Effects of Manipulated Daytime Experience on Mood, Stress, and Productivity in a Work Environment

Zhiwen Qiu[1], Debbie Jung[1], Sydney Polando[1], Chloe Chen[1], Saleh Kalantari[1]

Abstract

In colder months when the daytime becomes shorter and sunlight decreases, the weather in some regions can have an adverse impact on mood and emotional state. Such responses vary by individual, but in the most severe cases they can produce Seasonal Affective Disorder (SAD), which is associated with difficulties concentrating and engaging in productive activity. Prior research suggested that manipulating the lighting of indoor environments can help to improve such human performance in a variety of domains, including cognition, creativity, and learning outcomes (Lan et al., 2021; Ru et al., 2019). Additional research has concluded that experience of nature, even with minimal exposure, can aid in mental restoration and improved productivity (Gladwell et al., 2012). This study examined the effects of a modified indoor workspace with enhanced lighting features for college students who were suffering from mild SAD symptoms such as lack of concentration and low mood. Researchers hypothesized that such interventions that combined lighting and views would help reduce stress, increase mood, change perception of time, and promote work performance in this population.

We equipped a small (8 ft. by 10 ft.) indoor office with ceiling troffer capable of adjusting illuminance and a floor luminaire. A winter forest scene video was projected by high-luminosity output projector onto a dark brown wooden window frame (3 ft by 1.68 ft) was attached on the wall, and was placed in front of the working desk. Participants were randomly assigned to the experiment or control group. The experiment group had lighting from both the ceiling troffer (500 lux, 4,000 K) and floor luminaire (1,000 lux, 7,500K), while the control group had high illuminance ceiling troffer lighting (1,000 lux, 4,000 K). We collected data about participants perceived affective responses, time perception, and spatial awareness, and asked them to complete three cognitive tasks—a Psychomotor Vigilance Task, Stroop Test, and Digit Span Memory Test—while in the office environment. The results indicated that the experiment group performed significantly better than the control group in the cognitive tests, and that they expressed lower levels of negative affect and stress. Participants in the experiment group also perceived time as passing more slowly compared to those in the control group. The outcomes of the study indicate some novel suggestions for indoor lighting design to enhance the work performance of individuals suffering from SAD.

1 Introduction

In colder months when the daytime becomes shorter, the decrease in the amount of daylight that occurs in winter can have an adverse impact on mood and emotional state (Partonen & Lönnqvist, 1998). Such responses vary by individual, but in the most severe cases they can produce Seasonal Affective Disorder (SAD), which is associated with symptoms of depression such as low mood, loss of interest, difficulties with concentration, loss of energy, and fatigue (Magnusson & Boivin, 2003). Some people may experience increased sleep and increased appetite with weight gain. Despite the increased sleep duration, there is often an intense daytime drowsiness which is negatively correlated with productivity.

The atypical symptoms that these people experience responding to low daylight levels are closely associated with the recurrence of depressive episodes (Young et al., 1991), which is not common

[1] Human Centered Design, Cornell University

or typical for the development of depression that is not influenced by the weather conditions. In addition, the circadian cycle of people who experience winter SAD appear to be more variable across days than in health individuals (Teicher et al., 1997), partly due to the unstable melatonin levels. Although the winter blues are not as severe as long-term depressions, they can change the way a person thinks, reacts, and delas with everyday works, especially for college students in high latitude regions such as Ithaca.

1.1 Light Therapy

Bright light therapy (BLT) is one of the mostly used Among various methods for SAD treatment. In most cases, a light box is placed on a desk in front of the people with 1.6 to 3.2 ft where they receive lightings with illuminance of 2,000 to 10,000 lux (Magnusson & Boivin, 2003). Some studies indicated that using bright white light with at least 1,000 lux (either light box or light visor), mimicking the illuminance of outside, was effective in treating SAD compared to no therapy or dim light with less than 400 lux (Pjrek et al., 2020). The light exposure usually lasts 30-120 minutes per day, with some research administered light therapy twice in a day between 6:00–9:00 am in the morning and 6:00-9:00 pm at night and each had 45-min doses (Rohan et al., 2004). Exposure to 20-min high intensity blue-enriched lighting (9,000 lux, 17,000 K) was also found effective in reducing depressive mood (Gordijn, Mannetje & Meesters, 2012). During the therapy session, people can engage with any kind of activities, such as reading or working on computers or tablets. People relapse a few days after the light treatment is discontinued until the person receive enough of natura daylight (Magnusson & Boivin, 2003). Although the light treatment is effective in different times of the day, morning and nighttime are usually administered.

1.2 The Effects of Light on Mood and Performance

Light illuminance and color temperature have been shown to affect mood and productivity. Baron et al.'s (1992) study indicated that dim warm light could enhance mood, while dim cool or bright warm light had negative effects on mood. Lan et al.'s (2021) study revealed that warm color at normal illuminance level (300 lux, 3,000K) and bright cool color lighting (2,000 lux, 6,000K) induced higher positive mood than bright warm light (2,000 lux, 3,000K). Although there is no conclusive findings on the effects of light on cognition, Lan et al. found the combined effects of CCT and illuminance influenced task performance differently, such that bright cool color had positive influence in verbal creative tasks, while cool color at normal illuminance had positive impact on analytic skills. Other research indicated that high illuminance light can have beneficial effects cognition, such as sustained attention, response inhibition, and working memory (Ru et al., 2019), while high and low CCT had no significant benefits on task performance, but an increase in negative effects.

1.3 The Effect of Natural Views on Restorative Activities

Experience of nature exhibit healing and restorative qualities (Kaplan, 1995). Even minimal exposure to plants has been demonstrated to facilitate stress reduction and physical recovery (Gladwell, 2012).

1.4 Study Objectives and Hypothesis

While previous research has examined either the relation of light illuminance and CCT or natural engagement to mood and performance, the premise of this study is that the quality of both lighting and views (ability to see outside) are linked to mood and performance of students who experience mild symptoms of low mood, lack of concentration and energy in winter times. In addition, this study examines the possible role of change in perception of time as mediator of the relation between the manipulation of daytime experience to mood and performance (**Figure 1**). The present study was designed to test the following hypothesis:

Hypothesis 1: The daytime manipulation experience has positively influence on performance, subjective mood, and reduced stress.

Hypothesis 2: The daytime manipulation experience are associated with time perception such that people felt time passed slow.

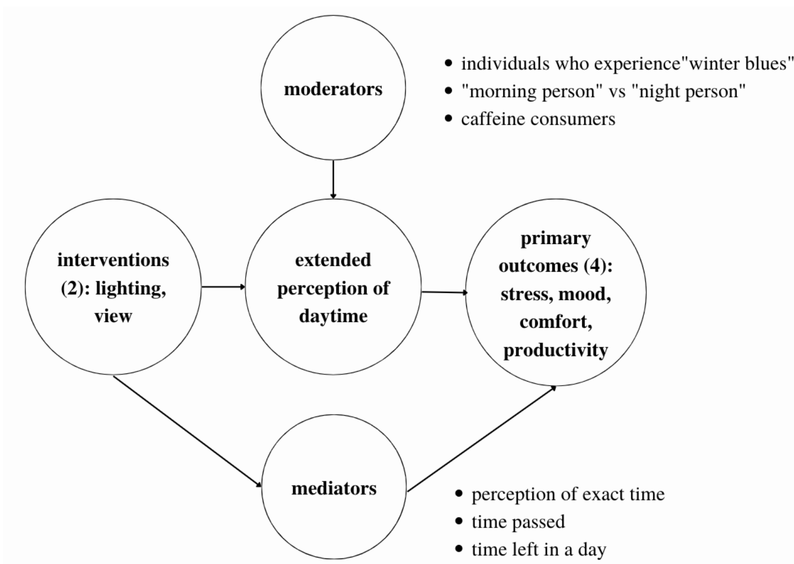

Figure 1. Concept Model

2 Methods

2.1 Design

The study employed a within-subjects (pre and post-test of self-administered survey) and between-subjects (manipulated daytime experience vs. control group) mixed experimental design. Participants came to the same research lab for both conditions and were assigned in a randomized order. The study was carried out during nighttime hours (6:00-10:00 pm).

2.2 Participants

Nine college students (7 females, M = 21.5) participated in the laboratory study. Five students were assigned to manipulated daytime experience, while the others were assigned to the control group, which is a neutral working space. Criterion sampling method was used in this study as it allowed us to identify participants that meet predetermined criterion of importance. The eligibility criteria were Cornell undergrad and first-year graduate students: (1) worked more efficiently at daytime than nighttime (morning person), (2) have experiences with some levels of winter blues (i.e., less motivation, lack of concentration, sleepiness, loss of interest, mood swings etc.) in winter times when it gets dark early than in summer times, (3) were *not* previously diagnosed with mental disorder such as SADs. For the purpose of this study, we used convenience samples by asking few people around for recommendation, with screening questions such as "Do you experience any winter blues previously in Ithaca?" All participants give oral informed consent form before the start of the experiment, and followed the complete experiment protocol.

2.3 Setting

The lab room where the experiment was conducted was room T212 on T level of Martha Van Rensselaer (MVR) Hall at Cornell University. The prototype was implemented in a windowless rectangular room, with 8 ft by 10 ft and a ceiling height of 10 ft. The room was separated by gray partitions with one area intended for completing surveys and another for conducting the experiment. There was one small work desk (2 ft by 4 ft) for experiment, one desk for researchers (2.5 ft by 6 ft) and a black chair. One Dell laptop (Latitude 13.3-in display Full HD – 1920 x 1080) and a mouse were placed on the small work desk to complete cognitive tasks.

The room was initially equipped with two ceiling mounted LED troffers of 1 ft by 2 ft, and each had approximately 4000K correlated color temperature (CCT) that was capable of adjusting illuminance levels from 100-1,000 lux. There was another floor luminaire installed next to the small work desk that had high CCT of 5500 K and high illuminance of 1,000 lux. For the video projection, we used a high-luminosity output projector (NEC V260x). The projected video was taken outside of an apartment in Ithaca, New York and showed a semi-rural forest scene in winter with cold lighting. There was no camera motion. The perspective suggested that the view was resting, and trees were planted near streets. The video was 2 minutes long and looped throughout the experimental session. A custom dark brown wooden window frame (3 ft by 1.68 ft) was attached on the wall for the projection, mimicking the experience of the views outside during the daytime. The display was placed in front of the working desk is leveled to the height of a sitting person.

Figure 2. Images of the test conditions

For the control group, one ceiling mounted troffer was turned on and provided illumination of approximately 1,000 lux on the table surface with 4,000 K CCT. The wooden window frame was taken off and there was no projection. For the experiment group, the ceiling mounted troffer provided illumination of 500 lux on the table surface with 4,000 K, and the floor luminaire had blue-enriched lighting with approximately illuminance of 1,000 lux and high CCT of 7,500 K. The video projection was turned on throughout the session (**Table 1**).

	Lighting			Views
Conditions	Luminaire	CCT(k)	Illuminance(lx)	
Experiment Group	Ceiling troffer	4,000	500	Video projection of a winter forest scene outside of campus in a sunny day
	Floor lamp	7,500	1,000	
Control Group	Ceiling troffer	4,000	1,000	Blank wall without windows

Table 1. Conditions for experiment and control groups

2.4 Assessment of Subjective Ratings

Self-administered surveys were used for both pretest and post-test using the following measures for the constructs:

2.4.1 Perceived Stress

A total of seven items from Perceived Stress Questionnaire (PSQ) were adapted to measure the perception of stress. It is a measure of the degree to which situations in one's life are appraised as stressful.

2.4.2 Affective Emotions

The Positive and Negative Affect Schedule (PANAS) is a scale that consists of two 10-item scales to measure both positive and negative effects. Seven items were adapted from PANAS onto the survey with Likert scale from 1 (Very slighting) to 5 (Extremely).

2.4.3 Focus

Three items were used to assess participant's focus levels, such as "I feel concentrated", or "I feel attentive".

2.4.4 Time Perception

Three items were designed to evaluate how participants perceive the time, such as "I feel time passed slow". Additional question on the length (in minutes) they feel after the experiment session was also used.

2.4.5 Spatial Presence

Four items adapted from spatial presence (MEC-SPQ) subscale questionnaire were used to assess how immersive or realistic participants feel about the daytime manipulation in post-test.

2.5 Cognitive performance measurement

Three tasks were employed to assess the effect of daytime manipulation on different aspects of cognitive functioning, developed by Inquisit Lab. We used a 10-min auditory psychomotor vigilance task (PVT) to test simple sustained attention (Dinges & Powell, 1985). In the test, participants had to press the key button when the timer showed instantly on the screen to record their reaction speed, with intervals randomly vary from 1 to 9s.

The second test was the Stroop Test, which consists of quickly identifying the font color of a textually congruent or incongruent word shown on the screen, and participants were instructed to press buttons with the right color (Stroop, 1935). For example, they need to press button for green when the word "red" appears on the screen with green color. Words were presented in a sequentially order with new work presented immediately after each response. The frequency of the congruent and incongruent conditions was balanced. Participants were given two 3-min sessions with a 2-min break in between where they stayed on the chair and relaxed. Scores of cumulative accuracy were recorded for each participant.

The last test was Digit Span Test (Wechsler, 1981), which was used to assess working memory. Participants were presented with a sequence of random digits and then asked to repeat the sequence by selecting the correct digits on the screen. The study used five sequences of progressively greater lengths (three, four, five, six and seven digits), and the screen showed one digit at a time. Participants were given visual feedback with correct and incorrect answers. The scores were based on the total number of correct digits to the longest complete span of correct numbers.

2.6 Procedure

All eligible participants were invited to the research room at nighttime from 6:00 – 10:00pm. After arriving at the room, they first sit next to the large working desk with the research with the partitions and that they could not see the prototype. They were informed about the study objectives and gave their oral consent before the experiment started. Participants were then asked to fill out the pretest survey, including perceived stress, mood, perception of time, and demographic information such as age and gender for about 3-5 minutes.

Subsequently, participated were guided to the small work desk next to the partition while they were still sitting on the chair to not to block the projection with their shadows standing up. They were either moved by the researcher or themselves to the designated position that the computer was right in front of them. The experiment started with a 3-min light adaption session the familiarize themselves with the environment. They were then instructed and completed all three tasks in order. The task order (PVT – ST - DST) was identical for each participant. After the tasks, participants reported on their perceived stress, mood, time perception and additional questions on spatial presence for the experiment group. A schematic representation of full experimental session is depicted in **Figure 3**.

<table>
<tr><td colspan="9">Full experiemental design</td></tr>
<tr><td></td><td>100 lux
(at desk)</td><td colspan="7">500 lux or 1,000 lux</td></tr>
<tr><td>4,000K</td><td rowspan="2">Introduction & Questionnaires</td><td rowspan="2">Light adaption</td><td colspan="5">Task Session</td><td rowspan="2">Questionnaires</td></tr>
<tr><td>7,500K</td><td>PVT</td><td>ST-1</td><td>Break</td><td>ST-2</td><td>DVT</td></tr>
<tr><td></td><td>5 min</td><td>5 min</td><td>10 min</td><td>3 min</td><td>2 min</td><td>3 min</td><td>5 min</td><td>5 min</td></tr>
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Figure 3. Overview experimental and control conditions, and schematic representation of one full session. (PVT: Psychomotor Vigilance Task; ST: Stroop Test; DST: Digit Span Test)

2.7 Data Analysis

The scores of the negative subscale of items from PANAS and PSQ were reverse coded and averaged for each participant respectively. Each participant had four self-reported scores of perceived stress, mood, focus, and time perception. Reaction times on practice trials (practice sessions before PVT and ST) and outliers were removed per participant for the various performance tasks before calculating the means. For the PVT data, the lapses were not investigated as the number of lapses was quite low and not normally distributed. SPSS (Version 28.0, IBM) was used to analyze all data from cognitive tasks and survey measures. With the limitation of the number of the participants (N =9), the means and difference of pre and post-test of each measure were calculated for both within-subjects and between-subjects comparison.

3 Results

3.1 Mood and Comfort

In the experimental group, there was an overall increase in mood by 1.0 points after participants completed their tasks (Figure 4). From the pre-test survey, the mean reported mood score was 19.6 with a standard deviation of 4.62. From the post-test survey, the mean reported mood score was 20.6 with a standard deviation of 5.55.

In the control group, there was a slight decrease in mood by 2.75 points after participants completed their tasks (Figure 5). From the pre-test survey, the mean reported mood score was 19.75 with a standard deviation of 4.86. From the post-test survey, the mean reported mood score was 15.0 with a standard deviation of 5.47.

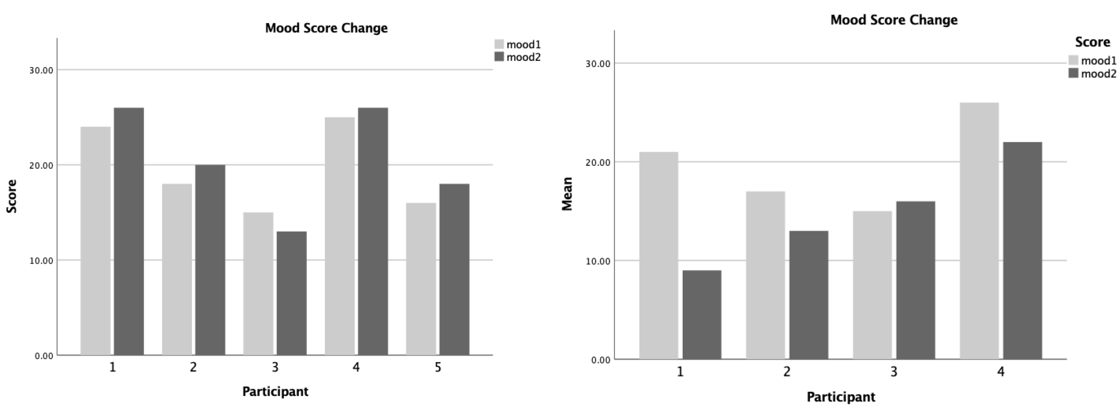

Figure 4. Experiment (Left) and Control (Right) Group Mood Score

3.2 Stress

In the control group, there was an overall increase in reported stress by 5 points after participants completed their tasks (Figure 7). From the pre-test survey, the mean reported stress level was

19.75 with a standard deviation of 5.5. From the post-test survey, the mean reported stress level was 24.75 with a standard deviation of 3.78.

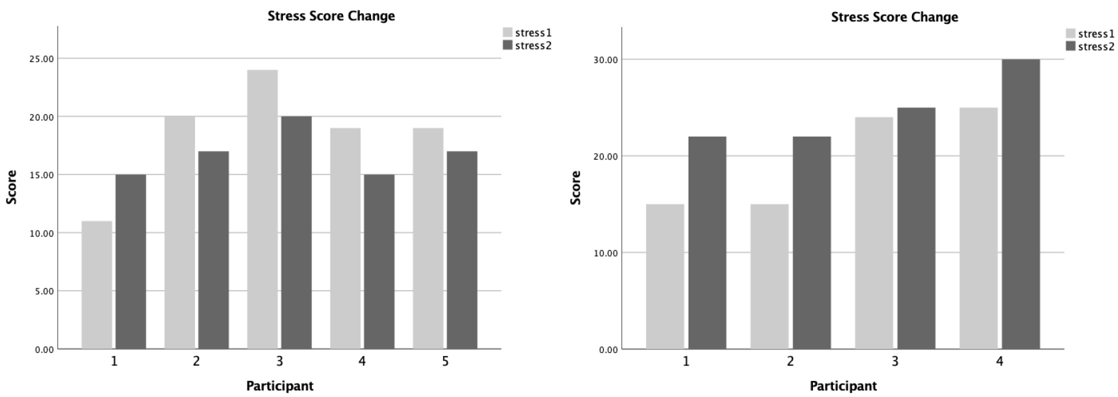

Figure 5. Experiment (Left) and Control (Right) Group Stress Score

3.3 Focus Level

In the experimental group, there was an overall increase of reported focus level by 1.2 points after participants completed their tasks (Figure 8). From the pre-test survey, the mean reported stress level was 7.0 with a standard deviation of 1.22. From the post-test survey, the mean reported stress level was 8.2 with a standard deviation of 2.42.

In the control group, there was an overall decrease in focus by 0.5 points after participants completed their tasks (Figure 9). From the pre-test survey, the mean reported stress level was 6.25 with a standard deviation of 0.96. From the post-test survey, the mean reported stress level was 5.75 with a standard deviation of 2.22.

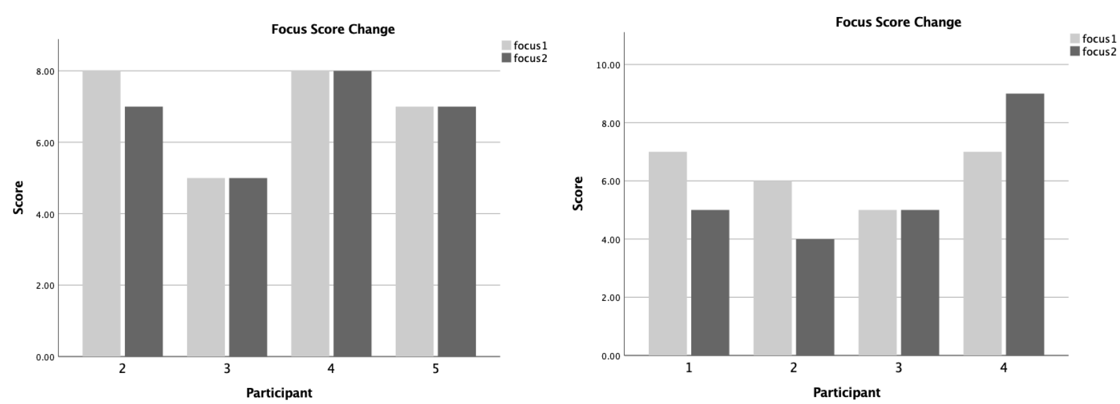

Figure 6. Experiment (Left) and Control (Right) Group Focus Level Change

3.4 Digital Span Task

The experimental group had performance scores higher by 2.95 points overall on the Digit Span Task than the control group. The mean performance score for the experiment group was 16.2 with a standard deviation of 4.49 while the control group had a mean score of 13.25 with a standard deviation of 2.28.

3.5 Stroop Task

The experimental group had higher accuracy scores overall by 30.6 points on the Stroop Task than the control group. The mean accuracy score for the experimental group was 320.6 with a standard deviation of 6.62 while the control group had a mean accuracy score of 290 with a standard deviation of 39.89. The experimental group had lower latency overall than the control group as well. The mean latency was 1138.92 milliseconds for the experimental group with a standard deviation of 52.56 and 1239.52 for the control group with a standard deviation of 251.60.

3.6 Psychomotor Vigilance Task

The experimental group had faster reaction times overall by 82.85.6 milliseconds on the Psychomotor Vigilance Task than the control group. The mean reaction time for the experimental group was 338.72 with a standard deviation of 53.82 while the control group had a mean reaction time of 421.57 with a standard deviation of 138.42.

3.7 Time Perception

For time perception questions, we calculated scores by adding up participants' responses to the question “I feel time passed slowly” and “It seems that I have a long day remaining.” In the experimental group, there was an increase of 1.7 points before and after participants completed the pre-test and post-test surveys (Figure 10). The mean score was 5.2 with a standard deviation of 2.05 from the pre-test, and 6.8 with a standard deviation of 1.31 from the post-test.

In the control group, there was an increase of 1.5 points before and after participants completed the pre-test and post-test surveys (Figure 11). The mean score was 5.75 with a standard deviation of 2.06 from the pre-test, and 7.25 with a standard deviation of 1.26 from the post-test.

In the experimental group, participants perceived the experiment to have been 5.6 minutes shorter overall than the actual experiment duration time (Figure 12). The average experiment duration for the experimental group was 35.6 minutes with a standard deviation of 0.89. The mean amount of time perceived to have passed was 30 minutes with a standard deviation of 7.07.

The control group perceived the experiment to be 4.5 minutes longer overall than the actual experiment duration time (Figure 13). The mean experiment time for the control group was 36.75 minutes with a standard deviation of 3.09, and the overall perceived experiment duration was 41.25 minutes with a standard deviation of 13.15.

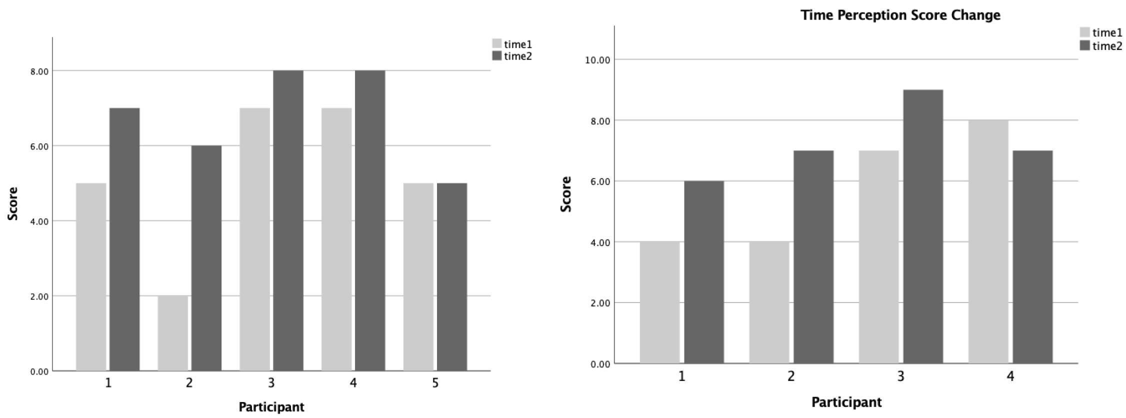

Figure 7. Experiment (Left) and Control (Right) Group Time Perception Change

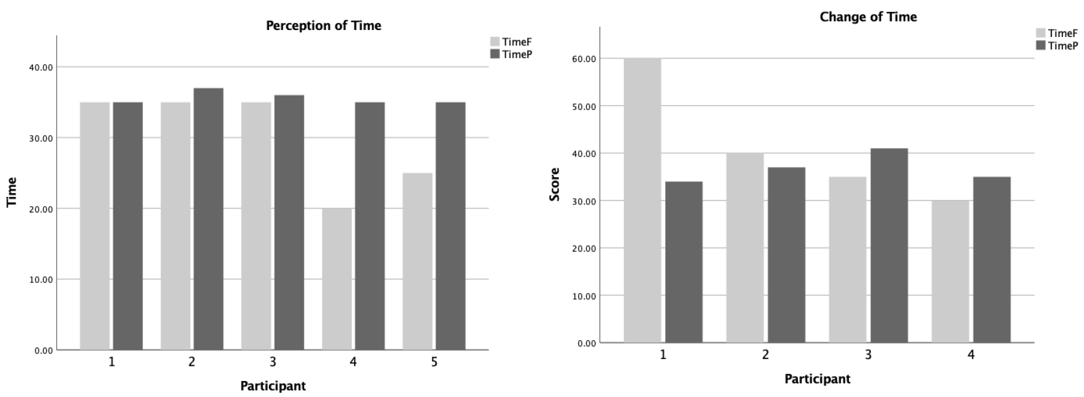

Figure 8. Experiment (Left) and Control (Right) Group Time Passed

3.8 Spatial Presence

Participants in the experimental group responded to questions about spatial attention, immersiveness, and performance benefits. To measure spatial attention, participants responded to the questions “My attention was claimed by the environment” and “My perception focused on the window almost automatically.” The spatial presence score was calculated by finding the sum of participants’ responses to these two questions. The overall score was 5.2 with a standard deviation of 2.6.

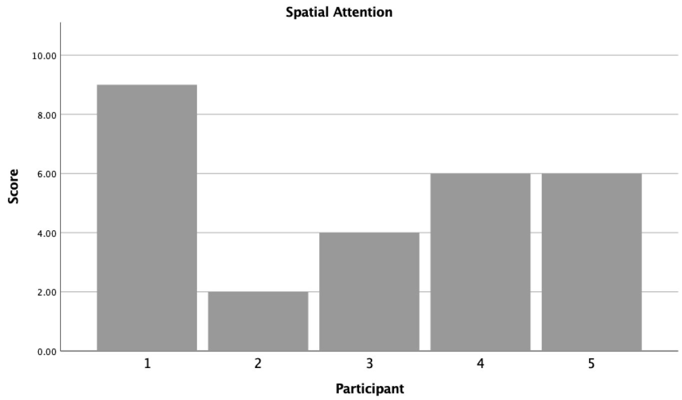

Figure 9. Spatial Attention Scores

The "spatial immersiveness score" was found by summing participants' responses to the questions "I felt that I was in the middle of the action" and "I felt like I was actually there in the environment." The mean score was 5.6 with a standard deviation of 2.3.

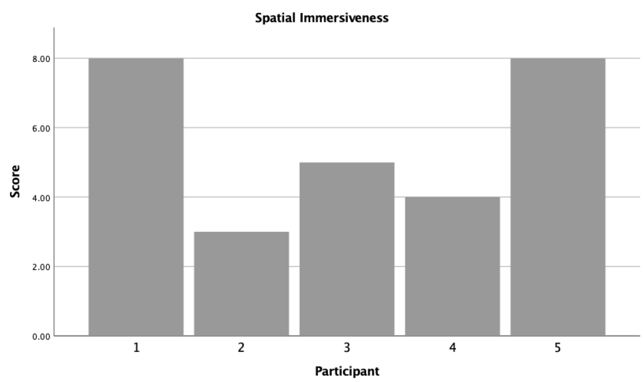

Figure 10. Spatial Immersiveness Scores

Participants also responded to the question "The environment benefits my performance" which yielded a mean score of 2.6 with a standard deviation of 1.1.

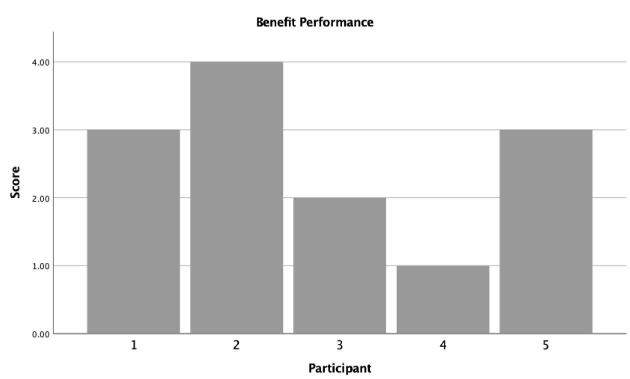

Figure 11. Performance Benefit Scores

4 Discussion

In the experimental group, reported mood and comfort rose, stress decreased, focus increased, and task performance scores and reaction times were higher and lower respectively than those of the control group group. These results suggest that including elements in a work environment that simulate daytime including blue light and a digital view to a daytime outdoor environment positively affect one's sense of wellbeing and ability to focus. Contrastingly, the control group, which lacked a blue light and view to the outdoors, experienced decreased mood and comfort, increased stress, decreased focus, lower task performance scores and slower reaction times. We could interpret this to mean that the lack of daytime qualities in a work environment may negatively impact one's sense of wellbeing or productivity. We could also interpret this to mean that the lack of artificial interventions to emulate daytime gives people a baseline disadvantage that is not necessarily the result of a negative influence.

Participants in the experimental group also perceived less time to have passed than the control group, which suggests that people may find it more tiring or tedious to pass time doing work when they do not have ambient qualities of daytime to support them. Participants all reported spatial attention, immersiveness, and performance benefit above zero which implies that our daytime view intervention was somewhat effective.

5 Limitations

There were a few limitations in this experiment that could have been sources of bias or error. First, we did not control for the varying degrees of susceptibility to the winter blues of participants. Additionally, participants had varying levels of experience with cold winter seasons that we could not account for. Additionally, the view that we showed in our artificial window had slightly lighting. In the future, we would repeat this experiment with a view in which the light is warmer and brighter. Another limitation is that the tasks may have been too long and caused the participants to feel fatigued or stressed simply because of the duration of the tasks.

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