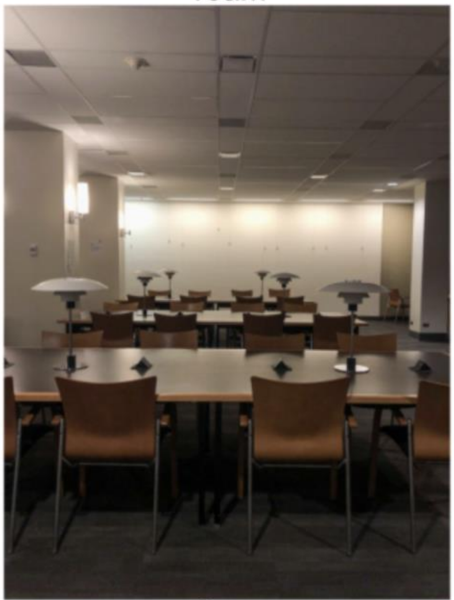
Looking at the following images, imagine yourself in the room working or studying. The first photo is of the room at 10am, the next is at 2pm, then 6pm and 10pm.



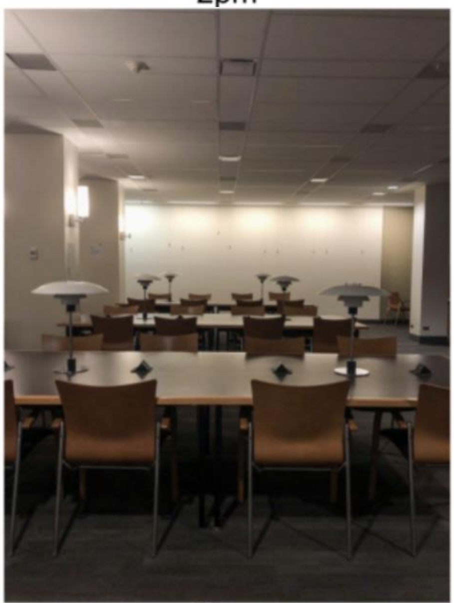
10am



2pm



6pm



10pm

Please imagine you are in the room throughout the day. Please rate the following in terms of how much you agree or disagree with each statement.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
I feel valued.	○	○	○	○	○	○	○
I feel cared for.	○	○	○	○	○	○	○
I feel safe.	○	○	○	○	○	○	○
I have been smiling often.	○	○	○	○	○	○	○
I feel thankful.	○	○	○	○	○	○	○
I feel informed.	○	○	○	○	○	○	○
I feel at ease.	○	○	○	○	○	○	○
I feel calm.	○	○	○	○	○	○	○
I feel relaxed.	○	○	○	○	○	○	○
I feel in control.	○	○	○	○	○	○	○
I feel energized.	○	○	○	○	○	○	○
I feel content.	○	○	○	○	○	○	○

Estimate your productivity level in this room. How productive do you expect yourself to be here?

- Very productive
- Productive
- Somewhat productive
- I don't know
- Somewhat unproductive
- Unproductive
- Very unproductive

→

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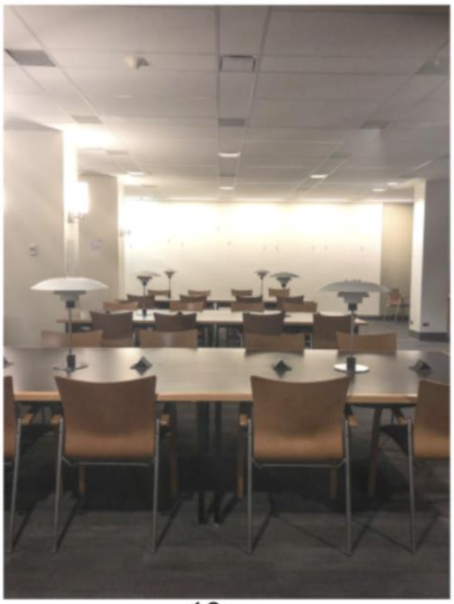
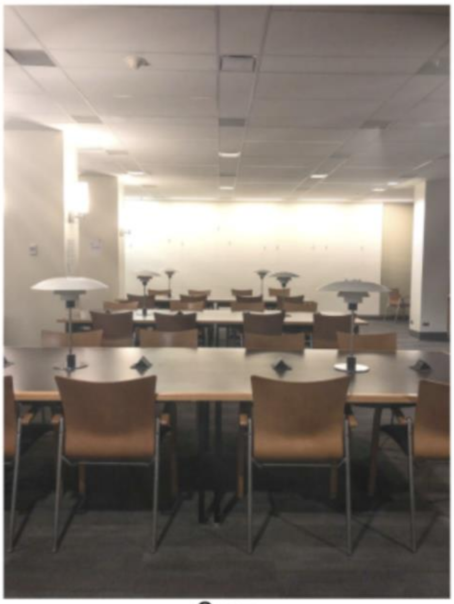
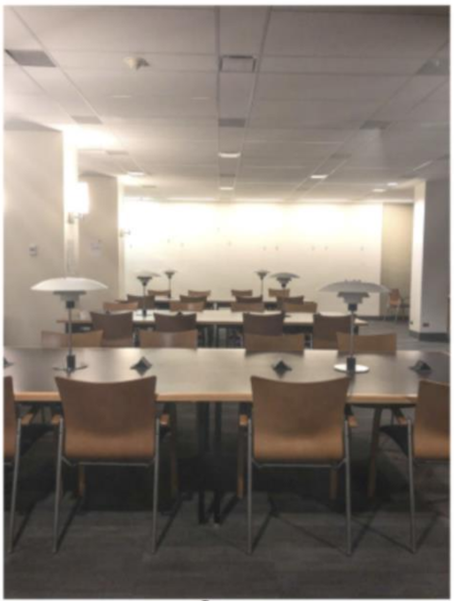
Looking at the following images, imagine yourself in the room working or studying. The first photo is of the room at 10am, the next is at 2pm, then 6pm and 10pm.



10am



2pm

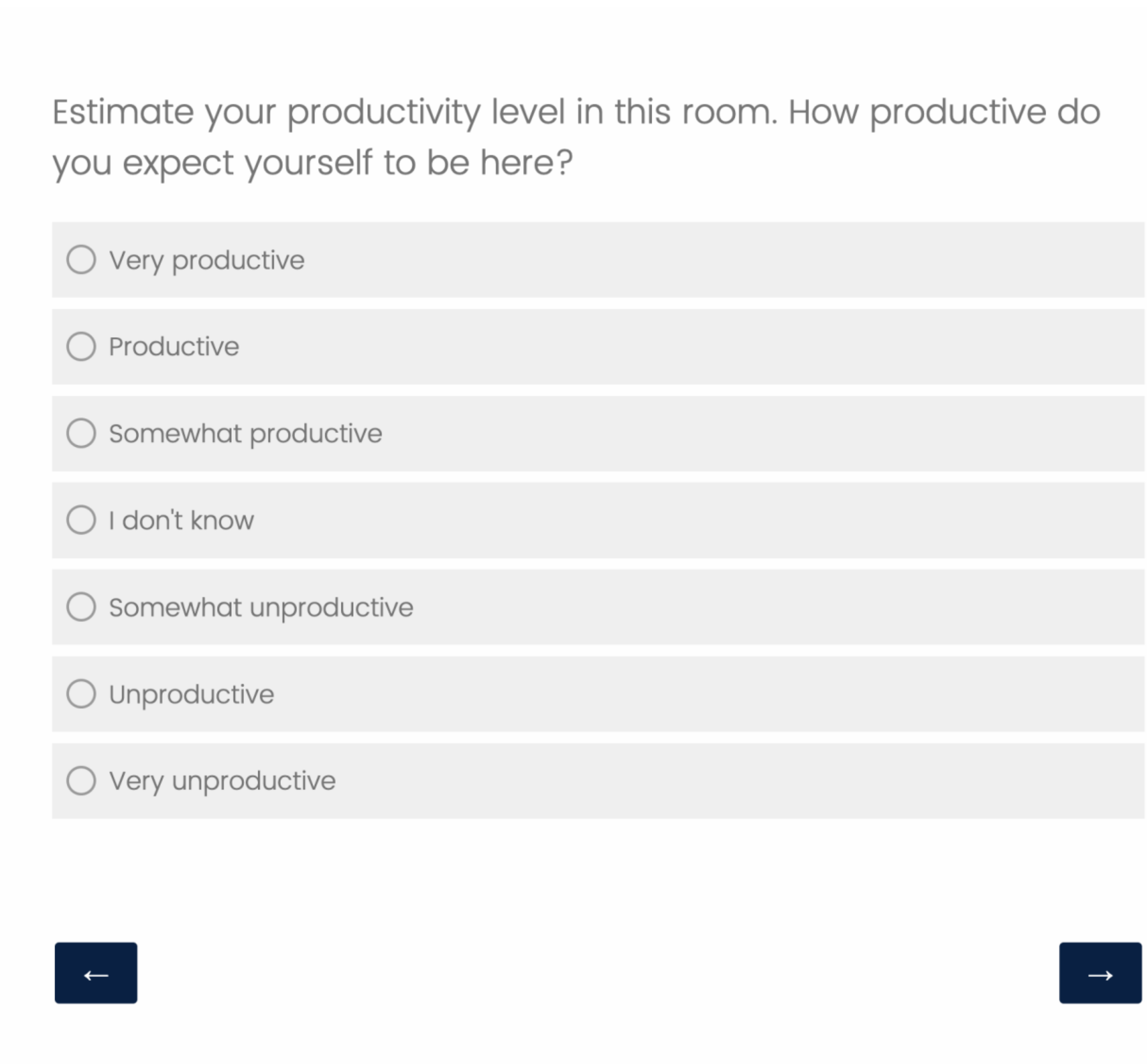


6pm

10pm

Please imagine yourself in the room throughout the day. Please rate the following in terms of how much you agree or disagree with each statement.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
I feel valued.	○	○	○	○	○	○	○
I feel cared for.	○	○	○	○	○	○	○
I feel safe.	○	○	○	○	○	○	○
I have been smiling often.	○	○	○	○	○	○	○
I feel thankful.	○	○	○	○	○	○	○
I feel informed.	○	○	○	○	○	○	○
I feel at ease.	○	○	○	○	○	○	○
Please select Agree.	○	○	○	○	○	○	○
I feel calm.	○	○	○	○	○	○	○
I feel relaxed.	○	○	○	○	○	○	○
I feel in control.	○	○	○	○	○	○	○
I feel energized.	○	○	○	○	○	○	○
I feel content.	○	○	○	○	○	○	○



Estimate your productivity level in this room. How productive do you expect yourself to be here?

- ◯ Very productive
- ◯ Productive
- ◯ Somewhat productive
- ◯ I don't know
- ◯ Somewhat unproductive
- ◯ Unproductive
- ◯ Very unproductive

← →

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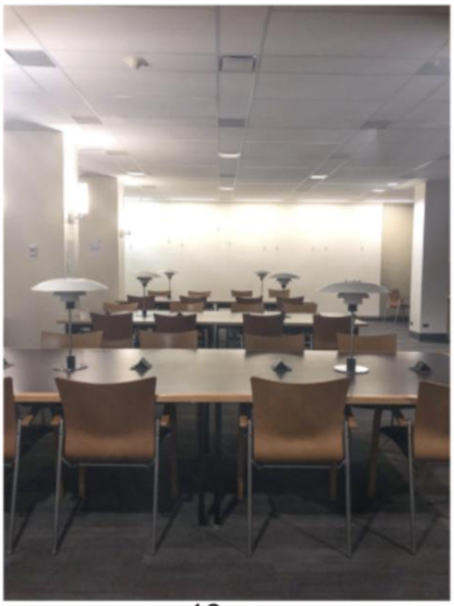
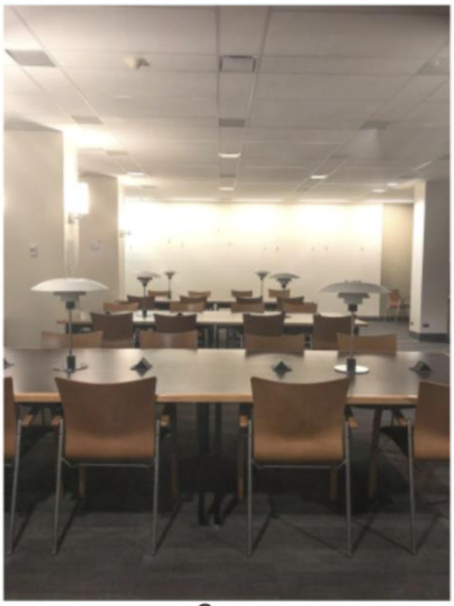
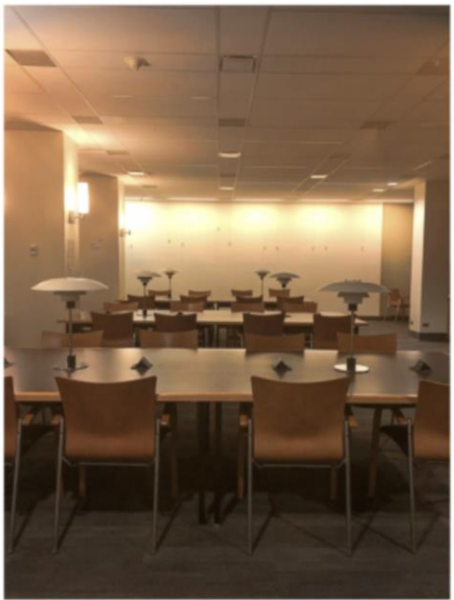
Looking at the following images, imagine yourself in the room working or studying. The first photo is of the room at 10am, the next is at 2pm, then 6pm and 10pm.



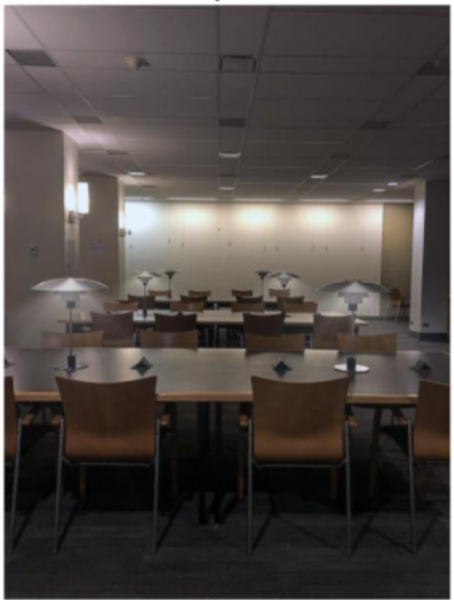
10am



2pm



6pm



10pm

Please imagine yourself in the room throughout the day. Please rate the following in terms of how much you agree or disagree with each statement.

	Strongly Agree	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree	Strongly Disagree
I feel valued.	◯	◯	◯	◯	◯	◯	◯
I feel cared for.	◯	◯	◯	◯	◯	◯	◯
I feel safe.	◯	◯	◯	◯	◯	◯	◯
I have been smiling often.	◯	◯	◯	◯	◯	◯	◯
I feel thankful.	◯	◯	◯	◯	◯	◯	◯
I feel informed	◯	◯	◯	◯	◯	◯	◯
I feel at ease.	◯	◯	◯	◯	◯	◯	◯
I feel calm.	◯	◯	◯	◯	◯	◯	◯
I feel relaxed.	◯	◯	◯	◯	◯	◯	◯
I feel in control.	◯	◯	◯	◯	◯	◯	◯
I feel energized.	◯	◯	◯	◯	◯	◯	◯
I feel content.	◯	◯	◯	◯	◯	◯	◯

Estimate your productivity level in this room. How productive do you expect yourself to be here?

- ◯ Very productive
- ◯ Productive
- ◯ Somewhat productive
- ◯ I don't know
- ◯ Somewhat unproductive
- ◯ Unproductive
- ◯ Very unproductive

← →

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Here we ask questions about yourself. You may skip the questions you do not wish to answer.

Are you a student?

- ◯ Yes, I'm a UBC student
- ◯ Yes, but I'm not a UBC student
- ◯ No

Which year are you in?

- ◯ Undergraduate Year 1
- ◯ Undergraduate Year 2
- ◯ Undergraduate Year 3
- ◯ Undergraduate Year 4
- ◯ Undergraduate Year 5+
- ◯ Postgraduate
- ◯ Other
- ◯ Prefer not to say

What gender do you identify with?

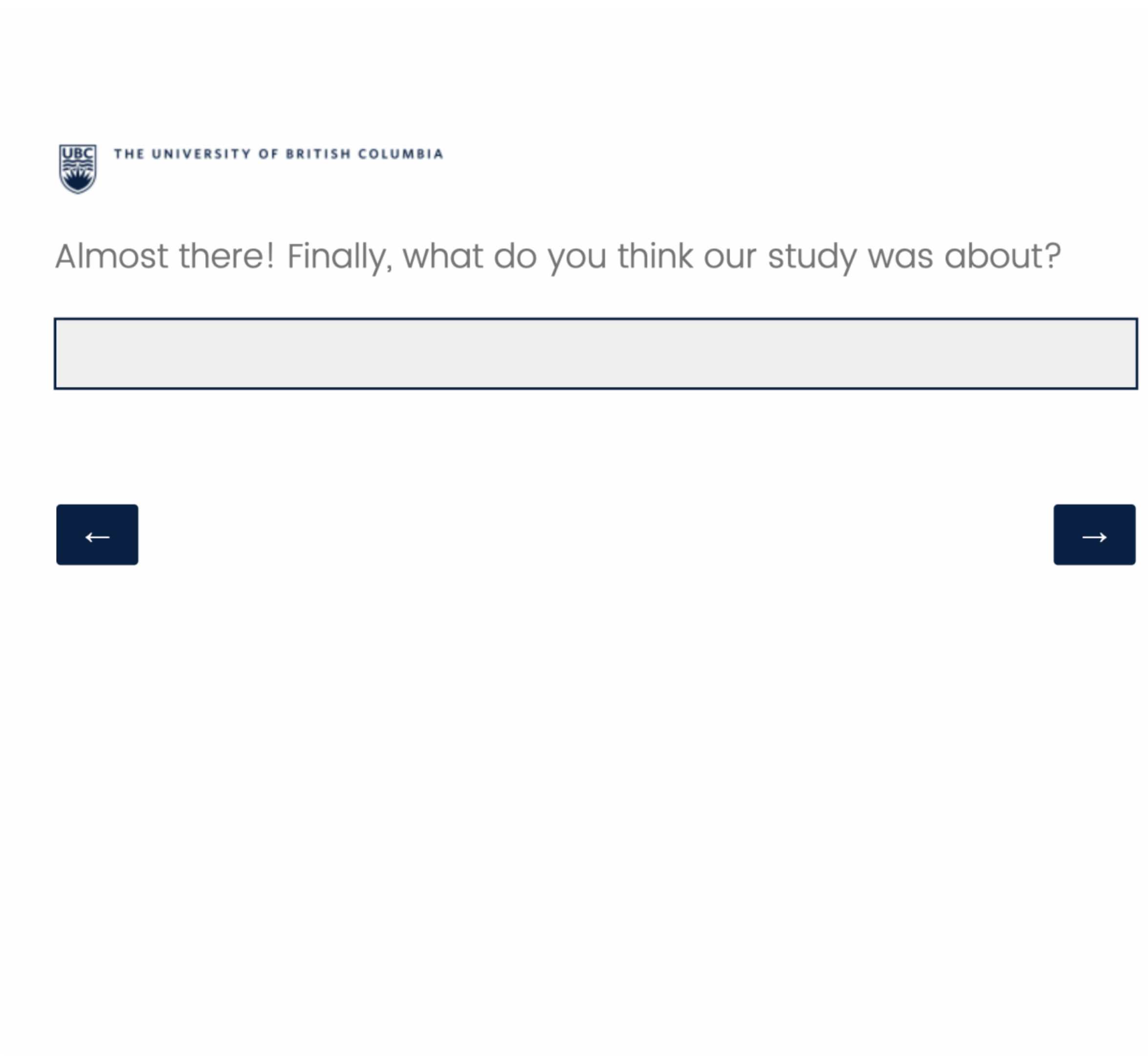
- ○ Woman
- ○ Man
- ○ Non-binary person
- ○ Transgender
- ○ Two spirited
- ○ Other
- ○ Prefer not to say

What is your age (in years)? (If you wish not to say, please say "no".)

With which of the following do yo identify? (select all that apply)

- ☐ Aboriginal/Indigenous Canadian/Native Canadian/First Nations/Métis/InuitP
- ☐ South Asian
- ☐ East Asian
- ☐ Black/African Canadian
- ☐ East Indian
- ☐ Hispanic/Latin
- ☐ Middle Eastern
- ☐ White/Caucasian
- ☐ None of the above or other
- ☐ Prefer not to say

← →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Almost there! Finally, what do you think our study was about?

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That's the end of the survey, thank you for participating in our experiment.

The goal of our study was to determine whether biophilic lighting elements influence student comfort and productivity compared to artificial lighting in basement work spaces. The independent variables were images of biophilic and artificial lighting elements utilized in basement work spaces in which it was presented. The dependent variables were 1) a 7-point Likert scale to measure the participant's level of wellbeing and 2) productivity level, based on the lighting elements presented in a basement work space. The 7 point Likert scale questions were adopted from the Patient Evaluation of Emotional Comfort Experienced (PEECE). This same test was given to all participants for them to complete. Since we have three conditions, we included three hypotheses. We first hypothesized that the artificial lighting that mimics natural daylight (t2) will have a more positive effect on levels of wellbeing compared to artificial lighting itself (control). In addition, our second hypothesis was again the artificial lighting that mimics natural daylight (t2), will have a more positive effect on levels of wellbeing compared to lighting that mimicked our circadian rhythm (t3). Our last hypothesis was that lighting that followed our circadian rhythm (t3), will have a more positive effect compared to artificial lighting itself (control).

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We thank you for your time spent taking this survey.
Your response has been recorded.

Appendix P
Team Member Contributions

Jyoti Deol:

- Project Conceptualization:
    - Research
    - SEEDS meeting
- Proposal:
    - Methods
    - Editing
- Survey:
    - Distribution online & in-person outreach
- Statistics:
    - JASP & Excel
    - SEM & effect size calculations
- Presentation:
    - Results
- Final Report:
    - JASP
    - SEM & effect size calculations
    - Results
    - Appendix
    - Recommendations
- Meeting attendance

Hakyoung Lee

- Led the meetings
    - With professor
    - With group members
- Project conceptualization:
    - Research
    - SEEDS meeting
- Proposal:
    - Methods
    - Asking extra feedback and questions to Dr Zhao
- Photoshop for the three conditions
- Survey:
    - Created and managed the survey
    - Distribution through online channels and in-person outreach
- Statistics:
    - JASP
- Presentation:
    - Conditions
    - Measures
- Final report:
    - Appendix
    - JASP
    - Results
    - Discussion
    - Editing

    - Formatting

Adam Kwok

- Proposal:
    - Research Question
    - Hypothesis
- Survey:
    - Helped create the Qualtrics survey
    - Distributed the survey via online.
- Presentation:
    - Introduction
    - Hypothesis
    - Demographics
- Final Report:
    - Research Question & Hypothesis
    - Conditions
    - Measures & Procedures
    - Recommendations
- Meetings:
    - Attended all meetings

Jo Pappo:

- Project conceptualization:
    - Research
    - Led SEEDS meeting
- Proposal:
    - Background literature
    - Anticipated outcomes
- Survey:
    - Took initial study photos
    - Distribution through online channels and in-person outreach
- Presentation:
    - Discussion
    - Recommendations
    - Formatting
- Final report:
    - Introduction
    - Recommendations
    - References
    - Editing
    - Formatting
- Meeting attendance

Rita Zhou

- Project Conceptualization:
    - Research
    - SEEDS meeting
- Proposal
    - Literature review
    - Driving and restraining force

    - Methods
- Survey:
    - Online and in-person distribution
- Presentation:
    - Research Question
    - Why it is important
- Final Report:
    - Executive Summary
    - Literature review & Gaps
    - Participants
    - Driving & Restraining forces
    - Conditions
- Meeting attendance
- Emailing questions to Dr. Zhao