Thermal comfort in the AMS Nest

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Executive Summary:

The present study aims to determine Nest users subjective feeling of thermal comfort and whether the different space in the Nest bring about varying levels of comfort. During the month of March, a survey about thermal comfort was distributed to the UBC Nest users utilizing the high-traffic spaces of the building as well as office spaces and study rooms. Results demonstrate that no statistical significance was found in three out of the four condition, namely the main atrium, shops and open study space. However, the study rooms and office spaces were found to be significantly hotter. Factors that may have contributed to this finding may be the lack of airflow and the room being in an enclosed space.

The AMS Nest located in the heart of the University of British Columbia serves as a significant facility that symbolizes students' commitment to sustainability. Currently, the AMS Nest's average temperature ranges between 16 to 26 degrees. The rooms with self-adjustable temperatures range from 21 degrees plus or minus 3 degrees. However, due to a series of complaints regarding the temperature of the Nest, we have decided to undertake this research hosted by the SEEDS Sustainability Program, which aims to support campus sustainability through partnerships between students, staff and faculty by research projects. This particular project focuses on understanding thermal comfort as it relates to the different types of occupants and the different spaces in a multi-use building, such as the Nest. The Nest is a common gathering area where shops operate, students occupy the multitude of study spaces, and where users are able to purchase meals. Therefore, we seek to ask whether users of the Nest find the different spaces thermally comfortable namely the main atrium, open study spaces, shops and study rooms/office spaces. By answering this research question, we hope to lower the current temperature set points by 3 degrees.

We hypothesize that AMS Nest users will have different feelings about the different occupiable spaces. Focusing on our four conditions, we hypothesize that: A. users will find the main atrium too cold, B. Users will find the open study spaces too cold, C. Users will find the shops too hot, and D. Users will find the study rooms/ office spaces to be neutral. The four conditions were chosen due to the high volume of students in each space and due to the different ways in which the spaces are heated.

Methods

Participants

Information were gathered from four different areas of the AMS Nest, located at the University of British Columbia by conducting in-person surveys. In total, 96 people including 43 Males (n=43) and 53 females (n=53) at the AMS Nest agreed to take part in the survey and were all randomly selected. For the Main Atrium condition, there were 22 participants (n=22) (8 males 14 females). The study rooms/ office spaces had 28 participants (n=28) (12 males 16 females) The Open Study Area condition had 27 participants (n=27) (15 males 12 females). The shops condition had 19 participants (n=19) (8 males 11 females). Participant ages ranged from 16 to 30 years old, and 88% of participants were between the ages of 19 to 24.

Conditions

The Nest's primary heating source comes from the hydronic heating and cooling system, also known as the in-slab heating and cooling system, where it circulates hot water through tubes or slabs in the floor. Furthermore, the Nest does not require much artificial lighting due to the abundance of natural light, therefore, natural lights plays an important role in affecting the temperature in the building. The four conditions were chosen based off of the information gathered at a private facility tour with the AMS Nest engineer. The four spaces are heated by separate means and air flow affects each space differently, therefore it was appropriate to consider all four conditions (See Appendix A).

1.Main atrium

The main atrium is located in the heart of the AMS Nest and is a popular meeting ground for students and staff to socialize and eat. The space is surrounded by food shops and retail stores, as well as having plenty of sitting space. In terms of heating, the main atrium is heated

differently than other areas of the building because it is not heated directly. Rather, heat is continuously recycled by the natural ventilation that the Nest is equipped with. Another source of heat the atrium relies on are the radiant in-slab heating and cooling systems that is placed around the perimeter of the Nest as mentioned above.

2. Study rooms/ office spaces

The heat is distributed through the ventilation system, and can be self-controlled by users by the thermostat that is located in each room. The rooms are set at 21 degrees with set points at plus or minus 3 degrees. However, the rooms are not equipped with active cooling. Office spaces are furnished with a ventilation system which assist in bringing in outdoor air as well as actively circulating the air.

3. Open Study Area

Triple-pane, argon filled windows prevent cold air from transferring inside the building and incoming sun from the large windows surrounding the building provide additional heat. However, similar to the setup of the Main Atrium, the open study areas are not directly heated and mostly rely on the circulation of air for heat.

4. Shops

Shops are heated differently compared to other areas in the AMS Nest. They are mostly located around the perimeter of the building with individual heating systems and can be self-adjusted and are also furnished with the in-slab heating. In addition, shops are usually equipped with machineries that produce excess heat. The shops chosen to survey were Uppercase, Pie R Squared and Palate.

Measure

In our correlational design, an online survey was created through surveymonkey.com and consisted of nine questions regarding participant's thermal comfort in their current location along with the clothing they were wearing at the time (See Appendix B). The survey questions were designed to measure one's thermal comfort in their location and describe the source of their discomfort if there was any. Participant's level of thermal comfort was measured on a seven-point Likert scale and stated their source of discomfort from a checkbox that was provided on the survey. Information regarding clothing worn at the time was also gathered in order to correlate the layers of clothing to the level of thermal comfort or discomfort. For further analysis, the survey asked whether their thermal discomfort affected participants' level of concentration, studying, or socializing. To combat any biases when answering the questions, the most important questions regarding thermal comfort were placed at the beginning of the survey and the basic demographic questions were placed at the end.

Procedure

The experiment was done throughout the month of March of 2017. Participants were randomly selected and approached in no specific order. Participants were asked whether they felt comfortable to participate in the experiment and those who agreed to participate in the survey were either asked the survey questions orally and their answers were recorded, or participants were given a survey via laptops and the answers were recorded from survey monkey.

Surveys were conducted in person and answers were recorded on laptops. Results were collected from 11am to 2pm, this time range is during peak hours for the AMS Nest in the day. The results were plotted on Survey Monkey and analyzed on Microsoft Excel. Also, correlational analysis was done on JASP. The independent variable is the location and the dependent variable is the participant's level of thermal comfort. Surveys were carried out on days where weather patterns followed similar trend where it was overcast, though not rainy, therefore the average temperature was 11°C, plus or minus 1°C each day.

Results

Post Hoc Tests ▼

Post Hoc Comparisons - Location

		Mean Difference	SE	t	ptukey
Atrium	Open Study Area	0.268	0.263	1.019	0.738
	Shops (ie. Food)	−0.323	0.287	−1.127	0.673
	Study Rooms	−0.490	0.261	−1.881	0.243
Open Study Area	Shops (ie. Food)	−0.591	0.274	−2.156	0.143
	Study Rooms	−0.758	0.247	−3.071	0.014
Shops (ie. Food)	Study Rooms	−0.167	0.272	−0.615	0.927

After running an ANOVA test, results demonstrated a statistical significance, as suggested by the p-value of 0.017 (See Appendix C, Table C1). Upon furthering the analysis, however, it was found that the study room were significantly hotter than the open study areas. However, the atrium, shops and open study spaces exhibited no statistical significance. In the study rooms, 39% of the participants reported general feeling of too hot while 28% reports having not enough air movement. Furthermore, for the study rooms, participants reported the current temperature to affect their concentration (32%) and studying (32%). Another 10% reported the temperature affect their task performance(See Appendix F3).
In the Main Atrium, the average response was ($\overline{X}$ = 4.04) with a standard deviation of (S=0.65). Using a one sample T-Test, the calculated p-value was (p= 0.747), showing no statistical significance. In the open study area, the average response was ($\overline{X}$ = 3.78), with a standard deviation of (S = 0.97). Using a one sample T-Test, the calculated p-value was (p = 0.247), showing no statistical significance was found. In the shops, the average response was ($\overline{X}$ = 4.37), with a standard deviation of (S = 0.96). Using a one sample T-Test, the calculated p-value was (p = 0.110), showing no statistical significance was found. Lastly, in the study rooms and office spaces, the average response was ($\overline{X}$ = 4.54), with a standard deviation of (S = 0.99). Using a one sample T-Test, the calculated p-value was (p = 0.009), showing people feel significantly warmer in study rooms than the population mean.

Discussion

Based on the findings, the atrium, open study space, and shops found no statistical significance. However, in the study room and office space conditions, it was found that users feel significantly warmer in this space than the population mean. This may be due to the self-adjustable thermostat that each room is equipped with. Furthermore, the rooms are small enclosed spaces, making air-flow difficult. As a result, 28% of participants reported having not enough air movement in this space. In addition, in the main atrium, 63% of participants reported no discomfort- following this, 22% report general feeling of too cold. Similarly, 33% of

participants report no discomfort in the open study area, and another 18.5% reported a general feeling of too cold. This may be due to the cold vents, reported by 18.5%, or drafts from the open window (14.8%). Contrasting this, 42% of participants reported no discomfort in the shops, and 37% reported general feeling of too how. This may due to the machinery radiating excess heat, in combination with the in-slab heating and adjustable thermostat. Lastly, 28.5% of participants reported no discomfort in the study rooms and office spaces, whereas 39% reported feeling too hot. This is possible due the room being in an enclosed space, where air ventilation may be more difficult. In this space, participants reported not enough air movement (28%) and incoming sun (3.5%) as possible factors. In general, most participants felt little discomfort, where the mode from the scale of 1-7 was 4, representing neutral. For participants reporting to be "too hot" or "too cold", it was found that they were wearing either too many layers or very little, which may have influenced the results in this way. 80% of the participants were wearing up to two layers and 34% wore jackets.

Coming back to the original hypothesis, only C matched, with shops being slightly hotter, but they majority of reports being neutral. What was found after research was that the main atrium found no effect, the open study space reports no effect but with many reporting feelings of too cold. In addition, the study rooms and study spaces were found to be too hot and the shops to be slightly hotter, but again with many reports of no effect as well.

Strengths:

This study successfully operationalized four different conditions: The main atrium, the study rooms/office spaces, the open study area, and the shops. Each condition was chosen due to the distinct systems used for heating and ventilation. Notably, the four conditions were matched with four specific hypotheses and were analyzed separately to prevent extraneous factors. The questions created for this study were designed to be as neutral as possible, avoiding any bias towards being colder or hotter. For example, the first question regarding thermal comfort is straightforward and is designed on a 7 point Likert scale. As a result, none of the question were leading for the participants to answer their subjective feelings and "other" fields were available, as well. Additionally, confounding variables such as the weather and clothing were taken into account as the survey recorded participants clothing layers. As well, the survey was completed during on days where the weather patterns were similar, therefore we chose to survey participants on days where it was overcast and not rainy. The average temperature across the survey dates was 11 degrees, plus or minus 1 degrees. In addition, due to the overflow of surveys on campus, data were collected in person with the participants instead of distributing the survey online. This allowed for us to control to control for the environment and also clarify misunderstandings if needed.

Flaws/ Limitations:

Throughout the process of conducting our study, limitations and flaws were identified. The first was the participant sample size for each of our conditions. The samples were far too small that it affects the extrapolation of findings. Also, using a small sample size increases the likelihood of assuming as true a false premise. The proportion of staff to students in our sample was disproportionate as well. We only had the chance to survey 3 staff members while the rest were students. It would of have been beneficial to have a randomly selected sample that has a more equal ratio of students to staff. Not only is input from students valuable but from staff as well because they tend to occupy the Nest for much longer periods of time. One other limitation

regarding participants is the difficulty of testing people's subjective feeling of thermal comfort. Each individual has varying tolerances to different temperatures. For example, a person who prefers hotter areas could say that a room that is fairly hot is thermally comfortable. In regards to our survey we noticed a few issues. The collection was a bit inconsistent in that participants were either filling out the survey on their own or verbally giving answers while we recorded them. Also, the wording of one of the survey questions could of been improved to make analyzations and correlations. For example, we worded our question as such, "How long do you typically stay in the Nest?". A better question would of been, "How long have you been in the Nest for?". Not taking into account the length of time the participant has been in the Nest, prior to the survey could have influenced their ratings of thermal comfort greatly. Collecting data from only 11pm to 2pm also limited our findings, as it would of been beneficial to collect it at other times such as mornings or nights. Also, an aspect to the layers of clothing was overlooked. We did not take into account the level of warmth each clothing article provided. In other words, although two people may be wearing jackets, different jackets have varying amounts of insulation . In regards to season or timing of the study, data collection occurred in March during spring season where weather patterns were erratic. This made collecting data on a consistent schedule or on consecutive days difficult as weather conditions varied greatly.

Implications

If the findings of the research are successful, this implies that the temperature set point of the AMS Nest can be lowered by 3 degrees. Lowering the set points will not only help save in energy costs for UBC, it will also contribute in lowering Greenhouse Gas emissions. Due to this study taking place only during the month of March during specific temperatures, future studies can measure the thermal comfort during different seasons where people may be wearing different amounts of clothing. In this study, conditions on average included 24 participants, which we feel is not sufficient to make accurate generalized conclusions about the thermal comfort and clothing patterns of the AMS Nest, and future studies could include a larger participant pool. Due the limited usage and time constraints, the Pit Pub and Great Hall were excluded as areas to survey, however future studies may be more in-depth and survey the less populated areas of the Nest.

Recommendation for client

As a result from students not feeling significantly colder or warmer in the tested areas of the AMS Nest, we suggest to lower the temperature of the Nest by 3 degrees and run another study to determine if students notice the temperature difference and changes their clothing patterns. Furthermore, these results are not restricted to the AMS Nest and we hope that similar procedures can be carried out to other buildings on campus as well to contribute to UBC's new Climate Action Plan 2020 for the Vancouver campus. When creating a follow-up study, correlating clothes worn with the amount of time spent in the nest will help to provide valuable information. We were not able to do so in this study because of the phrasing of one of our questions. Moreover, it would be beneficial to consider other factors that may influence thermal comfort. For instance, one's activity level, one's wellbeing or health at time of study, food ingested, sensitivity to heat, and even different types of lighting. Seeing as how the study room and office spaces generated the most complaints on the level of warmth, it may be beneficial to put on reminders on the thermostat for students to turn them down or shut them off once finished with the room.

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Chan, Kenneth. (Photographer). *[photograph of University of British Columbia Student Union Building]UBC Student Nest: 28 Things To Do At The New Student Union Building*. Vancouver: N.p., 2015, from http://www.vancitybuzz.com/wp-content/uploads/2015/09/ubc-nest-student-union-building-24.jpg

Peters, Ema. (Photographer). *[photograph of University of British Columbia Student Union Building]*. *Alma Mater and Alumni Matters.* Vancouver: N.p., 2016, from March 30, 2017, from https://www.canadianarchitect.com/features/alma-mater-and-alumni-matters/.

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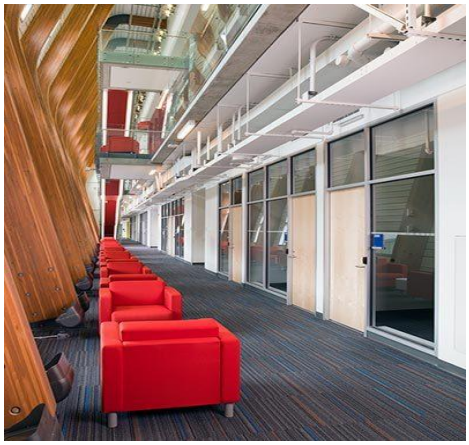
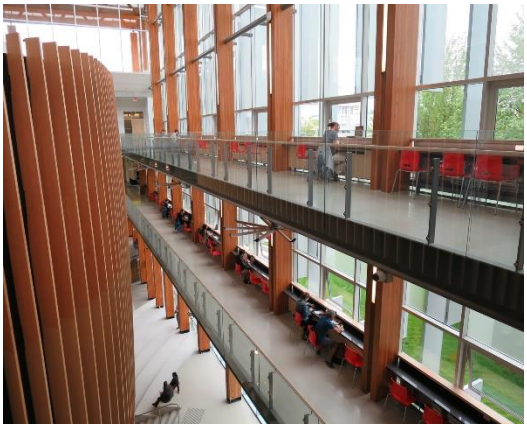
Appendix A

Conditions

A1: Main Atrium



A2: Study Rooms/ Office Spaces



A3: Open Study Area

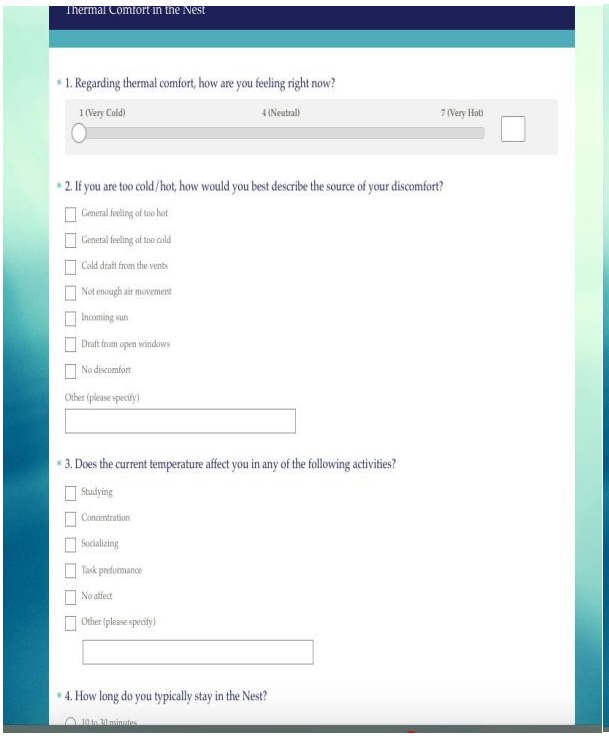
A4-1:Shops (Palate)

A4-2: Shops (PieRSquared)

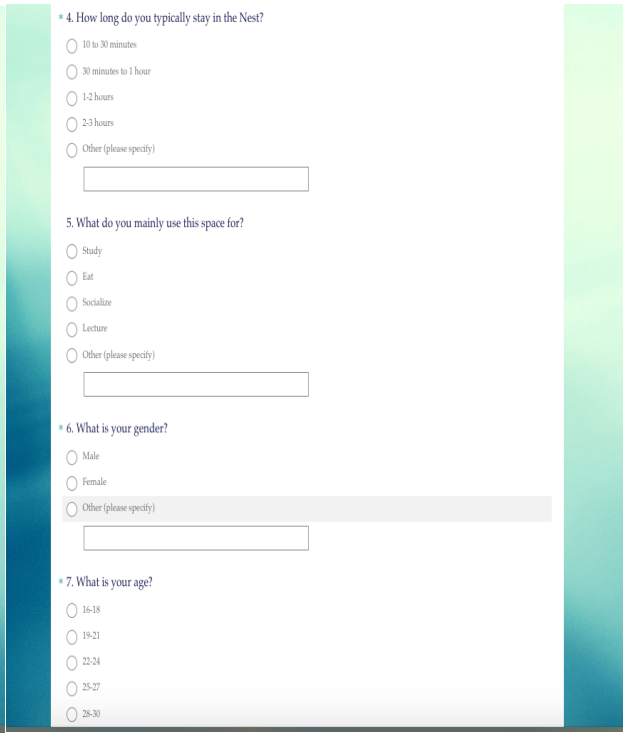
A4-3: Shops (Uppercase)

Appendix B

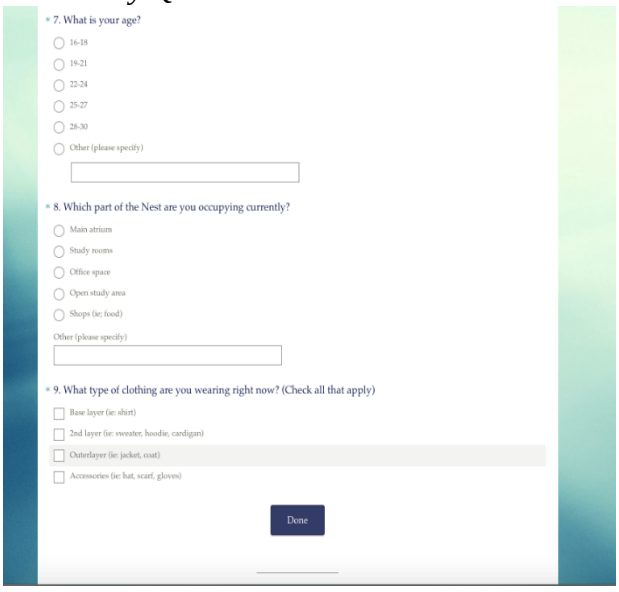
Surveys



B1: Survey Questions #1-3



B2: Survey Questions #4-6



B3: Survey Questions #7-9

Appendix C

ANOVA ▼

ANOVA - All Numbers

Cases	Sum of Squares	df	Mean Square	F	p
Location	8.983	3	2.994	3.577	0.017
Residual	77.007	92	0.837		

Note. Type III Sum of Squares

Table C1

Descriptives ▼

Descriptives Plot ▼

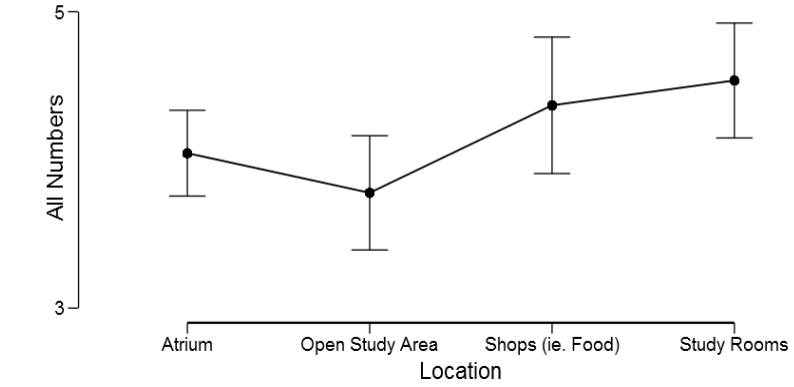
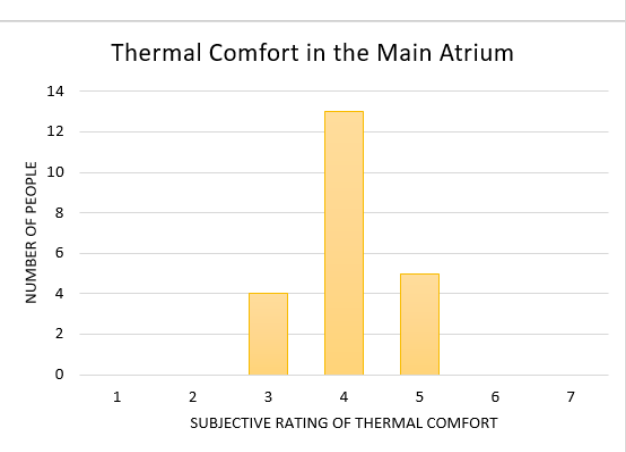
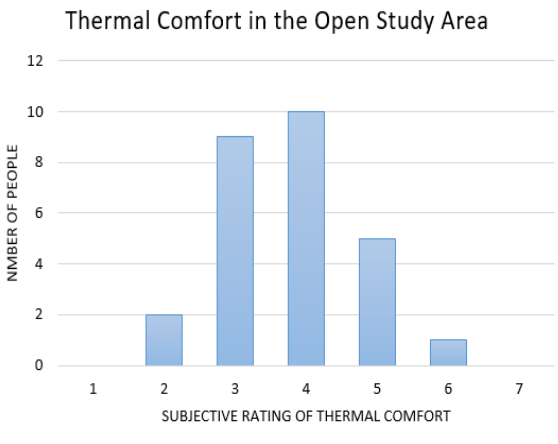


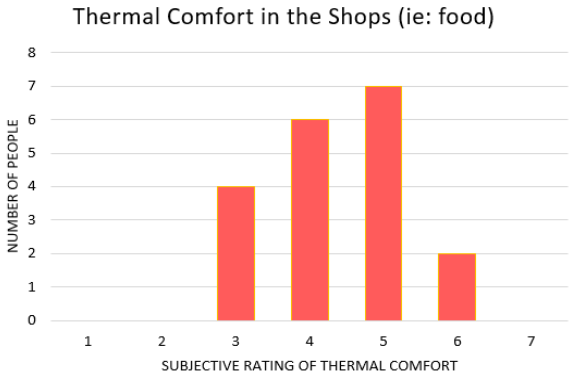
Table C2



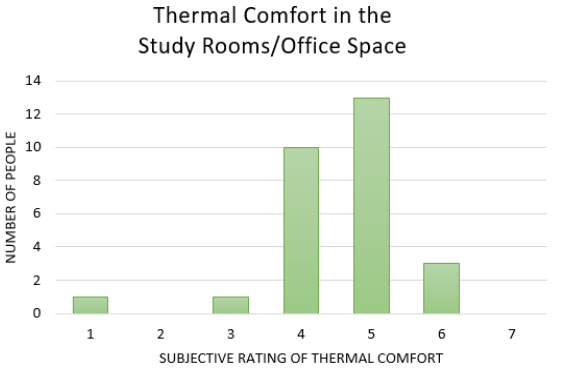
C3: Main Atrium Thermal Comfort Ratings



C4: Open Study Area Thermal Comfort Ratings



C5: Shops Thermal Comfort Ratings



C6: Study Rooms/ Office Spaces Thermal Comfort Ratings

Appendix E

Participant's source of discomfort

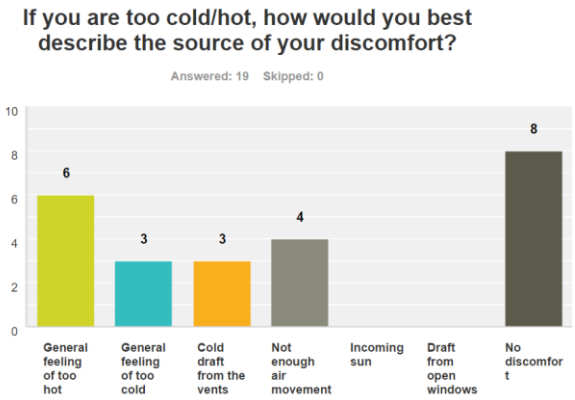


Table D1: source of discomfort in shops

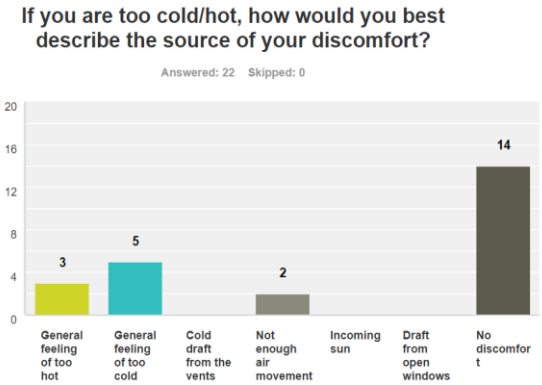


Table D2: Source of discomfort in Atrium

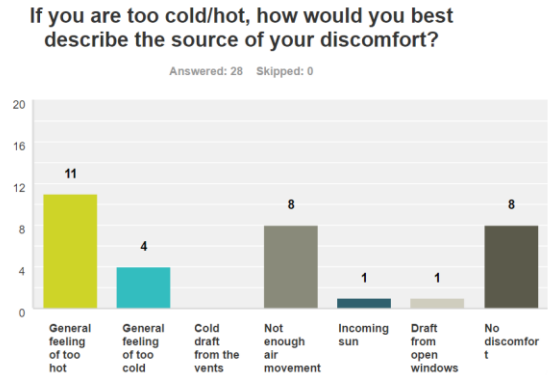


Table D3: Source of discomfort in study rooms

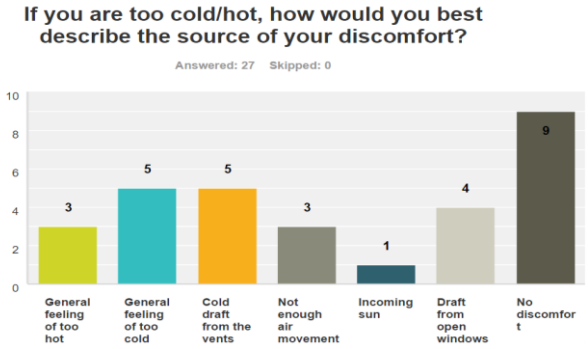


Table D4: Source of discomfort in Open area

Appendix F

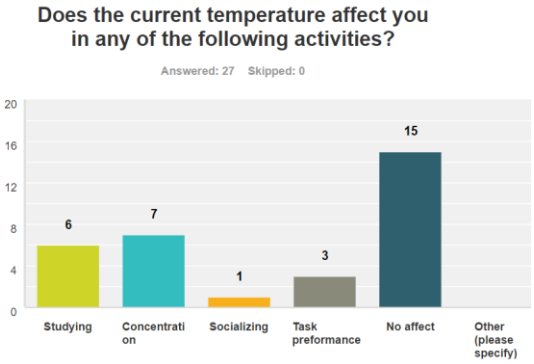


Table F1: Open study spaces

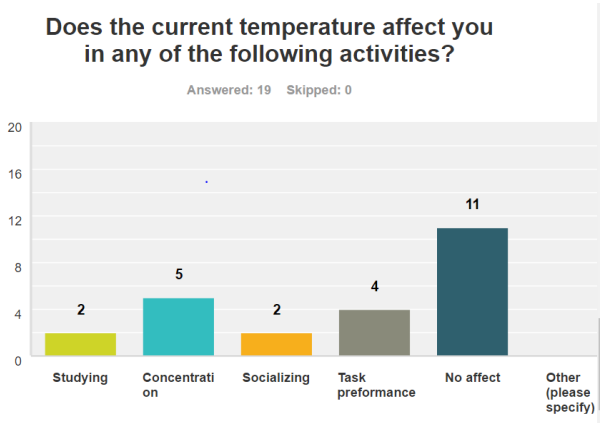


Table F2: Shops

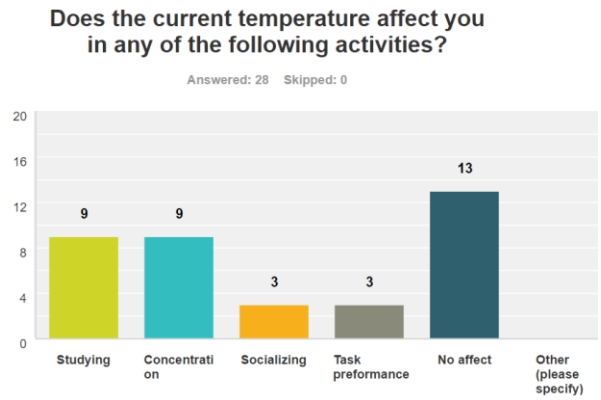


Table F3: Study room/office space

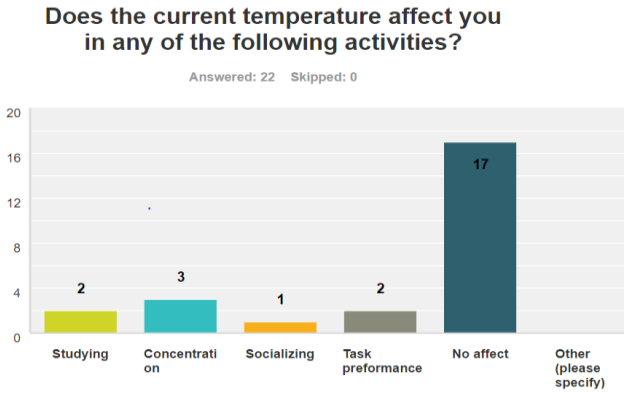


Table F4: Main Atrium