BUILDING 661, PHILADELPHIA, PA

ENVIRONMENTAL QUALITY REPORT

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Preface

Building 661, Philadelphia, PA

As a member of the Subtask 5.4 Indoor Environment Quality (IEQ) assessment team, the Center for Building Performance and Diagnostics (CBPD) at Carnegie Mellon University conducted a Post Occupancy Evaluation (POE) for Building 661 in Navy Yard, Philadelphia, PA, on July 10th, 2015.

The IEQ study was undertaken to assess spatial and environmental conditions as well as user satisfaction in the workplace after the renovation of the building which took place in 2014. The set of measures, described in detail in the full report, include: as built records of the technical attributes of building systems (TABS); spot measurements using the National Environmental Assessment Toolkit (NEAT) instrument cart; 24-hour continuous measurements using Aircuity system for the thermal and air quality in the workplace; and short-term user satisfaction questionnaires in the sampled workstations.

The study was focused on measuring IEQ on a cooling season - thermal, air, lighting and acoustics - capturing the physical attributes of the building systems that may be critical to those measurements as well as user satisfaction on a “right-now” basis for comparison to the measurements. This IEQ study will be used to test the effectiveness of energy conservation measures, and to provide further cost-benefit justifications for energy retrofit investments where possible.

BUILDING 661, PHILADELPHIA, PA

Building Post Occupancy Evaluation and Measurement (POE+M)

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Executive Summary

HVAC Recommendations

- Provide control of humidity for the perimeter closed offices. Dehumidify intake air from the headhouse corridor can be a solution.
- Provide control of temperature for the open offices. Having a high level of control ensures high level of occupant satisfaction, as shown in the COPE survey result for occupants in the closed offices.
- Correct set-point in the central system to ensure that all spaces meet code requirements for thermal comfort and that occupant satisfaction is maintained even at maximum occupant capacity for the symposium room and open offices.
- Provide CO_2 metering data to occupants in every office unit and educate them about the use of natural ventilation.
- Match current BAS schedule with the actual building schedule. BAS schedule for DOAS can be shortened in order to save energy, if it does not increase temperature and RH to create discomfort in the morning.

Lighting Recommendations

- Provide dimming controls for occupants on the 1st floor, who are experiencing glare due to lighting fixtures.
- Install motorized blinds for every window to avoid glare in the morning or late afternoon.
- Change the office lay-out to reduce daylight glare in the morning. Move table to face south to eliminate direct glare from morning sun.
- Install blind control system that takes into account orientation of windows, time of day and tasks of occupants (with manual override).
- Change the downlight fixtures to direct/indirect light fixtures to reduce glare from light fixtures.

Acoustic Recommendations

- Provide acoustic barrier to reduce the mechanical noise from mechanical room/outside chiller.
- Provide sound-absorbing treatments to offices near the mechanical room.
- Create better acoustic partition in open offices to reduce discomfort from background noise and other peoples' conversation.
- To increase speech privacy, sound masking may be employed to reduce unwanted high speech intelligibility.

BUILDING 661, PHILADELPHIA, PA

Building Post Occupancy Evaluation and Measurement (POE+M)

Introduction and Evaluation Method

Summer 2015

Center for Building Performance and Diagnostics
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Figure 1 Site plan, Building 661, Philadelphia, PA (Satellite image from Google Earth)

Figure 2 Exterior image, Building 661, Philadelphia, PA

This environmental quality report (EQR) describes the results from spot and continuous measurements and user satisfaction surveys as well as recommendations for improving the indoor environment quality (IEQ) of Building 661.

Building 661, the headquarters building for the Consortium for Building Energy Innovation (CBEI), is a 38,000-square-foot former U.S. Navy recreation center located at 12th & Kitty Hawk Ave. Called the Penn State Center for Building Energy Science and Engineering, the building houses the headquarters of CBEI, which just relocated from Building 101 in late 2014 (Source: http://www.navyyard.org/theyardblog/). On July 10th, 2015, the CBPD team conducted the spot measurement with NEAT cart on the first and second floor, and the user satisfactory surveys were distributed based on the measured workstations.

Table 1 Office layout of Building 661

Open office, no partition, 1F

Open office room135

	
Open office, High partition, 1F	**Open office room131**
	
Closed office, 1F	**Closed office room123**

Table 1 shows the four typical use of room by their function in the Building 661. On the first floor, there are open offices with no partition, open offices with high partition, and closed offices. The team conducted IEQ field measurements for lighting, thermal, air and acoustic qualities of the open and closed off Based on the availability and willingness of the occupants to participate, 26 occupants completed the survey on the cooling season. 30 workstations were identified for which the data was collected. Figure 3shows the location of each of the IEQ measured workstations on the first floor. The thermal and air quality continuously measured data for office 135 and office 104 from the installed Aircuity system was also collected during that day.

Figure 4 indicates the levels of user satisfaction with lighting, thermal/IAQ, privacy/acoustic, and spatial conditions derived from 26 surveys taken in the whole building, 21 taken in the open office, and 5 taken on the closed office, respectively. The figures were generated from the charts on the NEAT website which are listed in the Appendix.

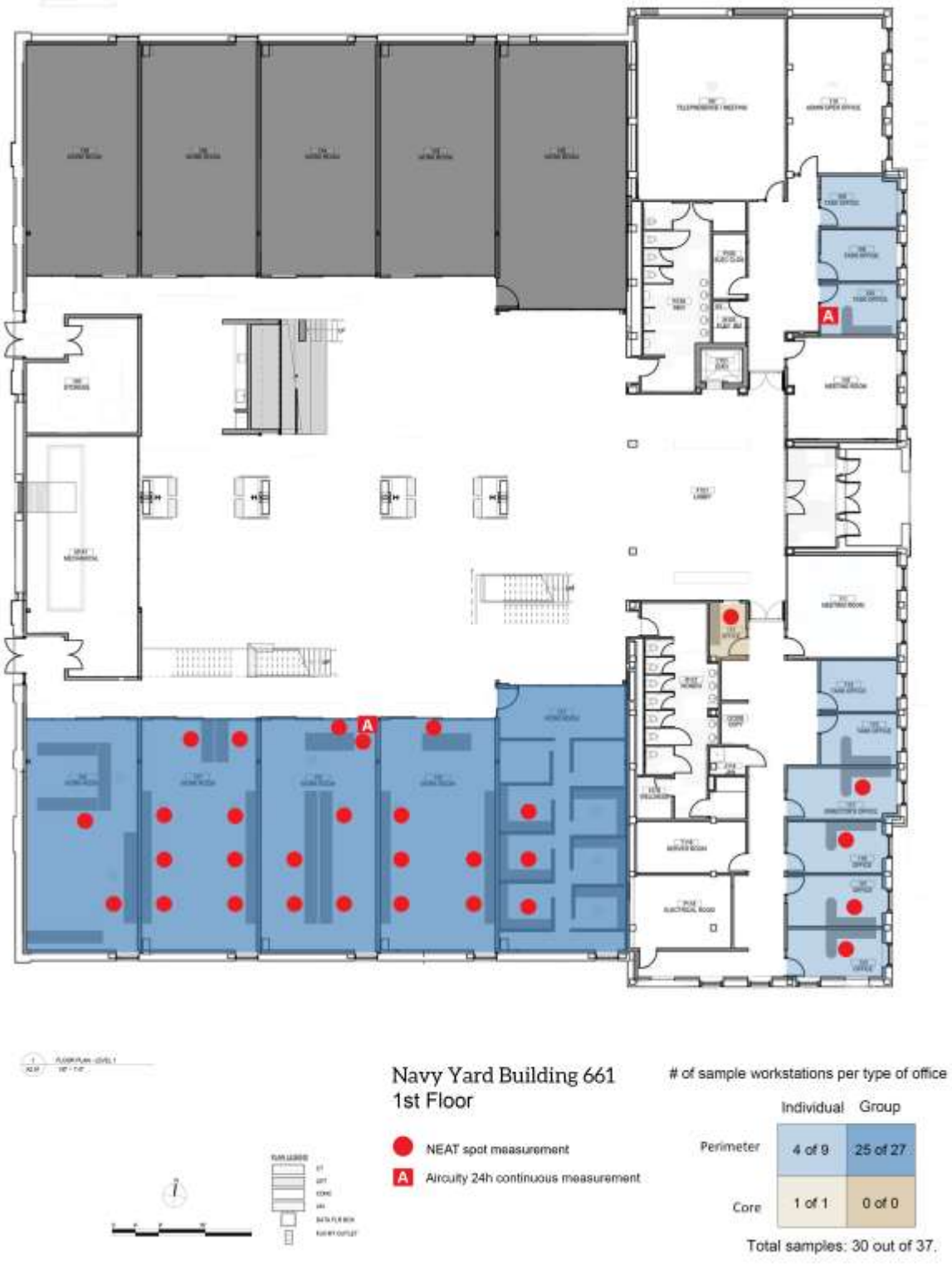

Figure 3 Building 661 1st Floor Plan

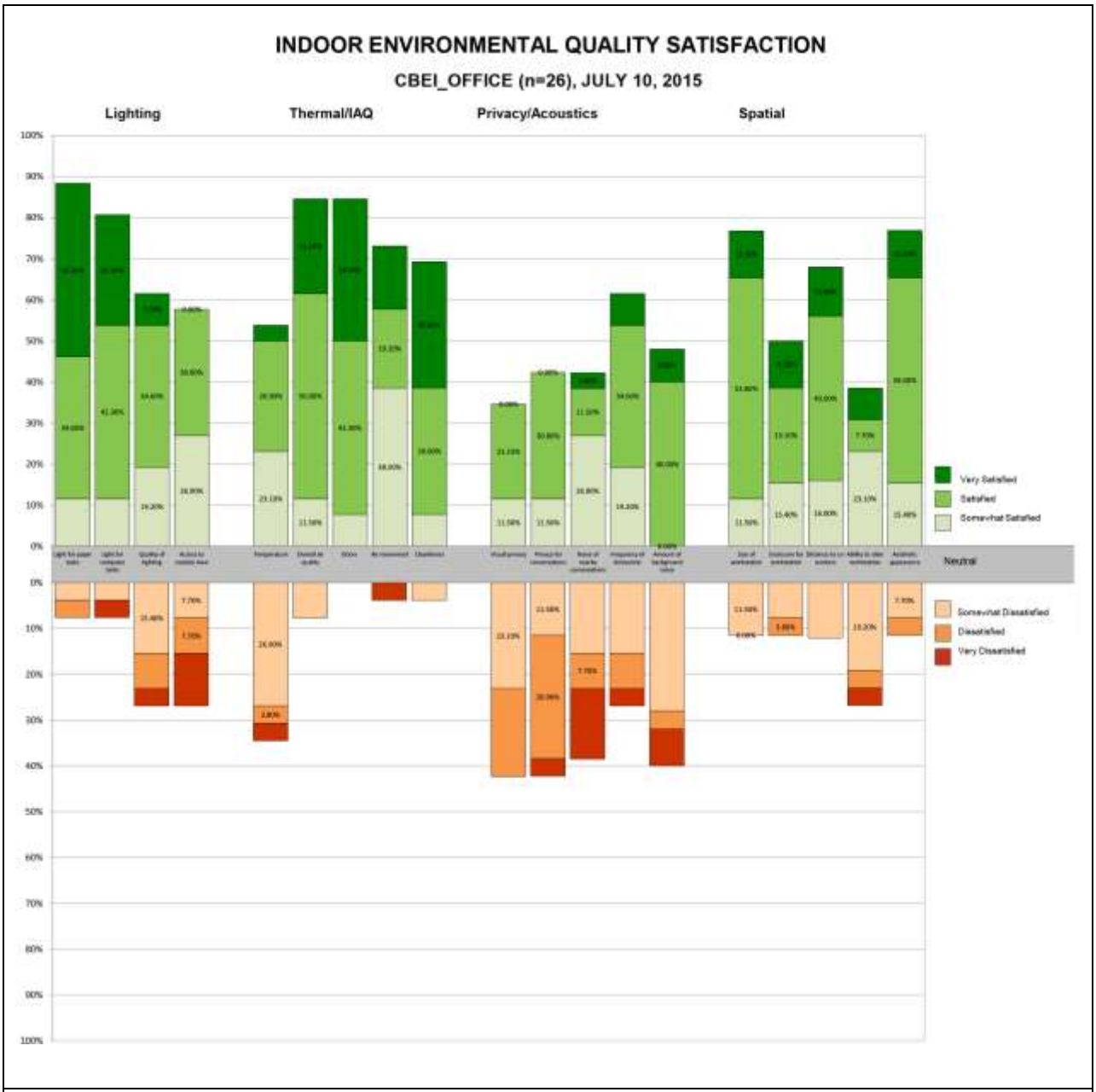

Figure 4 IEQ User Satisfaction Survey Result: Building 661 open and closed office (n=26) July 10th, 2015 (Cooling Season)

Objective Data Collection Procedures

The Center for Building Performance and Diagnostics at Carnegie Mellon with support from the General Services Administration developed the National Environmental Assessment Toolkit (NEAT) to measure thermal, air quality, lighting and acoustic quality in the indoor environment. The toolkit is comprised of an instrument cart (Figure 5) for spot measurements, a checklist on the technical attributes of the building systems (TABS) that define each location, and a user satisfaction questionnaire. A detailed manual defines each step of the sampling strategy, in order to ensure consistency in data collection. In summary, the instrument cart shown in Figure 5 is placed in the position of the occupant for approximately 15 minutes for each occupant location sampled. For the first few minutes, the sensors are allowed to acclimatize to the environment in the workspace. Then, automated sensor readings of temperature at three heights, relative humidity, and four air quality indices are taken over the next four minutes at 15-second intervals, and averaged to obtain the final measurements in that workstation. At the same time, hand held readings of light levels (6 readings) from the illuminance meter (Figure 6), radiant temperature (2-4 readings), and air velocity (2 readings) are logged into the data logger. Furthermore, the hand-held Analyzer Type 2250-L with Microphone Type 4950 (Figure 7) is utilized to measure the acoustic level of the workstation and store the data in the CF card for future analysis using computers.

Before leaving the workstation, four digital pictures with a fish eye lens capture brightness contrast, and two conventional digital photographs are taken to record the workstation configuration and furniture as well as the layout of the primary work surfaces. Environmental indicators revealing individual control or modification of lighting, thermal, indoor air quality, acoustic, and spatial/ergonomic conditions are also logged. Each location sampled is given an identification number on building plans, along with a time and date stamp, recorded in TABS checklists and workstation data sheets. The instrument cart and hand held measurements are then entered into the NEAT data base for data display and analysis.

While spot measurements capture the diversity of conditions across a space, 24-hour continuous measures capture the diversity of conditions across time. Aircuity's system containing two monitors on the first floor (one in an open office135, the other in a closed office104), is utilized to measure temperature, relative humidity, and CO_2.

Figure 5 Spot measurement with NEAT cart

Figure 6 Illuminance Meter

Figure 7 Sound Level Meter

Meeting the standards developed for NEAT, spot and continuous measurements, as well as user satisfaction questions, were completed for thermal, air quality, lighting and acoustic quality in each of the Building 661 workspaces studied. The subset variables of each of these environmental measures are identified in Table2, and the industry performance standards used for evaluation of performance is identified in Table3.

Subjective Data Collection Procedures: On-site User Satisfaction Questionnaires

During the time when the physical measurements are recorded, the occupant is asked to complete a "User Satisfaction Questionnaire" related to today's specific environmental conditions, as compared to annual satisfaction questionnaires. The COPE Questionnaire was developed by the National Research Council Canada to support the Cost-effective Open-Plan Environment (COPE) Project. The two-page, 25-question survey (plus 4 demographic questions) has been utilized by the NRC in their ongoing research about measured environmental performance and simultaneous levels of user satisfaction in various open plan office environments. A few questions have been modified as the result of recommendations

from the lighting research group of Public Works Government Services Canada, and ongoing input in field use.

Table 2 Environmental quality measures taken

	Indices	*Measured items*	*Unit*	*Spot measurements*	*Continuous measurements*	*User surveys*
1	Thermal quality	Temperature Relative humidity	°F %	√ √	√ √	√
2	Air quality	CO_2 CO TVOC Radon Ozone Particulates	ppm ppm index pCi/L ppm #/ft^3	√ √ √ - - √	√ √ √ √ √ √	√
3	Lighting quality	Illuminance Glare Luminance Ratio	lux - -	√ √ √	- - -	√
4	Daylight and Views	Glare Access to view Space appearance	- - -	- - -	- - -	√
5	Acoustic quality	RC/NC/NCB QAI	- -	√ √	- -	√
6	Spatial quality	Multiple variables		- -	- -	√
7	Overall satisfaction	Multiple variables	-	-	-	√

Table 3 The measurements taken at each workstation, as well as calculated variables

CATEGORIES	STANDARD GUIDELINES				SOURCES
THERMAL QUALTY					
Temperature	Cooling Season (0.5 clo)		76-82 ^{0}F (RH: 30%)		ASHRAE 55 (2010)
			74-78 ^{0}F (RH: 60%)		
	Heating Season (1.0 clo)		69-78 ^{0}F (RH: 30%)		
			68-75 ^{0}F (RH: 60%)		
	Floor surface Temp.		66.2 – 84.2 ^{0}F		
Radiant Temperature Asymmetry	Warm Ceiling : < 9.0^{0}F				ASHRAE 55 (2010)
	Cool Wall : < 18.0^{0}F				
Relative Humidity	≤ 65 %				ASHRAE 62 (2010)
	≥ 30 %				CCOHS (2006)
Air Speed	≤ 40 ft/min				ASHRAE 55 (2010)
	≤ 50 ft/min				CCOHS
INDOOR AIR QUALITY					
Carbon Dioxide	700 ppm above outdoor CO_2 level				ASHRAE 62 (2010)
	< 5000 ppm				OSHA
Carbon Monoxide	< 9 ppm				EPA (IAQ spec.)
	50 ppm (1hour)				OSHA
TVOC	< 200 ug/m^3 above outdoor TVOC concentration				EPA
Particulates	PM 2.5 : 1 ≤ 1,665,278 #/CF or 20 ug/m^3				Airquity
	PM 10 : ≤ 17,204 #/CF or 40 ug/m^3				
	Total Particulates : < 20 ug/m^3				EPA
LIGHITNG QUALITY					
Default Luminance and Luminaire intensity recommendation for VDT applications	*Medium-to Good*	*CSA/ISO Type I and Type II monitors*	*Positive Polarity*	≤1500cd/m^2 at 65^o and above	IESNA HB-10-11 (2011)
			Negative Polarity	≤1000cd/m^2 at 65^o and above	
	Poor	CSA/ISO Type III Monitors	Positive Polarity	≤500cd/m^2 at 65^o and above	
			Negative Polarity	≤200cd/m^2 at 65^o and above	
	Luminaire Candlepower Limits		300cd @55^o, 185cd @75 ^{o}, 60cd @85 ^{o}		
Luminance Ratio	Paper task to negative(positive) polarity VDT screen 3:1 (1:3)				IESNA HB-10-11 (2011)
	Task to immediate background surface 3:1				
	Task to dimmer(bright) distance background 10:1 (1:10)				
Maintain visual comfort	Task to delight media 1:40, Task to luminaires 1:40				IESNA HB-10-11 (2011)
	Light-source-adjacent-surfaces to light source 1:20				
Minimize veiling reflections	*CSA/ISO Type I and II negative polarity monitors in critical/high situations*		Brighter ceiling and/or wall zone to dimmer ceiling and/or wall zone 4:1		IESNA HB-10-11 (2011)
	CSA/ISO Type I and II negative polarity monitors in normal/secondary situations		Brighter ceiling and/or wall zone to dimmer ceiling and/or wall zone 8:1		
ACOUSTIC COMPONENT					
Room Criteria	≤ 40 (Open-plan offices)				ASHRAE (2010)
	≤ 35 (Private offices)				
Quality Assessment Index	≤ 5 dB				ASHRAE (2010)

Data Analysis Procedures

In order to access or upload data to a project, one must logo onto the NEAT website using the provided user name and password. After successfully logging in, one will be directed to the project list window and then allowed to select a specific project for detailed results. Paper version user satisfaction survey results are required to be inserted manually by opting to “take satisfaction survey”, and data as to spot measurements and COPE surveys is visualized as charts which are automatically produced from the NEAT database. Moreover, to choose a specific work group, one will be redirected to a page that shows the number of spaces and responses for COPE on-site survey for the particular group. Moreover, the raw data of spot measurements and imported user satisfaction questionnaires can be accessed when a specific group is investigated.

The luminance measurement in the IEQ field study is achieved by the Photolux 2.1 which is a photometric measurement system, consisting of processing software and a calibrated digital camera with a fish eye lens. The processing software could create luminance maps using the photos from the fish eye camera when one chooses to “compute illuminance”. Coupling with the Excel spreadsheet template, the software could also calculate the UGR and contrast ratio required in the lighting analysis. There are several elements of analysis that are of significance during analysis. The zone characteristics allow you to give a name to a new or a selected zone and to apply a correction factor to the pixels of this zone. The luminance values inside the selected zone are recalculated accounting for the correction factor, which helps to test the impact of retrofitting actions (window screen, low luminance luminaries, etc.) on the UGR value inside a scene. And the “Statistics” window allows you to find the minimum, the average and the maximum luminance values, their standard deviation and the illuminance resulting from these luminances. One can compute the statistics for one or more selected zones (cumulated) or for the whole map. Images in the BMP format (file extension .bmp) will be produced from the luminance maps (including eventual marked values or zones), which can easily be inserted in a MS Word document or in a MS PowerPoint document. In Figure 8, the interface shows the four pictures imported into the software, and the one in Figure 9 demonstrates the luminance map as well as the statistical results generated by the software.

In terms of acoustic measurements, data is stored directly on SD or CF cards in the sound meter. Utility Software for Hand-held Analyzers BZ-5503 is an archiving tool for 2250 Light data and setups, and functions as the link between 2250 Light and post-processing or reporting software on a PC. Data can be directly read from the memory card by the included PC software BZ-5503, which means that even large amounts of data can be quickly transferred to a PC. When exported from the sound meter, data can be logged onto the NEAT website for further analysis and display.

Figure 8 Photolux 2.1 Interface – 4 pictures of same scene taken with different EVs

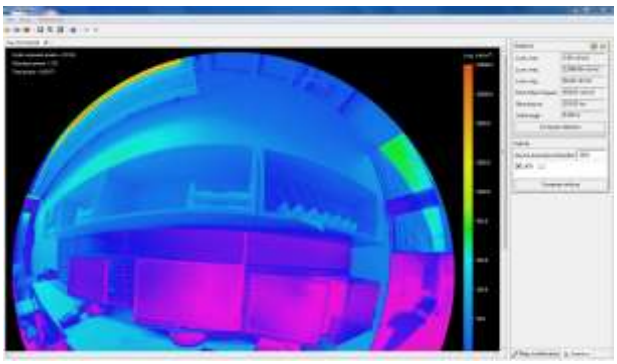

Figure 9 Photolux 2.1 Interface – luminance map

In this project, data from the continuous measurements using the mobile data-logging carts is analyzed. Specifically, the measurement results from the two carts on the first floor was imported into Microsoft Excel to generate charts to describe the thermal conditions and air quality in the measured workstations.

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Building Post Occupancy Evaluation and Measurement (POE+M)

Thermal and Air Quality:

Findings and Recommendations

Summer 2015

Center for Building Performance and Diagnostics
Carnegie Mellon University

Thermal & Air Quality HVAC TABS: baseline physical attributes/quality differences

Thermal and Air quality	First Floor		Second Floor
	Closed Office	**Open Office**	**Symposium, ICON LAB**
Core HVAC system type	Ductless split system	DOAS	RTU
Perimeter System Type	-	Chilled Beams	VAV
Thermostats	Accessible thermostat with set point and status	Locked but visible with status	
Number of occupants per thermostat	1	5 - 8	Max 152
Diffuser alignment	Good alignment, high panels, cluttered		
Seasonal switchover	Scheduled according to outside Temperature/Relative Humidity (No seasonal switch over)		
Window thermal quality	Double pane, Tight		
Window light quality	High visible transmission, group internal roller shades (Not operating)		

Thermal and IAQ NEAT Measurements and User Satisfaction

Figure 10 illustrates the continuous air temperature measurements results for July 10, 2015 12:00AM – 23:50PM in typical open-office (Room 133) and closed office (Room104).

In the open office, indoor temperature varies from 74 °F to 76 °F during work hours, 100% of time meeting the ASHRAE standard.

According to the building automation system (BAS), temperatures of open offices are controlled during the preset occupied hours-6:00 AM to 9:00PM on weekdays. During this time periods BAS operates the mechanical system to meet the desired set point. However, the actual work hour of the building is from 8:00AM to 5:00PM during the weekdays. According to the data collected by Aircuity system, it is observed that the temperature hits the lowest boundary of the ASHRAE standard by multiple times. If it is guaranteed that there is no remaining occupant, the set-point after 5:00PM can be higher or the offices even can be uncontrolled. Providing manual override for temperature set-point can be a solution to save energy and satisfy occupants' thermal comfort.

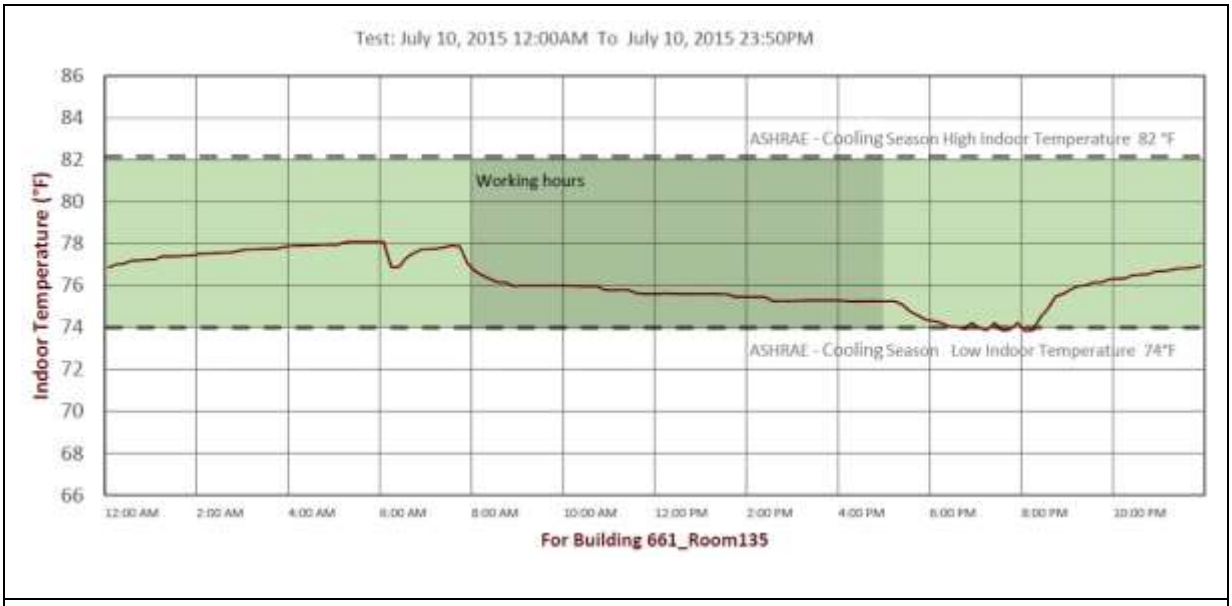


Figure 10 Continuous air temperature measurements , July 10, 2015 (Open office 135)

On the other hand, indoor air temperature of the closed office ranged 67 - 72°F throughout the occupied hours, not meeting the ASRHAE standard for the cooling season. Unlike in open offices where the air temperature is controlled exclusively by BAS, occupants in the closed offices can control the set-point temperature as they want. Since the accessible thermostat is installed in every closed office, occupant comfort would not be an issue even the temperature is bit lower than the standard.

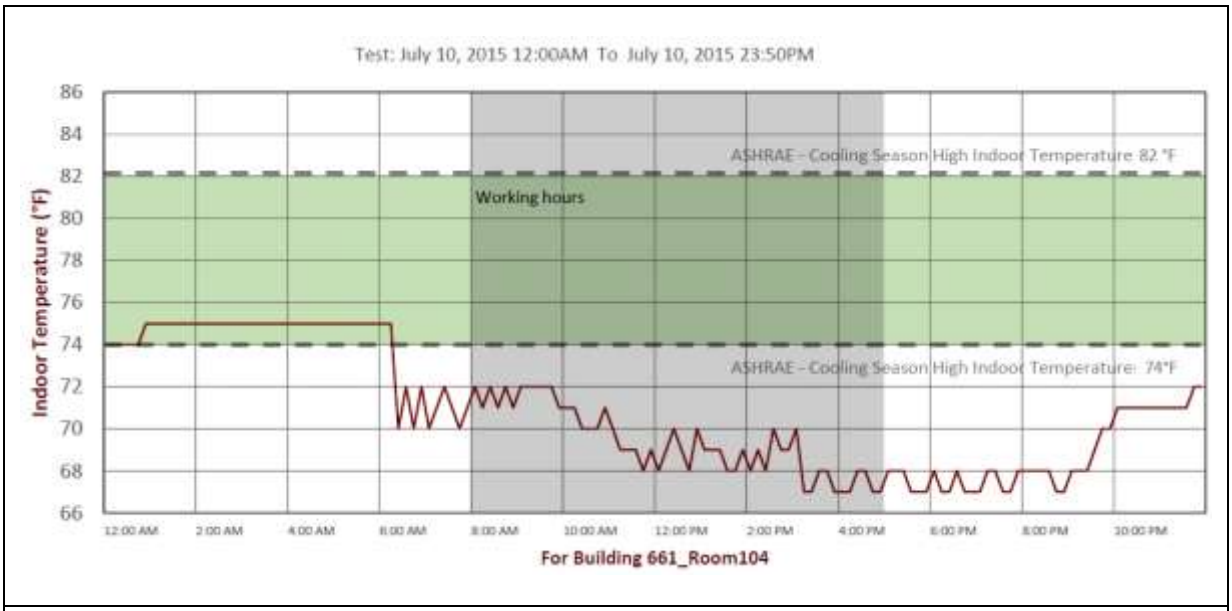


Figure 11 Continuous air temperature measurements , July 10, 2015 (Closed office 104)

Relative humidity in open office ranged from 44.3% to 58.7 %(timed average: 47.8%), kept decreasing during the mechanical systems operation, meeting the ASRHAE standard through the day.

Figure 12 Continuous relative humidity measurements, July 10, 2015(Open office 135)

In the closed office, relative humidity varied between 60.6% and 66.8 %(timed average: 64.2%). During the most of the time relative humidity meets, but maintain very close to the upper limit of the ASHRAE standard. Unlike open offices where the supply air is delivered from DOAS unit, ductless split unit in a closed office recirculates the air in the room, which means there is no way to control the amount of

moisture in the air in a mechanical way. To maintain thermal comfort, closed offices may need lower air temperature to offset the latent heat due to the high humidity, particularly in humid summer days.

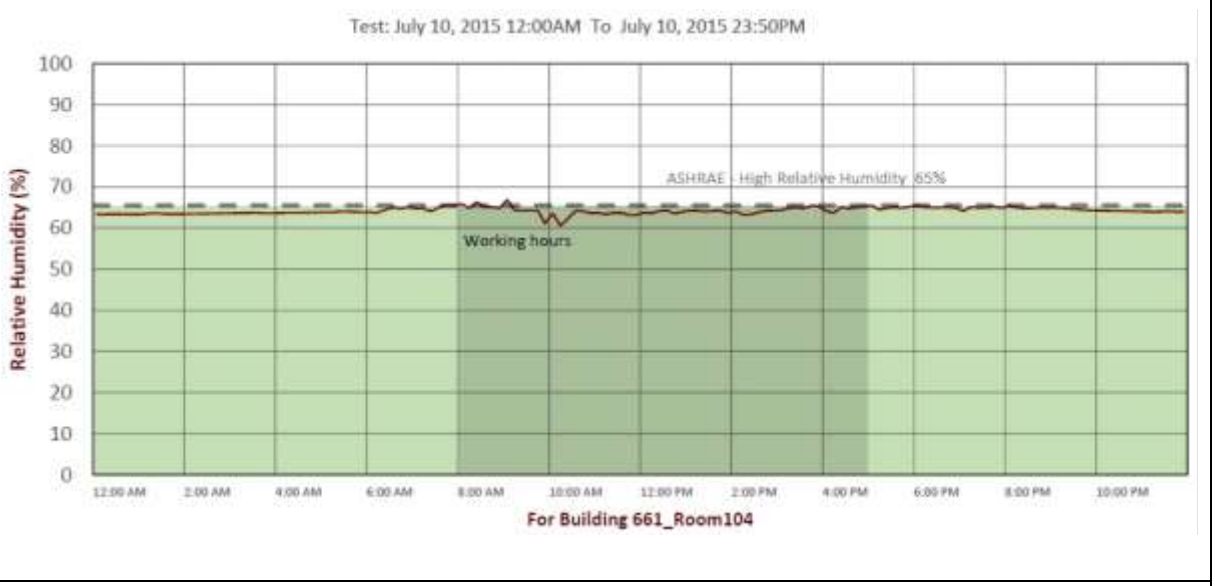


Figure 13 Continuous relative humidity measurements, July 10, 2015(Closed office 104)

On a typical cooling season day, Jul 10th, 2015 (Table 4), the temperature at 2 feet above the floor (average =75.1°F) satisfied 90.0 %(27 out of 30) of the spaces within the ASHRAE comfort range. The vertical temperature difference on all workstations was acceptable on the 1st floor except for one workstation. The horizontal and vertical radiant temperature difference in every workstation was in acceptable range on the 1st floor.

Table 4 Spot Measurement: Temperature at 0, 2 and 4 ft. from the floor

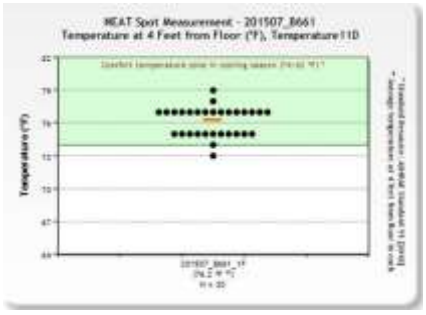
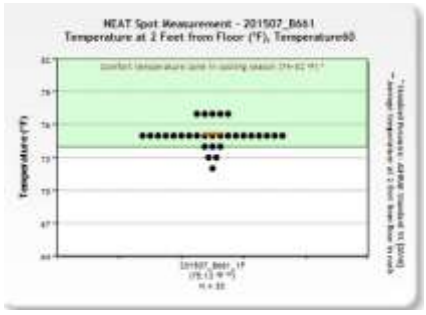
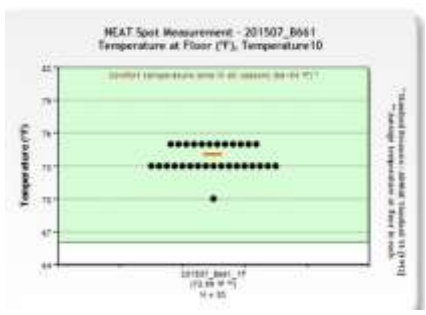
		
4 ft. from floor - 1st floor	**2 ft. from floor - 1st floor**	**0 ft. from floor - 1st floor**

Table 5 Spot Measurement: Radiant Temperature Difference (Cooling Season)

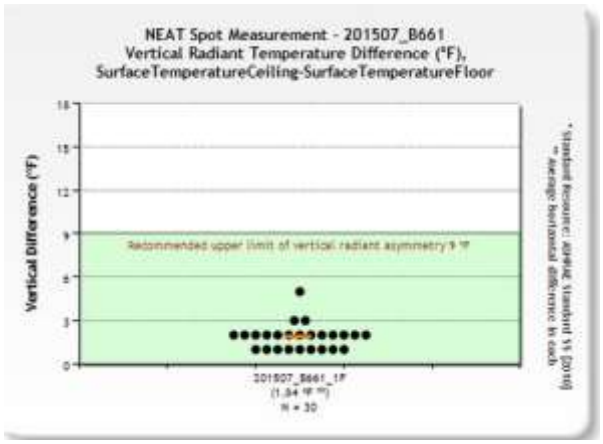
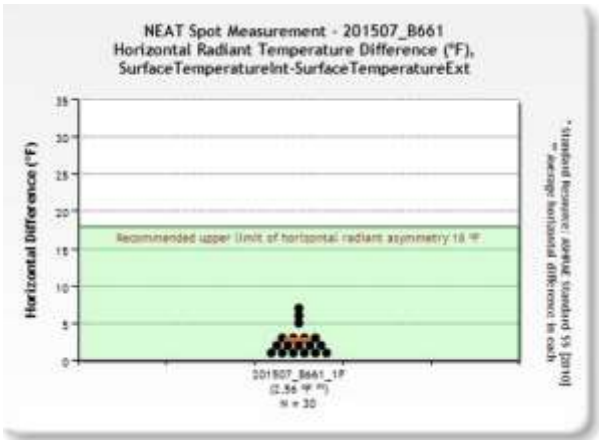
	
Vertical radiant temperature difference	**Horizontal radiant temperature difference**

Figure 14 shows that the relative humidity satisfies the ASHRAE standard in 93.3 %(28 out of 30) of the spots, which has upper boundary of 65%. Both of the spots that don't comply with the standard were closed offices. The RH average of 4 spots located in the perimeter closed offices was 66.1%, which is 16.1% higher than that of spaces controlled with DOAS and Rooftop unit+VAV system (50.0%). This difference is likely to happen particularly in typical summer days with high humidity in this region. Since there is high humidity in the outside air in this season and have no mechanical way to lower the RH, currently the only way to cope with thermal condition is to lower the set point temperature for the occupants' comfort.

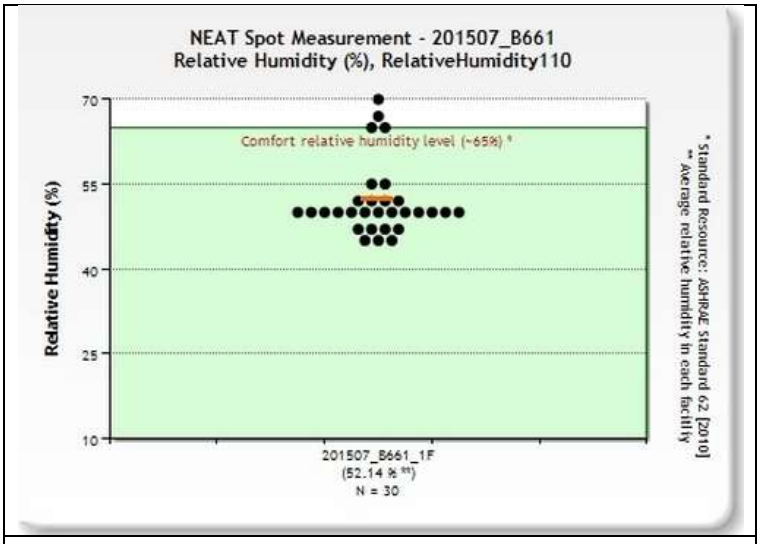


Figure 14 Spot Measurement: Relative humidity

Figure 15 shows that 34.6% of the surveyed occupants on the 1st floor were dissatisfied with the temperature in their work area during the summer, and the biggest complaint about the temperature from those surveyed occupants was about the cold indoor temperature in the cooling seasons (Figure 16). The number of occupants who answered the air temperature during the summer is cool or cold (46.1%) doubled the number of those who answered warm (23.0%). Set point can be set higher in order to reduce the number of occupants with thermal discomfort.

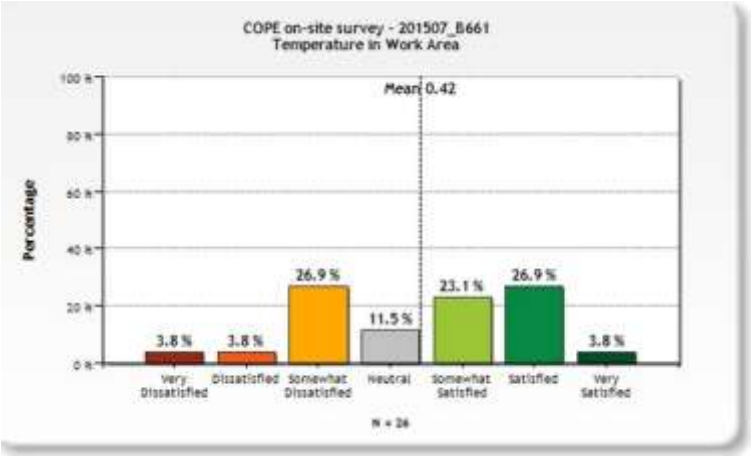


Figure 15 User Satisfaction Survey: Temperature in your work area

The overall thermal comfort is not satisfactory. The ASHRAE 55 considers as "acceptable dissatisfaction" as much as 10%. In the offices 34.6% of people are dissatisfied. It is most likely that occupants are not comfortable with the current temperature set point during working hours.

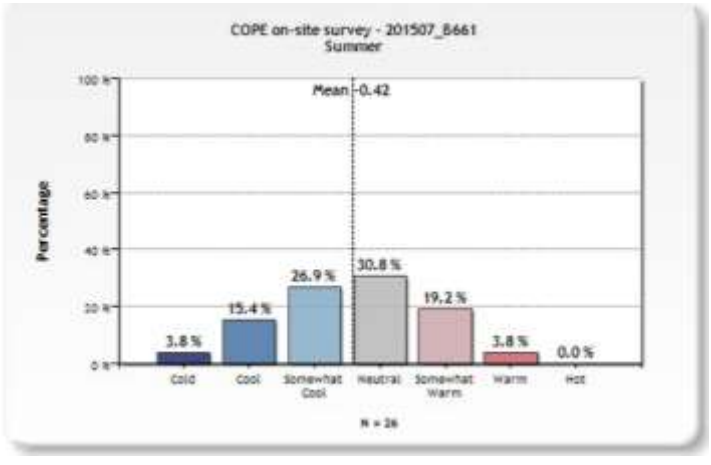


Figure 16 User Satisfaction Survey: Summer Temperatures

Color mapping of occupant satisfaction on workspace temperature doesn't shows noticeable spatial patterns of occupant satisfaction (Figure 17).

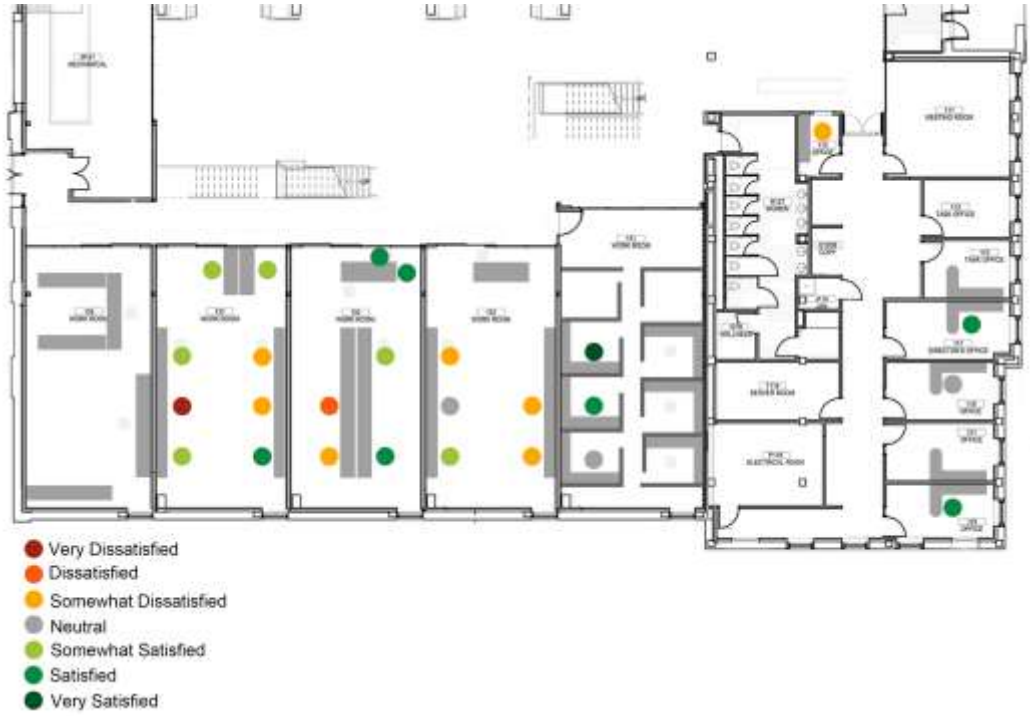


Figure 17 Color mapping of occupant satisfaction :Temperature of workspace

Thermal satisfaction was found to have a certain relationship between the gender of occupants. 77.8% of occupants (7 out of 9) who answered they are dissatisfied with current thermal condition was female. Those people accounts for 50% of the entire female respondents, which is about three times greater than that of male respondents' (16.7%). Among female respondents who are dissatisfied, 85.7 %(6 out of 7) answered the temperature is cool or cold during the summer season. When one of them-who is the only female occupant in the core individual office- is excluded, 100 %(6 out of 6) of thermally dissatisfied female respondents answered that their office is cool or cold. Although the size of the sample is not big (n=26), it can be driven that female occupants in building 661 are more sensitive to thermal discomfort from cool air temperature than male occupants in overall.

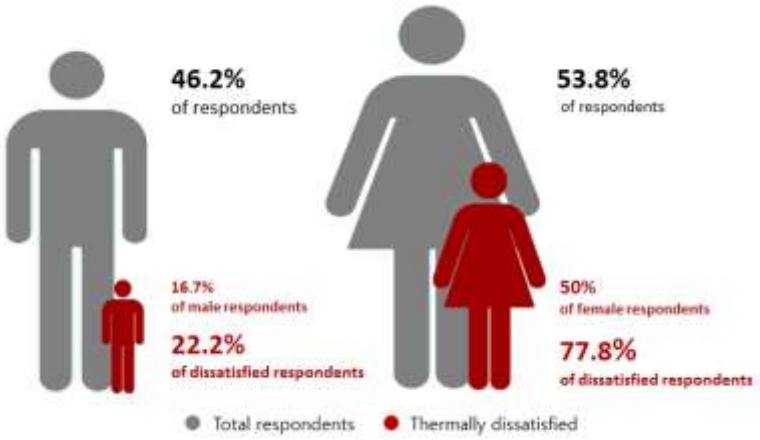


Figure 18 Gender demographics of thermally dissatisfied respondents

Overall thermal quality parameters are mostly satisfying the thermal quality standard such as ASHRAE 55. However, 34.6% of surveyed occupants (77.8% of them are female) are dissatisfied with thermal condition. Given that all of the dissatisfied occupants are in open-office which has lower level of control of thermal condition compared to closed offices, providing higher level of control (e.g. thermostat with set-point control) may help to maintain higher satisfaction on thermal environment.

Figure 19 Continuous CO2 Level (ppm) measurements in Open office 135, July 10th

Figure 20 Continuous CO2 Level (ppm) measurements in Closed office 104, July 10th

Both the open plan office and closed office shows CO_2 level less than 600 ppm throughout the whole day. Especially during the work hours, the CO_2 level is complied with the ASHRAE 62.1 standard. In the open offices, the BAS controls the mechanical system according to real-time CO_2 reading from the sensor installed in every workroom. Unlike in the open offices, there is no automated control for CO_2. Since the size of the closed offices is about 6 times smaller than open offices, CO_2 level may fluctuate in greater

pace and intensity. The only way is to ventilate the air is to open the operable window, which is undesirable in hot and humid day.

Thus the recommendations are displaying the CO_2 level properly with alarming system for occupant and educating adequate behavior based on the CO_2 level in this room such as natural ventilation. Introducing the air from the headhouse corridor, where the supply air delivered by Rooftop VAV system can be

Figure 21 Two different CO_2 monitored units in first floor (104, 135 from the left)

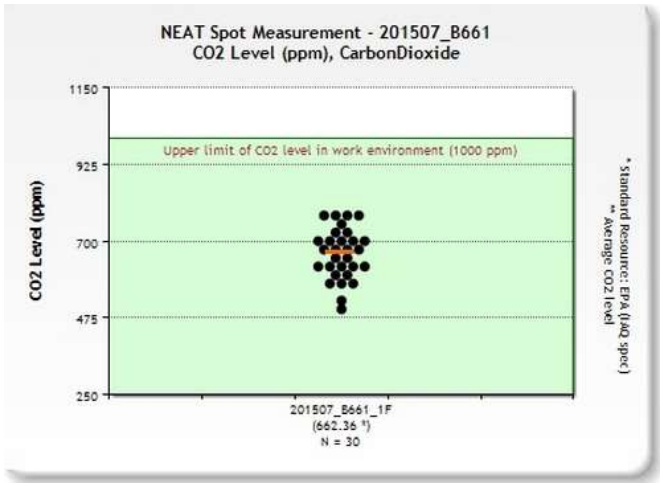


Figure 22 Spot Measurement: CO2 Level (ppm), Carbon Dioxide

On July 10th, 2015 outdoor CO2 level measured with NEAT cart was 412ppm. All the measurement spots in first floor are complied with the ASHRAE 62.1 standard which has upper boundary of 1112ppm (700ppm above outdoor CO_2 level-412ppm) for work environment. (Average CO_2 level: 662.4ppm,

maximum CO2 level: 784.8ppm) The average room CO_2 level was highest in Room137 (747.1pmm), which has 8 occupants, which is the largest number among occupied offices.

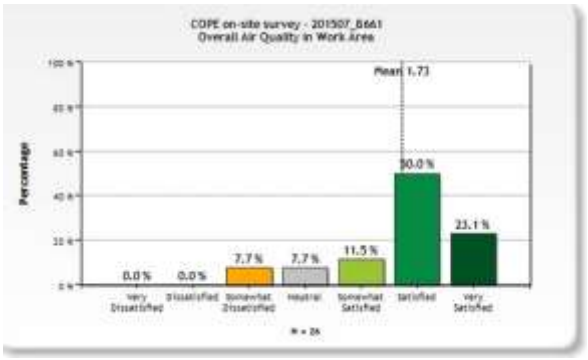
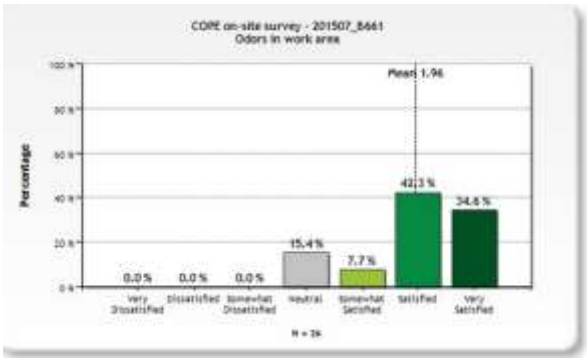
Among the open offices, the average of CO_2 level had a positive linear relationship, excluding room131, only which has 5 feet 8 inch height, two-sided partitions for each workstation.

Table 6 CO2 Average of Rooms

Room		Room CO2 Average (ppm)	# of Occupants
Open office	131	681.9	5
	133	596.2	5
	135	651.2	6
	137	747.1	8
	139	511.4	0
Closed office (average)		668.3	1 per room
1F office overall		662.4	26

Figure 23 Open plan office unit 131 and work station 131c

Table 7 User Satisfaction Survey: Overall air quality and odors

	
Overall air quality in work area	**Odors in work area**

Overall, the occupants satisfied with their indoor air quality in open and closed offices. 84.6% (22 out of 26) of respondents answered they are satisfied with the air quality.

HVAC Recommendations

The first step to improve the thermal quality is to improve ventilation systems / controls for greater thermal comfort of the occupants. In overall both thermal and air quality parameter measured with NEAT cart comply with IEQ standards. However, meeting the standards does not necessarily guarantee the comfort of occupants. In Building 661, 84.6% of occupants were satisfied with air quality, but not with thermal environment. The percentage of people of thermally dissatisfied was 34.5%, most of them answering the temperature is cooler or colder than the neutral. Occupants in the closed offices were having higher satisfaction compared to occupants in the open offices, despite of higher relative humidity. From the findings we recommendations are:

- *Provide control of humidity for the perimeter closed offices. Dehumidify intake air from the headhouse corridor can be a solution.*
- *Provide control of temperature for the open offices. Having a high level of control ensures high level of occupant satisfaction, as shown in the COPE survey result for occupants in the closed offices.*
- *Correct set-point in the central system to ensure that all spaces meet code requirements for thermal comfort and that occupant satisfaction is maintained even at maximum occupant capacity for the symposium room and open offices.*

- *Provide CO2 metering data to occupants in every office unit and educate them about the use of natural ventilation.*
- *Match current BAS schedule with the actual building schedule. BAS schedule for DOAS can be shortened in order to save energy, if it does not increase temperature and RH to create discomfort in the morning.*

BUILDING 661, PHILADELPHIA, PA

Building Post Occupancy Evaluation and Measurement (POE+M)

Lighting Quality:

Findings and Recommendations

Summer 2015

Center for Building Performance and Diagnostics
Carnegie Mellon University

Lighting TABS: Baseline Physical Attributes / Quality Differences

Lighting Quality		
Ceiling Fixture Type & Shape	Downlight fixture	
Ceiling Light Lamps	T-5	
Ceiling Light Ballast Type	User-Dimming electronic	
Alignment w/workstations	100%	
sq.ft./fixture	15	
Level of ceiling light control	**level of control**	2-10 workstations only
	type of control available	On-off
Type of computer screens	Flat screen desktop	
Daylight effectiveness	**percent with seated view of window**	20%
	average maximum distance to window	15ft
Window controls	Roll-down mesh shades (not being operated)	

Task ambient lighting system in most area of first floor workspace is 40W T-5 troffer. On the 2nd floor the conference room is also lit by 40W T-5 troffers. Ceiling lights control is only available in 2 to 10 workstations and is all in on-off control type, which limits occupants' operability. In addition to the task ambient lighting, several closed offices have their own task lights. Alignment of lighting in the whole workstation is 100%. The type of computer screens used in the workstation is all flat screen desktop which reduces the glare issues.

Table 8 Lighting Fixtures of Open-plan Workspace

T-5 40W 1st Floor

T-5 40W 2nd Floor

Though daylight access is sufficient in the workplace, the percentage with seated view of window is only 20% and workers' average maximum distance to window is about 15 ft. Building 661 is also equipped with roll-down mesh shades, an operable shading device offering opportunities for occupants to control daylight penetration.

Light levels in the offices

According to IESNA RP-104 standard, recommended light level for workspace is 300~500 lux. Readings from hand held photometer tells that only 40% of workstation monitors satisfy this range (12 out of 30).

Table 9 Spot Measurement: Light level with no task light

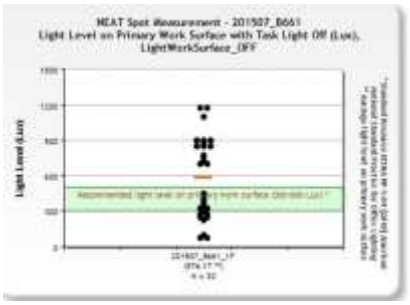
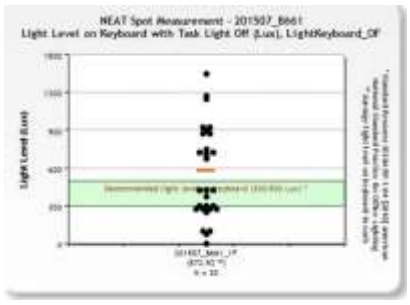
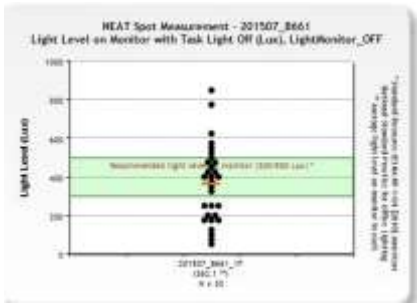
		
Primary Work Surface	**Keyboard**	**Monitor**

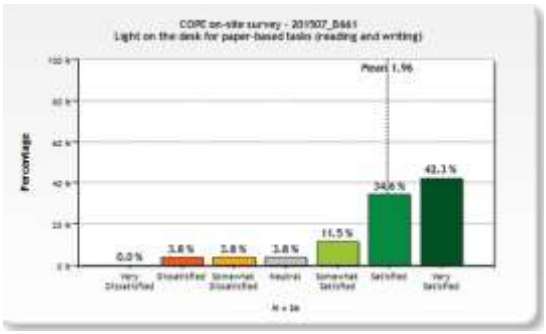
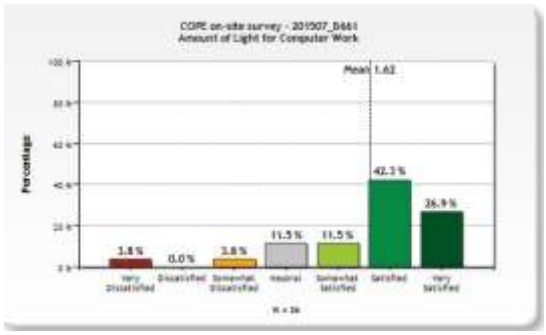
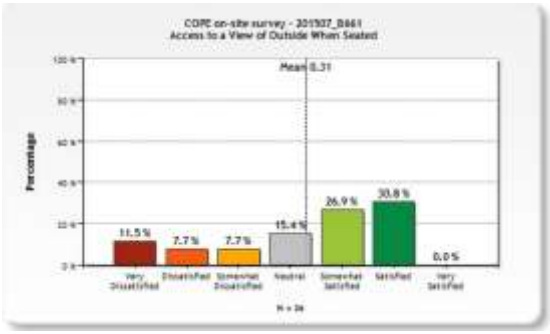
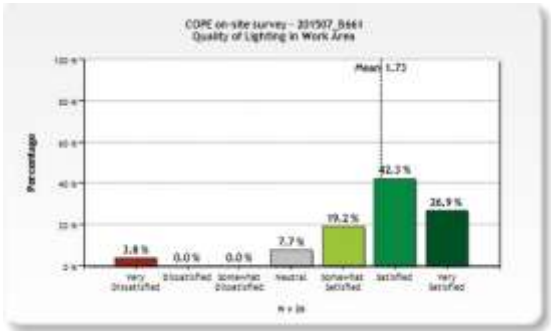
Figure 24 Color mapping of occupant satisfaction: Light level on monitor of workspace

Color mapping of the light level readings on monitors helps to find some spatial patterns with the workstation light levels. First, 100% of the closed offices and have lower light levels than the recommended range. Second, in all the spots in the core side of the open offices (inner part of the workspace) light levels ranged 100~300lux, lower than the standard. This is because these spots neither have lighting fixture on top nor have daylighting from the skylight in the 2nd floor mezzanine.

Since the light level keeps changing during the day due to sun position and other disturbances, there is a limitation to drive a certain conclusion with one-time spot measurement data. However, considering the hourly (or daily) daylight variation in the open offices (with window-to-wall ratio over 0.4) providing control of the dimming level is absolutely recommended. According to a building executive, basically the lighting system of the open offices was designed to have capability of dimming control. As shown in Figure 25, The switch on the wall in every open office has 5 buttons, so lighting in an open office can be controlled with 4 different dimming levels in maximum(Current lighting system has only 2 options: fully turned on/ fully turned off.).

Figure 25 Lighting switch in open offices

Table 10 User Satisfaction Survey: Lighting quality

	
Amount of light on desk for paper-based tasks	**Light for computer work**
	
Access to a view of outside when seated	**Quality of lighting in work area**

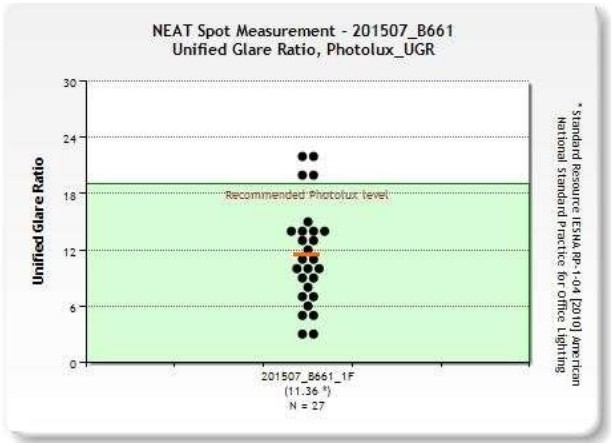
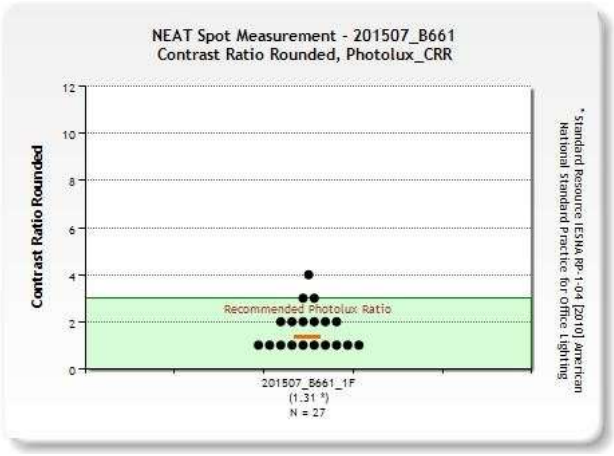
Although the high portion of workstations doesn't have recommended light levels by IESNA RP-1-04, occupants were satisfied with the amount of light on desk for paper-based and computer-based task in overall. Only 7.6% (2 out of 26) of occupants were dissatisfied with the amount of light on paper and computer based tasks.

Table 11 Spots dissatisfied with lighting quality

	
137b	**137d**

The insufficient access to outside view yields about 26.9 %(7 out of 26) of dissatisfaction, while on average occupants are slightly satisfied.

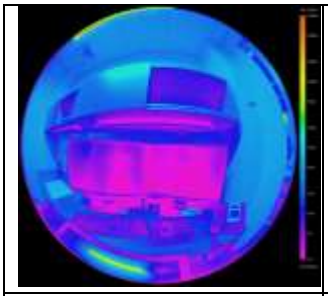
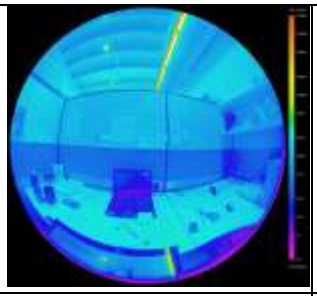
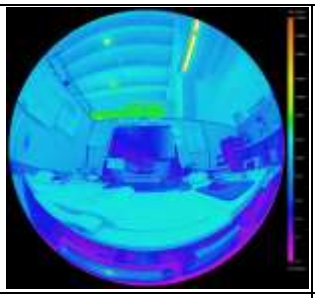
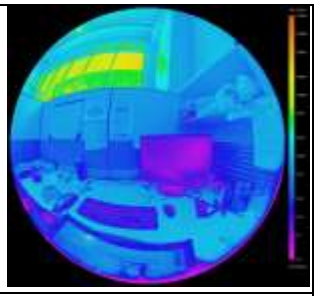
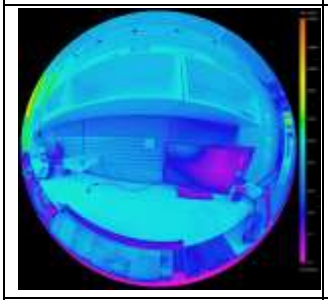
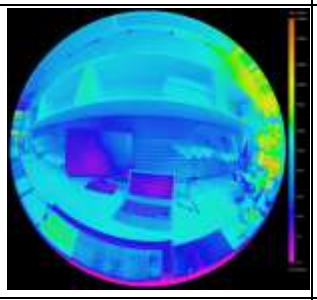
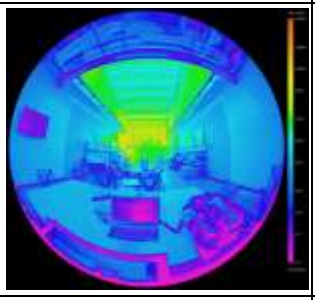
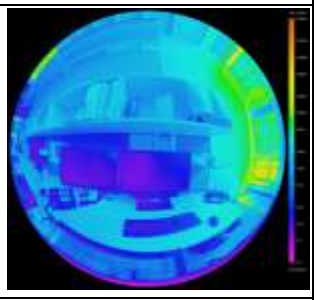
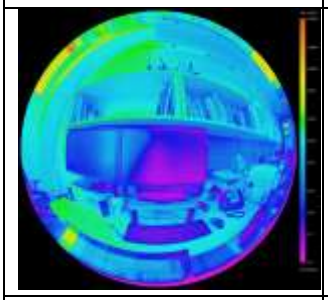
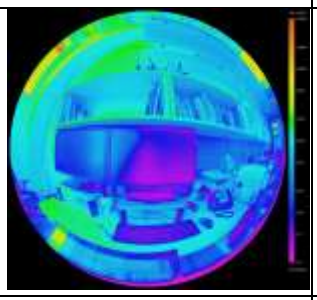
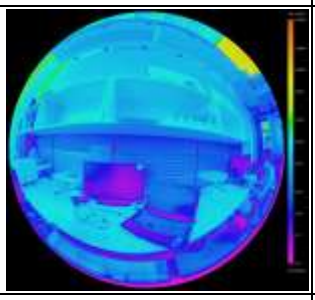
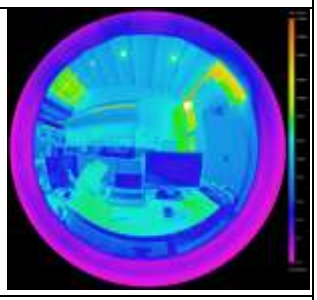
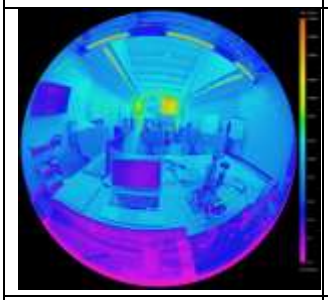
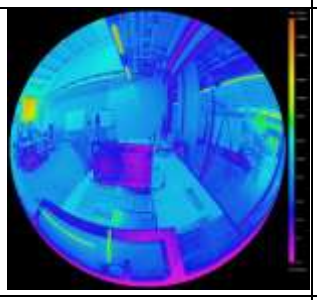
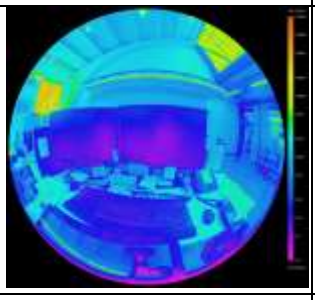
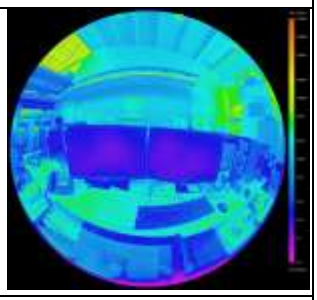
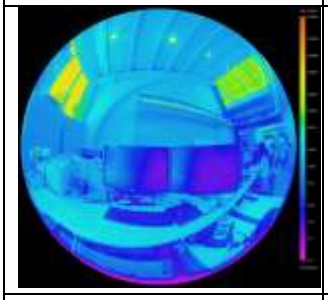
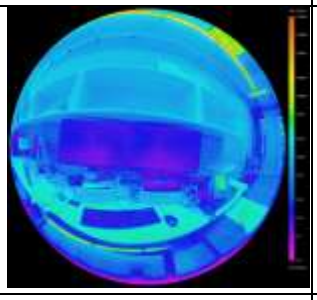
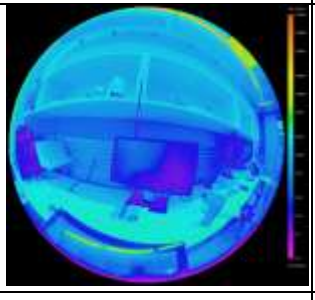
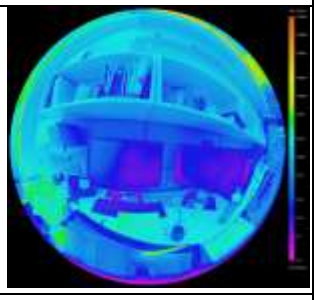
Table 12 Spot Measurement: Unified Glare Ratio (UGR) and Contrast Ratio

	
Spot measurement: Unified Glare Ratio	**Spot measurement: Contrast Ratio**

For the evaluation of glare in workstations, unified glare ratio (UGR) was used as a glare index. Recommended range of UGR is below 19 according to IESNA RP-1-04 standard. UGR evaluates glare from the background glare sources in the occupant's sight. NEAT measurement result shows 85% (23 out of 27) of the spots satisfies the standard, ranging from 2.8 ~ 22.1.

Contrast ratio is used to evaluate the brightness of monitor relative to the background. In only 1 spot contrast ratio is above recommended upper boundary of 3.0 by IESNA RP-104.

Table 12.1 Luminance Photos of offices

			
112	**131a**	**131b**	**131c**
			
133a	**133b**	**133c**	**133d**
			
133d	**133e**	**133f**	**135a**
			
135b	**135c**	**135d**	**135e**
			
135f	**137a**	**137b**	**137c**

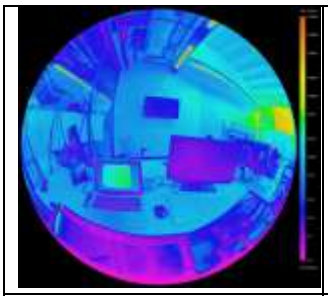
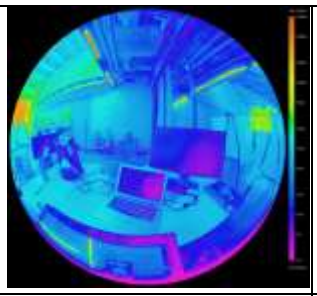
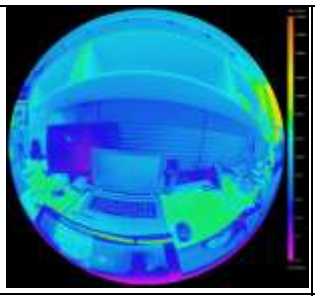
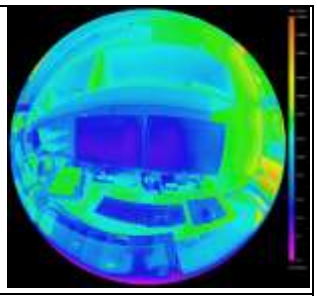
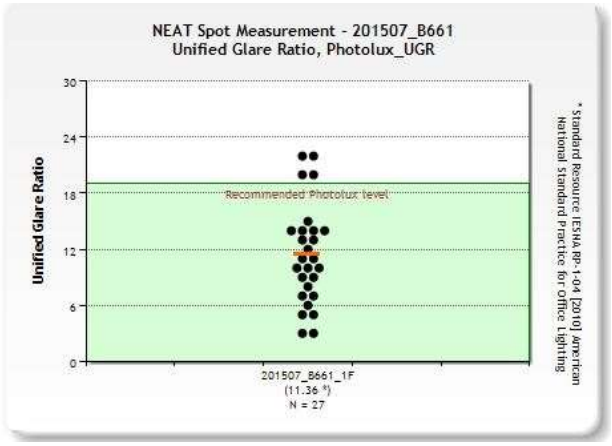
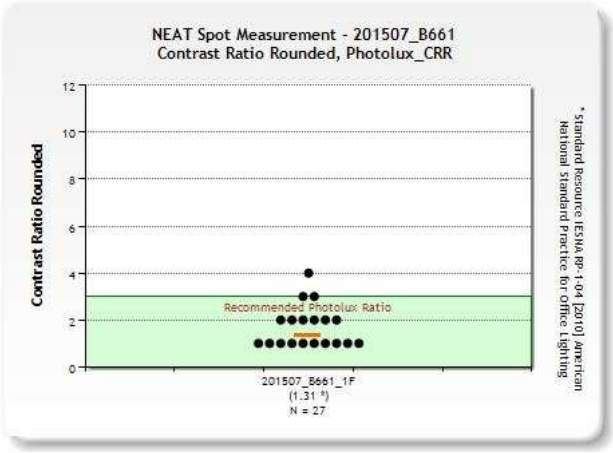
			
137d	**137e**	**137f**	**137h**

Table 13 Spot Measurement: Unified Glare Ratio and Contrast Ratio

	
Spot Measurement: Unified Glare Ratio	**Spot Measurement: Contrast Ratio**

For the evaluation of glare in workstations, unified glare ratio (UGR) was used as a glare index. Recommended range of UGR is below 19 according to IESNA RP-1-04 standard. UGR evaluates glare from the background glare sources in the occupant's sight. NEAT measurement result shows 85 %(23 out of 27) of the spots satisfies the standard, ranging from 2.8 ~ 22.1.

Contrast ratio is used to evaluate the brightness of monitor relative to the background. In only 1 spot contrast ratio is above recommended upper boundary of 3.0 by IESNA RP-104.

Table 13 demonstrates the luminance photos of the measured spots. The scales of the luminance are different in the photos, thus the range of scales for different photos are written in the table and marked yellow.

Table 14 User Satisfaction Survey: Glare experience

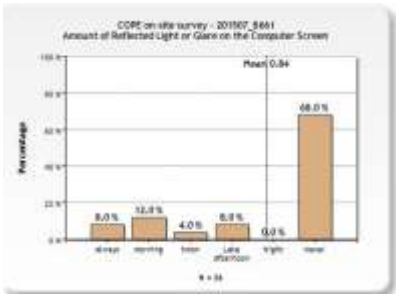
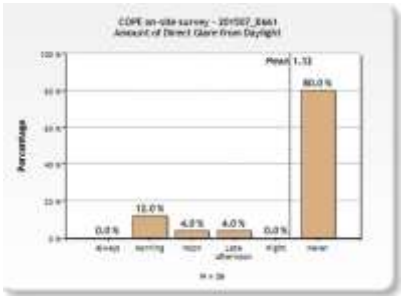
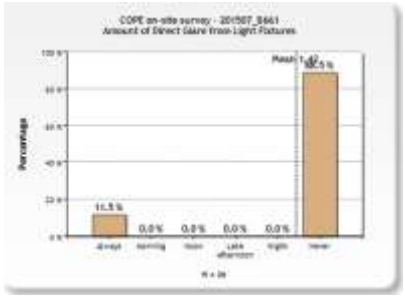
		
Glare on the computer screen	**Glare from Daylight**	**Glare from Lighting Fixtures**

Table 14 shows the survey results related to glare problems. The findings derived from survey results are:

- 32% of occupant experience glares on the computer screen.
- 88.5% of occupants never experience glare from light fixture.
- 66.3 %(5 out of 8) of occupants are experiencing glare on the computer screen responded they are having glare issue from the daylight.
- Glare experience from the daylight varies in time during the day, while the glare experience from lighting fixtures occurs constantly.

A detail analysis related to computer screens and daylight is conducted through color mapping. The findings from the analysis are:

- Occupant in a private office unit (the east wing of the 1st floor) experience glare in the morning. This is reasonable because their windows are facing east.
- Occupants in inner side of open offices don't experience glare. Only the occupant close to exterior wall experience glares. High solar altitude during the summer season may have caused this.

Figure 26 Color mapping of occupant satisfaction: Glare experience from daylight

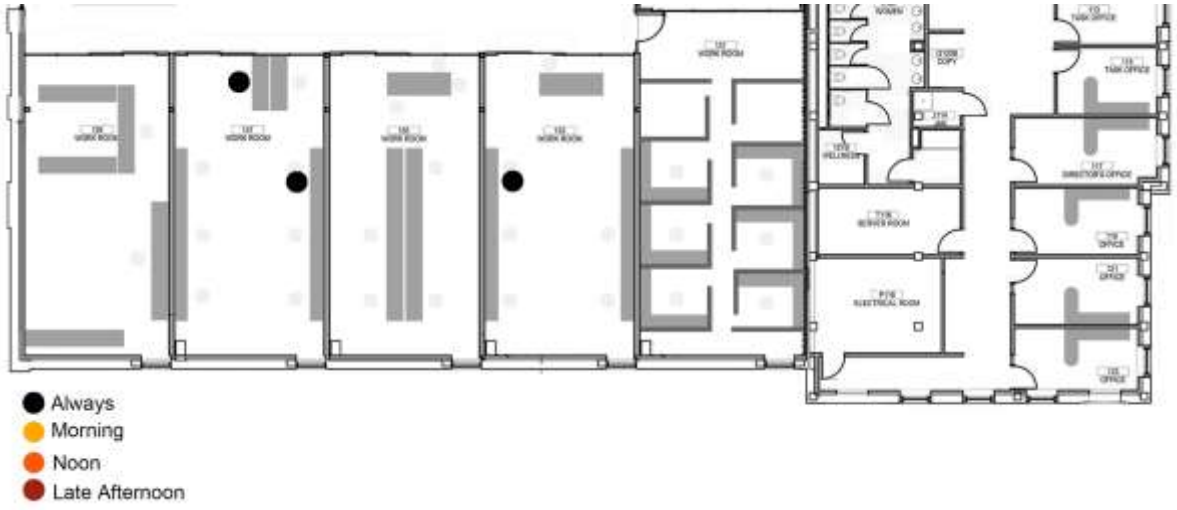


Figure 27 Color mapping of occupant satisfaction: Glare experience from lighting fixtures

Lighting Recommendations:

- *Provide dimming controls for occupants on the 1st floor, who are experiencing glare due to lighting fixtures.*
- *Install motorized blinds for every window to avoid glare in the morning or late afternoon.*
- *Change the office lay-out to reduce daylight glare in the morning. Move table to face south to eliminate direct glare from morning sun.*
- *Install blind control system that takes into account orientation of windows, time of day and tasks of occupants (with manual override).*
- *Change the downlight fixtures to direct/indirect light fixtures to reduce glare from light fixtures.*

BUILDING 661, PHILADELPHIA, PA

Building Post Occupancy Evaluation and Measurement (POE+M)

Acoustic Quality:

Findings and Recommendations

Summer 2015

Center for Building Performance and Diagnostics
Carnegie Mellon University

Acoustic & Spatial TABS: baseline physical attributes/quality differences

Acoustic Quality	
Ceiling quality	Mineral acoustic tile
Floor quality	Hard Surface throughout
Partition height inches & number of sides/workstation	No partitions
closed office/rooms wall quality	Gyp on wood stud, tight w/ floor & ceiling
Size/density of open workstations	>150 sqft
Distributed Noise: % of workstations <20 ft. from open meeting, coffee, copy, main circulation...	>40% of workstation W/in 20ft.
HVAC noise	Low frequency rumble
Masking Sound Y/N	No

Acoustic & Spatial TABS: baseline physical attributes/quality differences

Spatial Quality		
Partition height (inches) & number of sides (note % of each)	No panels	
Worksurface and Reconfigurability give % of workstations	Panel hung	
Storage per workstation (linear feet of shelf, drawer)	<10 ft.	
Seated Views	>20%	
Disruption from Circulation/ Wayfinding	Clear Signage for Visitors wayfinding	Yes
	% of desks visually open to circulation aisles	100%
Local Kitchen/break areas	if break areas include adequate sitting space	Yes
	dedicated exhaust	No
	Include windows	No
Local Copy/printing areas	7 in dedicated open spaces	
Quality of Finishes and Furnishings	New, high end quality	
Building amenities	Circle amenities within building or 3 blocks walk: cafeteria, gift store, free parking	

Acoustic Quality

Objective measurement in privacy/acoustic quality

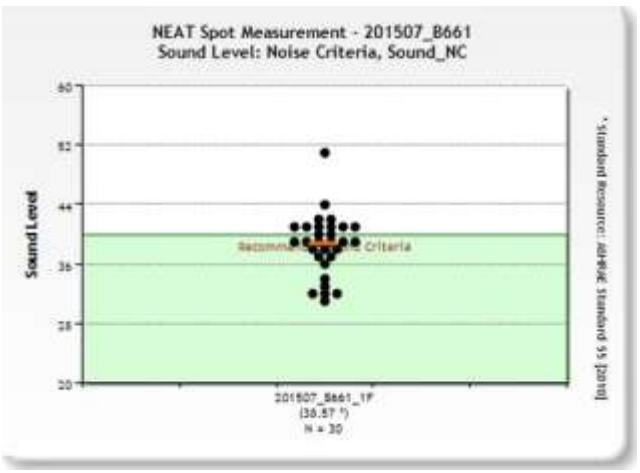


Figure 28 Spot measurement: Sound Level (NC)

In July, 2015, Noise Criterion (NC) is used to assess the background noise of the offices in Building 661. 46.7 %(14 out of 30) of spots the NC did not meet the ASHRAE 55 standard (upper boundary of 35 and 40 for private and open office). For the open offices, the average NC was 38.4, close to upper boundary of 40. Among 9 non-compliant spots, 5 were spots in room135. The reason for this was an individual fan turned in spot 135e. For the closed offices, 100 %(5 of 5) of the spots were not satisfying the upper boundary of 35, mainly due to mechanical noise from the ductless split unit.

Figure 29 Spot 135e with individual fan

Figure 30 Typical closed office with ductless split unit (Room 123)

Comparison between rooms gives us some findings on the sources of background noise. Except for room 135 which had the highest NC level because of the individual fan being operated, NC levels decreases as getting far from the mechanical room, which is a major source of background noise throughout the entire building. In the room 139, NC level was near upper boundary of 40(39.5) without any occupant or appliances operating. Major source of noise were two: a chiller operating right beside the exterior wall of room 139, and the mechanical room. Installing acoustic barriers for the chiller and mechanical room will help reducing the background noise level.

Table 15 NC average of office rooms

Office Type	Room	Room NC average	# of spots	IESNA RP-104 standard
Open office	131	34.6	3	NC < 40
	133	35.8	6	
	135	41.8	6	
	137	38.9	8	
	139	39.5	2	
Closed office	112, 117, 119, 121, 123	39.4	5	NC < 35

Table 16 Major source of background noise: chiller & mechanical room

	
Chiller	**Mechanical room**

Rooms 131 and 133 have acceptable NC level, both around 35. In room 131 NC level was even lower than room 133 with music being played on stereo in spot 131a. Main difference between two office rooms is that room 131 has high, acoustic partition.

Table 17 Office layout of Room131 & Room133

	
Room131	**Room133**

Subjective measurement in acoustic quality

Amount of Background noise

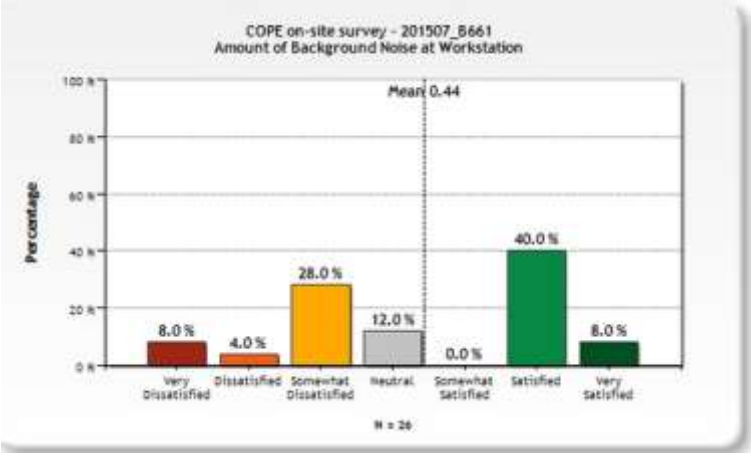


Figure 31 User Satisfaction Survey: Amount of background noise at workstation

40 %(10 out of 25) of occupants were dissatisfied with background noise level at their workstation. Consistent with the fact that room137 is the nearest room from the major source of background noise (chiller/mechanical room); room 137 has the highest percentage of occupant dissatisfied with the background noise. 62.5 %(5 out of 8) of the occupants in room137 were dissatisfied, two of them close to the door (which is the closet to the mechanical room) answering they are “very dissatisfied”.

Occupants in room131 were all satisfied with the background noise level. Room 131 is the open office has the longest distance from the major background noise sources, as well as high acoustic partitions.

Occupants in the closed offices were also satisfied with background noise level in overall. 75 %(3 of 4) occupants were satisfied, while remaining 1 occupant answered “neutral”.

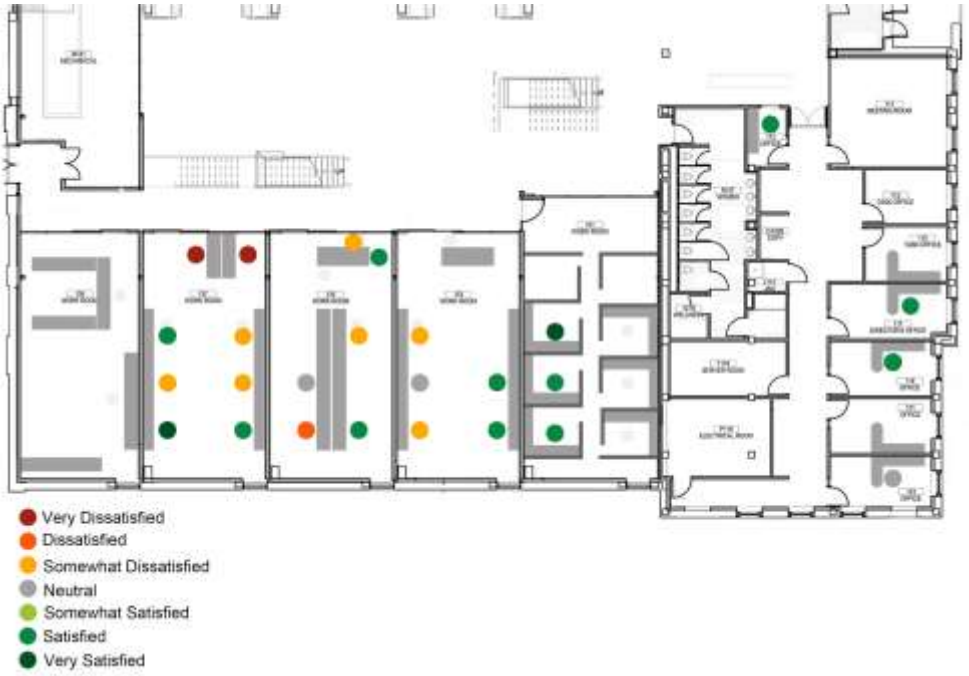


Figure 32 Color mapping of occupant satisfaction: Amount of background noise

Noise from other people's conversation

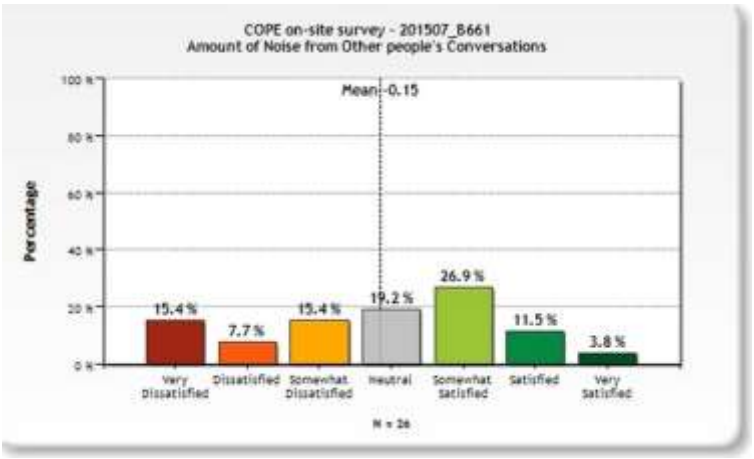


Figure 33 User Satisfaction Survey: Amount of noise from other people's conversations

38.5 %(10 out of 26) of occupants were dissatisfied with amount of noise from other people's conversation. Through the mapping of occupant satisfaction, it was found that the percentage of dissatisfied occupants were higher in the rooms with high NC levels. NC is evaluation criteria for noise

from mechanical system, not from the occupants' conversation. However, it is natural to speak louder in noisy rooms to have enough speech intelligibility. This might have caused higher dissatisfaction from other peoples' conversation in room135 and room137.

Table 18 Percentage of dissatisfied occupants by room

Office Type	Room	Percentage of dissatisfied occupants	NC average (High to Low)
Open office	135	66.7% (4 out of 6)	41.8
	137	50% (4 out of 8)	38.9
	133	20% (1 out of 5)	35.8
	131	0% (0 out of 3)	34.6

Figure 34 Color mapping of occupant satisfaction: Amount of noise from other people's conversations

Level of speech privacy

42.2 %(11 out of 26) of occupants were dissatisfied with the level of speech privacy in the office. Except for the room123 where the door is open to the reception area most of the time, all the occupants in the closed room were satisfied with level of speech privacy. Since the occupants in the closed offices do not share their spaces, high satisfaction of them makes sense.

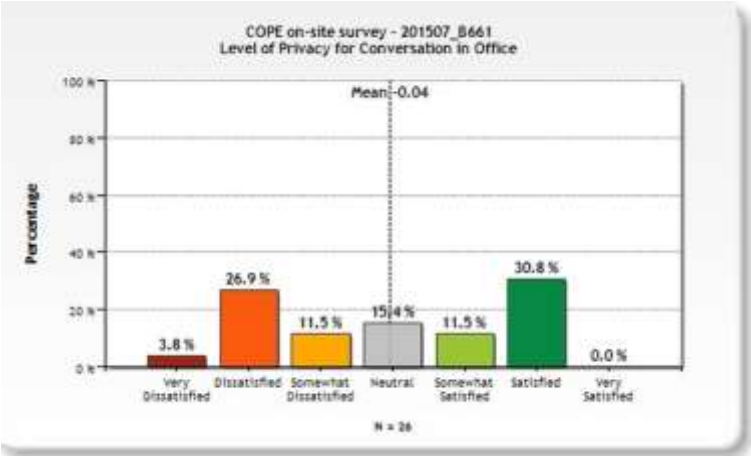


Figure 35 User Satisfaction Survey: Level of privacy for conversation in office

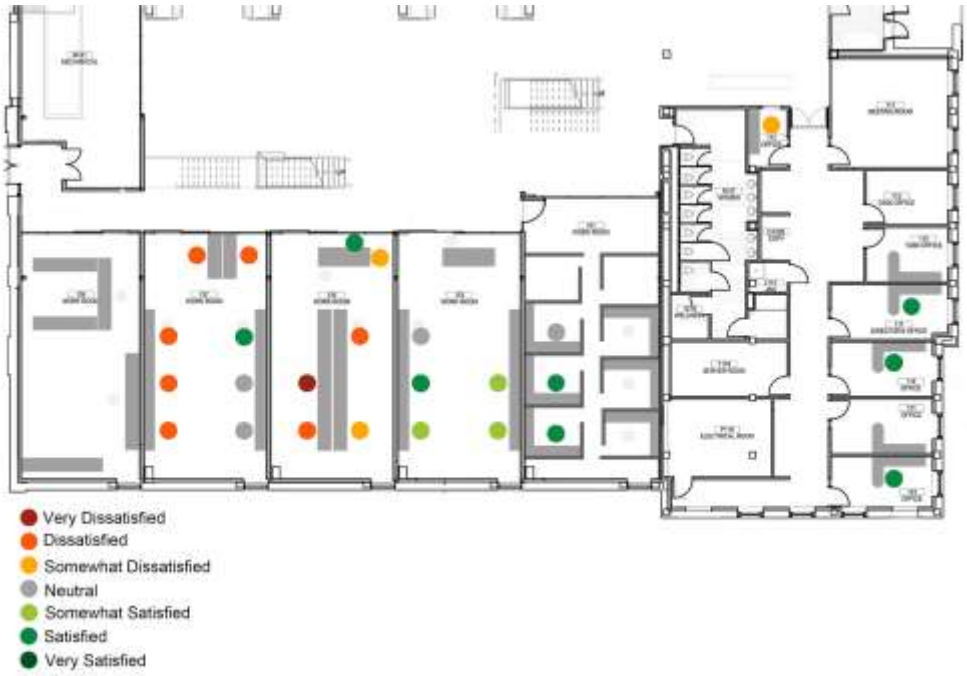


Figure 36 Color mapping of occupant satisfaction: Level of privacy for conversation in office

Acoustic Recommendations

The background noise level from the mechanical system was high, 46.7% of the spots not satisfying the ASHRAE 55 standard. However, the background noise level in room131 (high partitioned open office) and room133, which have further distance from mechanical room satisfies the standard.

Around 40% of occupants were dissatisfied with the amount of noise from other occupants' conversation or level of speech privacy in Building661. No occupant in perimeter closed offices has dissatisfaction with this, since only one occupant uses each room.

- *Provide acoustic barrier to reduce the mechanical noise from mechanical room/outside chiller.*
- *Provide sound-absorbing treatments to offices near the mechanical room.*
- *Create better acoustic partition in open offices to reduce discomfort from background noise and other peoples' conversation.*
- *To increase speech privacy, sound masking may be employed to reduce unwanted high speech intelligibility.*

BUILDING 661, PHILADELPHIA, PA

Building Post Occupancy Evaluation and Measurement (POE+M)

Overall Conclusion

Summer 2015

Center for Building Performance and Diagnostics
Carnegie Mellon University

Overall Conclusion

Post Occupancy Evaluation (POE) was conducted for Building 661 in Navy Yard, Philadelphia, PA, on July 10th (summer/cooling season). The IEQ study was undertaken to assess thermal, air quality, visual, and acoustic conditions as well as user satisfactions in the workplace. Figure 37 shows the user satisfaction survey about "Overall Indoor Environment in Workstation". We can see that most of the people were satisfied with their indoor environment in overall. Only 11.5 %(3 out of 26) of occupants were dissatisfied with overall environmental condition in their workstation. Among these occupants, temperature and acoustic/visual privacy were shown to be the most serious issues. To improve indoor environment quality, the following recommendations are proposed.

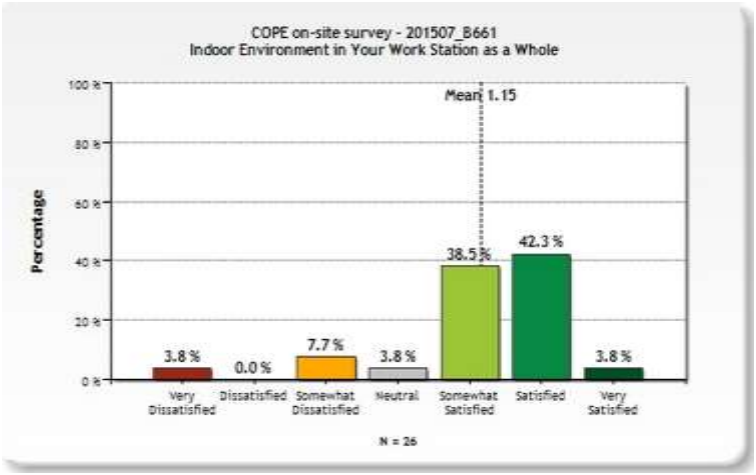


Figure 37 User Satisfaction Survey: Indoor environment in workstation as a whole

Thermal and Air Quality Recommendations

- Provide control of humidity for the perimeter closed offices. Dehumidify intake air from the headhouse corridor can be a solution.
- Provide control of temperature for the open offices. Having a high level of control ensures high level of occupant satisfaction, as shown in the COPE survey result for occupants in the closed offices.
- Correct set-point in the central system to ensure that all spaces meet code requirements for thermal comfort and that occupant satisfaction is maintained even at maximum occupant capacity for the symposium room and open offices.
- Provide CO_2 metering data to occupants in every office unit and educate them about the use of natural ventilation.

- Match current BAS schedule with the actual building schedule. BAS schedule for DOAS can be shortened in order to save energy, if it does not increase temperature and RH to create discomfort in the morning.

Lighting Recommendations

- Provide dimming controls for occupants on the 1st floor, who are experiencing glare due to lighting fixtures.
- Install motorized blinds for every window to avoid glare in the morning or late afternoon.
- Change the office lay-out to reduce daylight glare in the morning. Move table to face south to eliminate direct glare from morning sun.
- Install blind control system that takes into account orientation of windows, time of day and tasks of occupants (with manual override).
- Change the downlight fixtures to direct/indirect light fixtures to reduce glare from light fixtures.

Acoustic Recommendations

- Provide acoustic barrier to reduce the mechanical noise from mechanical room/outside chiller.
- Provide sound-absorbing treatments to offices near the mechanical room.
- Create better acoustic partition in open offices to reduce discomfort from background noise and other peoples' conversation.
- To increase speech privacy, sound masking may be employed to reduce unwanted high speech intelligibility.

BUILDING 661, PHILADELPHIA, PA

Building Post Occupancy Evaluation and Measurement (POE+M)

Appendix: Building 661

- Spot Measurement
- User Satisfaction Survey

2015

Center for Building Performance and Diagnostics

Carnegie Mellon University

BUILDING 661

SPOT MEASUREMENT

2015

Center for Building Performance and Diagnostics

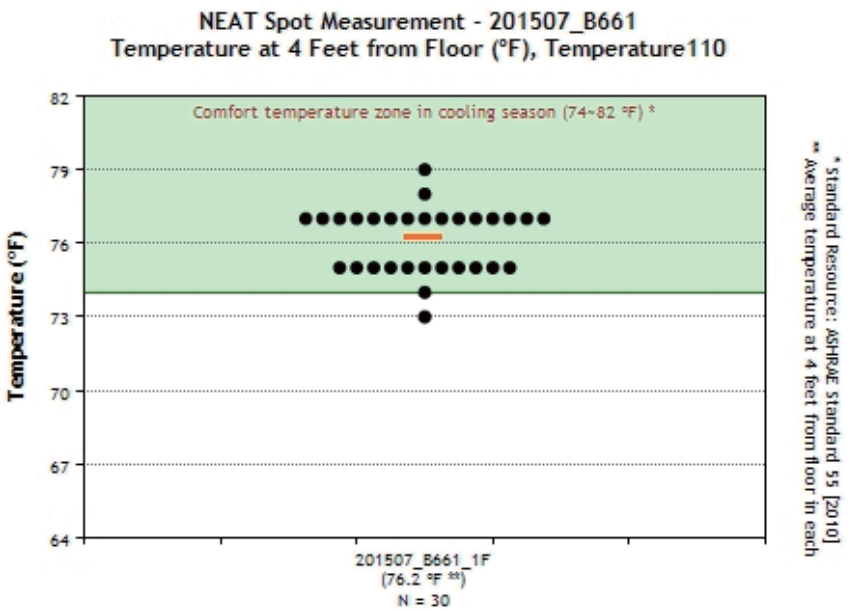
Carnegie Mellon University

Temperature at 4 Feet from Floor

SOURCE DATA

201507_B661_1F: 77, 78.8, 77, 78.47, 77, 77, 77, 77, 77, 75.2, 75.2, 75.2, 75.2, 75.2, 75.2, 75.2, 73.01, 77, 77, 77, 77, 77, 77, 77, 77, 75.2, 73.57, 75.2, 75.2, 75.2

Mean: 76.2, Min: 73.01, Max: 78.8
Percentage Within Comfort Zone: 93.33%

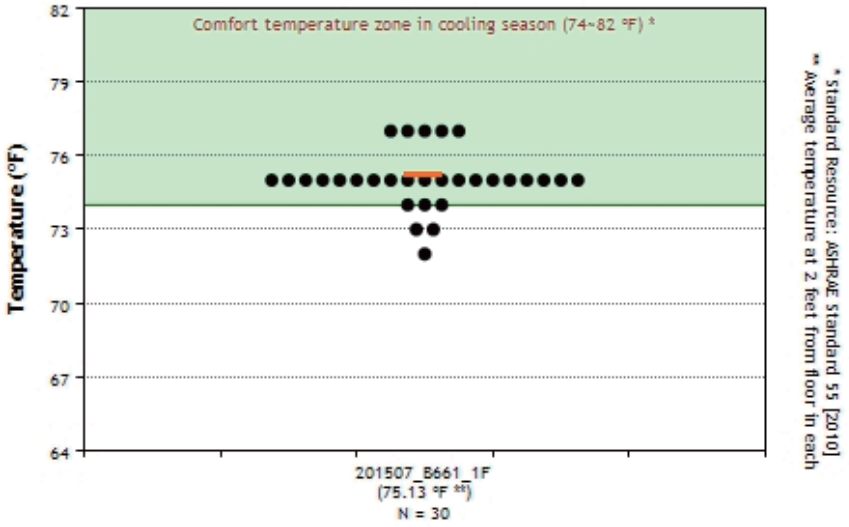


Temperature at 2 Feet from Floor

SOURCE DATA

201507_B661_1F: 77, 77, 75.2, 77, 75.2, 75.2, 75.2, 75.2, 75.2, 74.51, 75.2, 75.2, 75.2, 75.2, 75.2, 74.47, 71.6, 75.2, 75.2, 77, 75.2, 75.2, 75.2, 76.89, 75.2, 73.79, 73.4, 73.44, 75.2, 74.16

Mean: 75.13, Min: 71.6, Max: 77
Percentage Within Comfort Zone: 86.67%

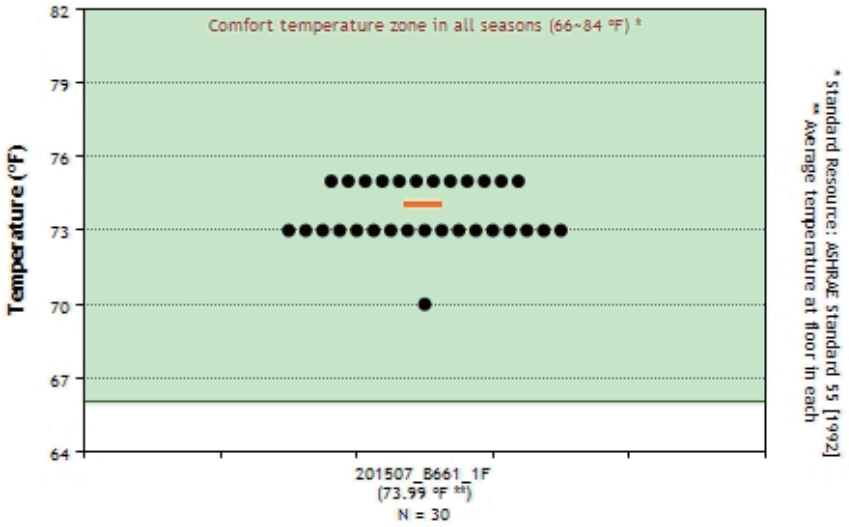


Temperature at Floor

SOURCE DATA

201507_B661_1F: 75.2, 75.2, 75.2, 75.2, 75.2, 73.4, 73.4, 73.4, 73.4, 73.4, 73.4, 73.4, 73.4, 73.4, 73.4, 73.4, 69.8, 75.2, 75.2, 75.2, 75.2, 75.2, 74.83, 75.2, 73.4, 73.4, 73.4, 73.4, 73.4, 73.4

Mean: 73.99, Min: 69.8, Max: 75.2
Percentage Within Comfort Zone: 100%

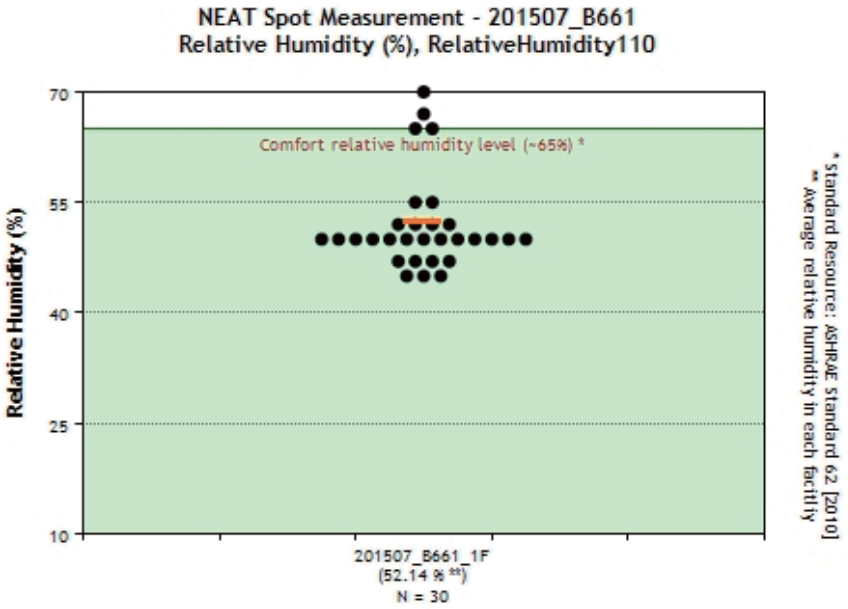


Relative Humidity

SOURCE DATA

201507_B661_1F: 54.71, 46.28, 46.16, 45.98, 47, 50.05, 49.38, 49.04, 48, 51.58, 51.32, 51.75, 51.31, 50.76, 69.09, 66.62, 64.75, 63.9, 49.11, 47.24, 48.98, 48.24, 48.73, 51, 50.16, 52.19, 55.89, 52.78, 50.91, 51.16

Mean: 52.14, Min: 45.98, Max: 69.09
Percentage Within Comfort Zone: 93.33%

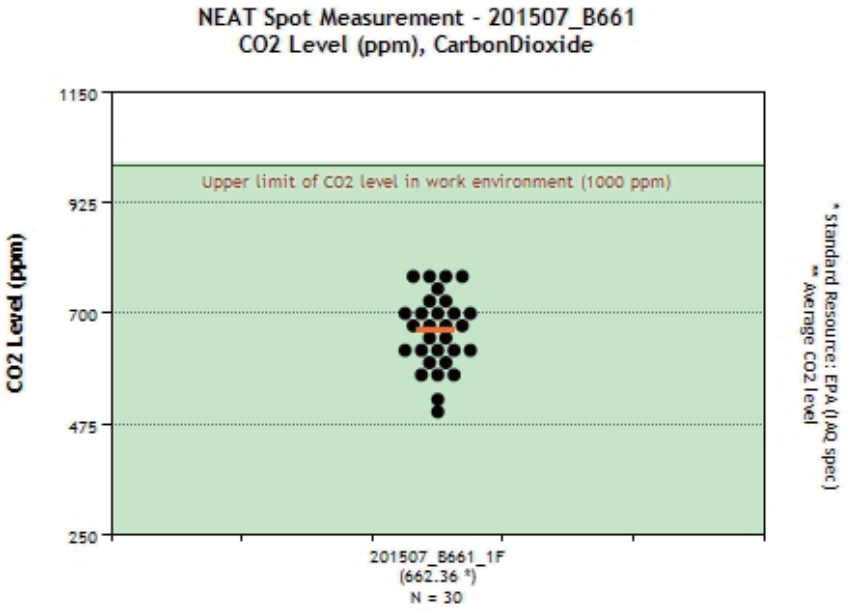


Concentration of CO_2

SOURCE DATA

201507_B661_1F: 619.86, 676.64, 589.7, 617.51, 623.61, 663.32, 655.16, 631.83, 636.39, 753.86, 766.58, 772.27, 783.15, 784.82, 603.03, 699.21, 719.66, 699.54, 676.23, 692.85, 573.44, 587.31, 585.52, 657.5, 663.06, 688.39, 706.44, 721.29, 514.03, 508.68

Mean: 662.36, Min: 508.68, Max: 784.82
Percentage Within Comfort Zone: 100%

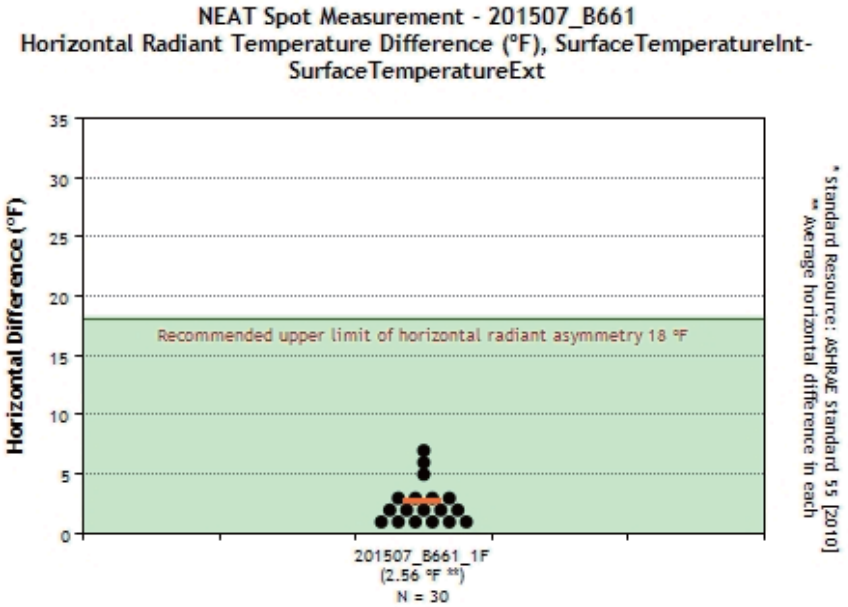


Horizontal Radiant Temperature Difference

SOURCE DATA

201507_B661_1F: 1, 0, 6, 0, 1, 3, 3, 0, 2, 3, 2, 2, 0, 0, 0, 0, 7, 0, 0, 0, 1, 5, 1, 0, 2, 2, 1, 0, 3, 1

Mean: 2.56, Min: 0, Max: 7
Percentage Within Comfort Zone: 100%

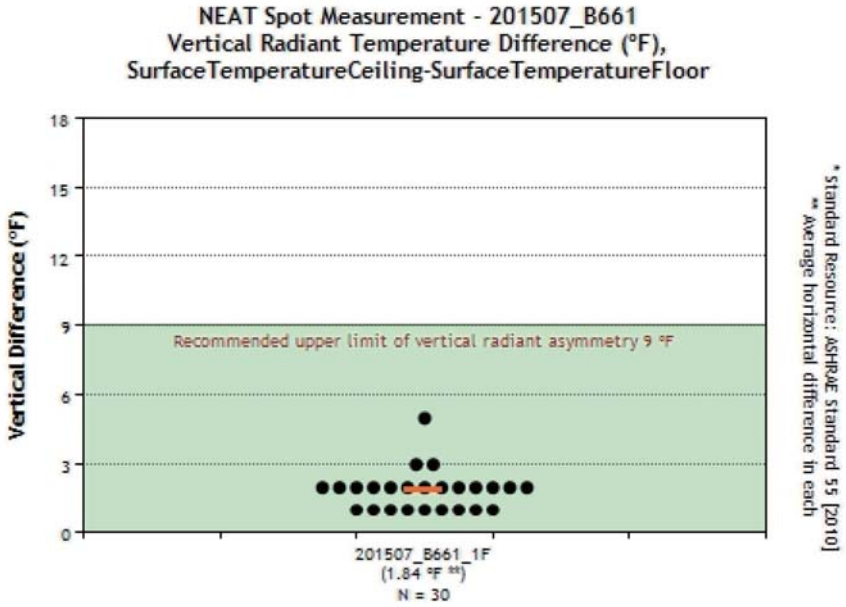


Vertical Radiant Temperature Difference

SOURCE DATA

201507_B661_1F: 1, 2, 1, 1, 1, 2, 2, 2, 3, 1, 1, 2, 5, 1, 0, 0, 3, 1, 2, 2, 0, 0, 0, 2, 2, 2, 2, 1, 2, 2

Mean: 1.84, Min: 0, Max: 5
Percentage Within Comfort Zone: 100%

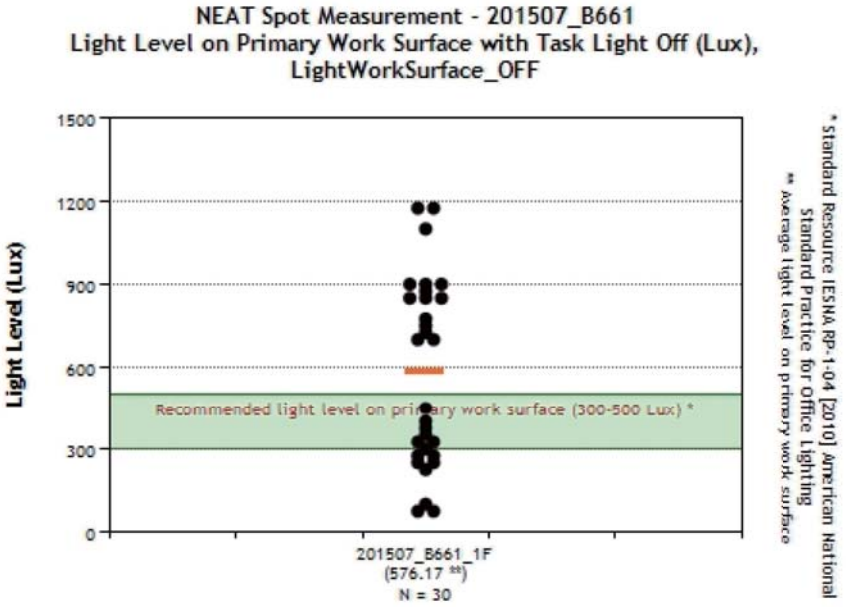


Light Level on Primary Work Surface with Task Light Off

SOURCE DATA

201507_B661_1F: 242, 368, 704, 317, 296, 455, 774, 869, 843, 282, 342, 1112, 1168, 1176, 243, 232, 78, 80, 734, 849, 271, 406, 109, 703, 329, 908, 845, 902, 745, 903

Mean: 576.17, Min: 78, Max: 1176
Percentage Within Comfort Zone: 20%

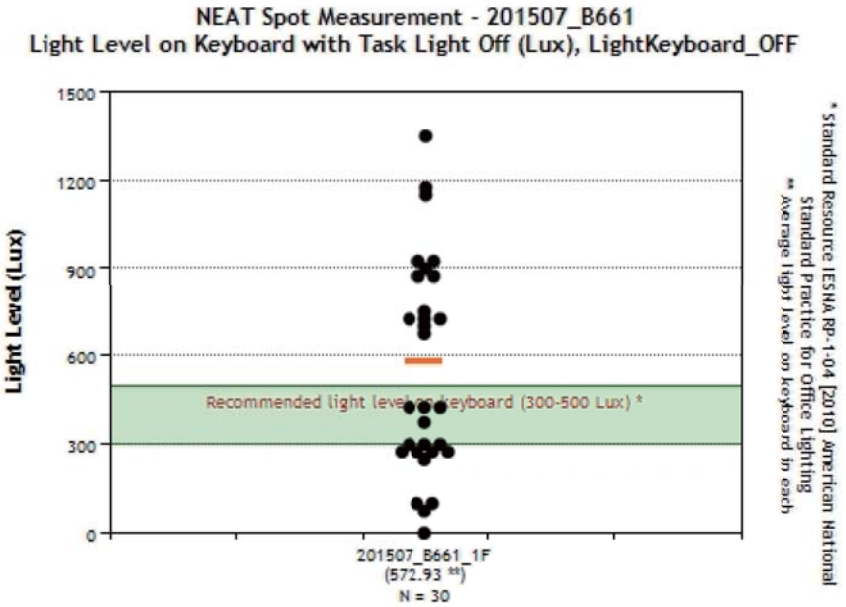


Light Level on Keyboard with Task Light Off

SOURCE DATA

201507_B661_1F: 263, 363, 732, 429, 292, 429, 680, 924, 875, 271, 312, 1163, 1140, 1350, 280, 252, 93, 84, 708, 725, 289, 419, 91, 727, 287, 913, 0, 863, 756, 905

Mean: 572.93, Min: 0, Max: 1350
Percentage Within Comfort Zone: 16.67%

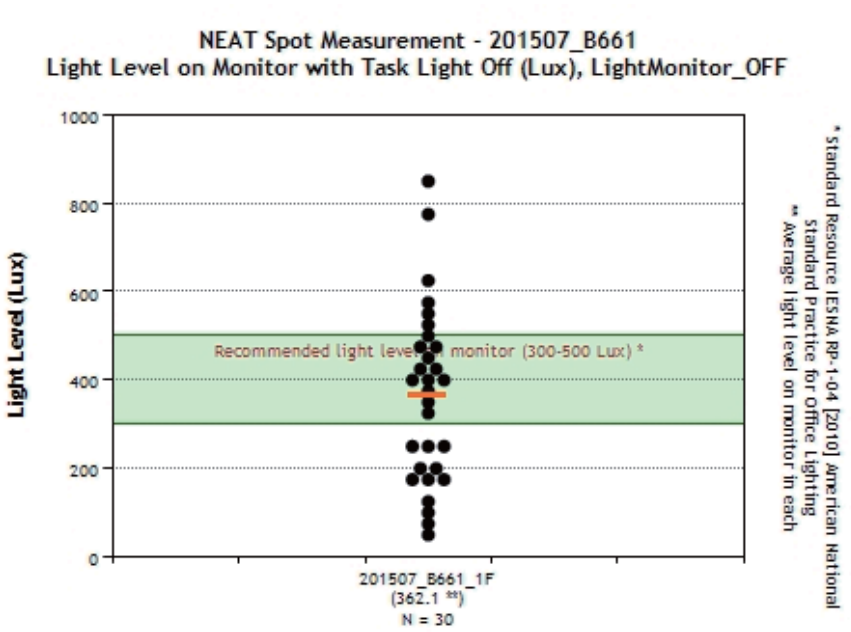


Light Level on Monitor with Task Light Off

SOURCE DATA

201507_B661_1F: 166, 247, 572, 406, 321, 212, 397, 617, 478, 185, 251, 552, 775, 842, 197, 163, 93, 39, 424, 513, 257, 464, 63, 453, 122, 353, 418, 492, 407, 384

Mean: 362.1, Min: 39, Max: 842
Percentage Within Comfort Zone: 40%

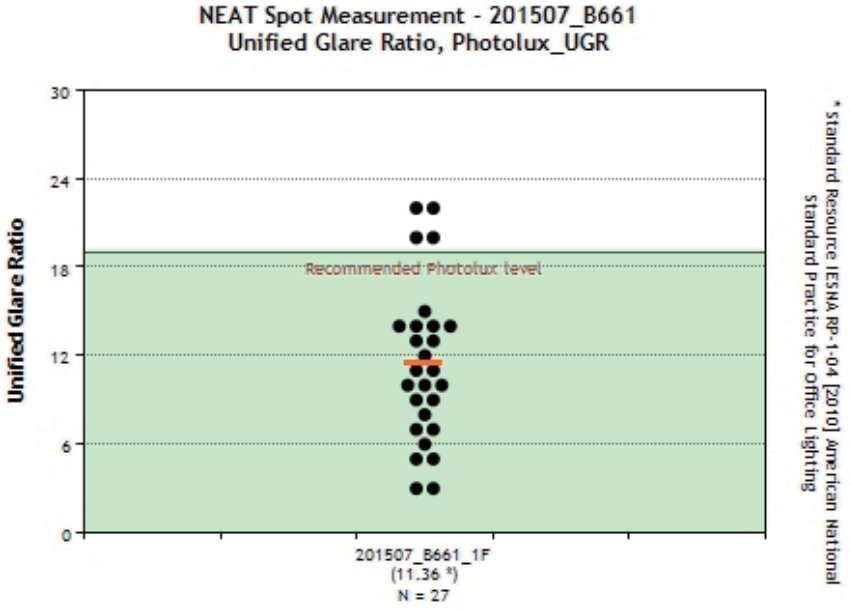


Unified Glare Ratio

SOURCE DATA

201507_B661_1F: 10.3, 9, 22.1, 11.5, 9.7, 14.3, 10.1, 8.6, 7.3, 6.6, 20.2, 13.9, 5.4, 4.6, 19.9, 21.7, 13, 13.3, 10.9, 14.9, 6, 3.2, 2.8, 11.3, 14.1, 8.1, 13.8

Mean: 11.36, Min: 2.8, Max: 22.1
Percentage Within Comfort Zone: 85.19%

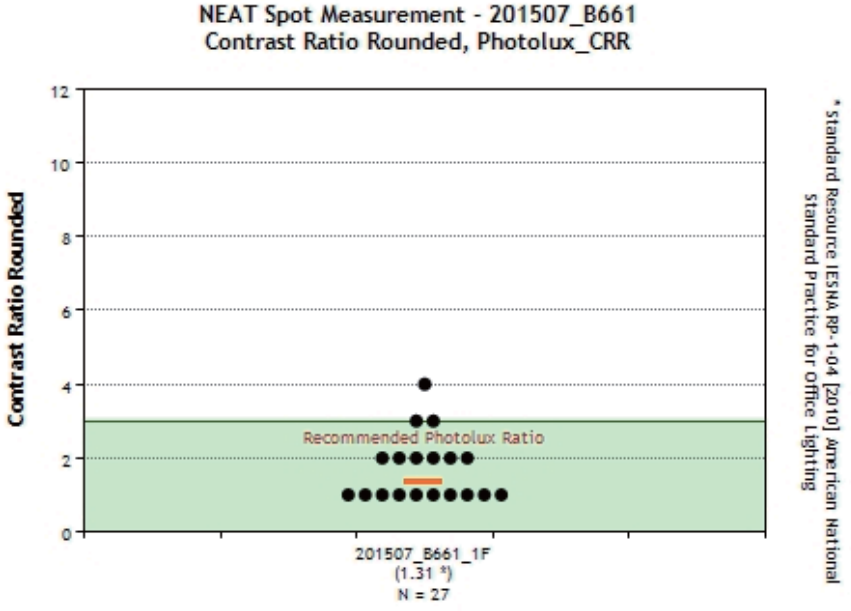


Contrast Ratio Rounded

SOURCE DATA

201507_B661_1F: 3, 3, 1.5, 4.5, 2.5, 0.5, 1, 1, 2, 1, 1.5, 0.5, 1.5, 2, 0.5, 1, 1, 0.5, 0.5, 0.5, 0.5, 1, 1, 1, 1, 1, 0.5

Mean: 1.31, Min: 0.5, Max: 4.5
Percentage Within Comfort Zone: 96.3%

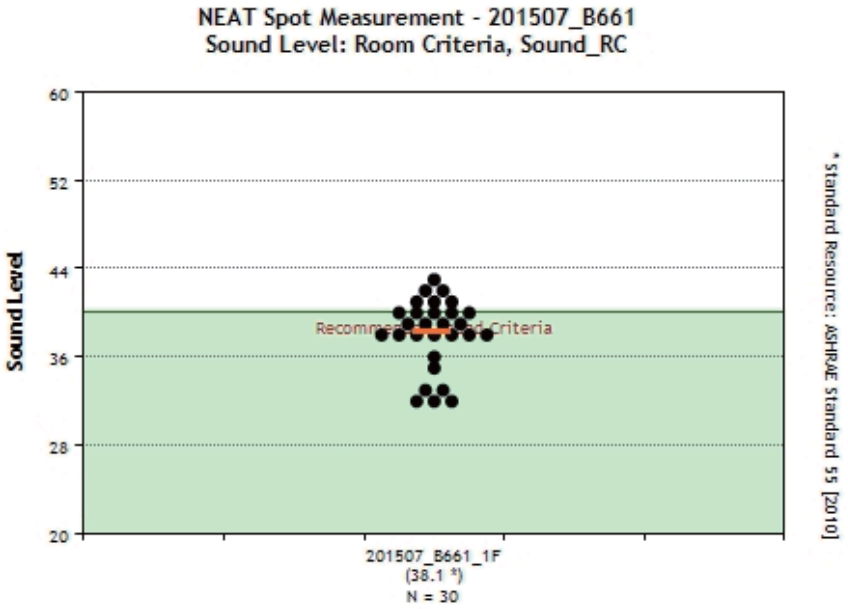


Sound Level: Room Criteria

SOURCE DATA

201507_B661_1F: 38, 40, 39, 39, 40, 41, 40, 38, 38, 38, 43, 41, 42, **0**, 38, 33, 38, 40, 33, 35, 32, 38, 32, 32, 36, 41, 39, 40, 39, 42

Mean: 38.1, Min: 0, Max: 43
Percentage Within Comfort Zone: 76.67%

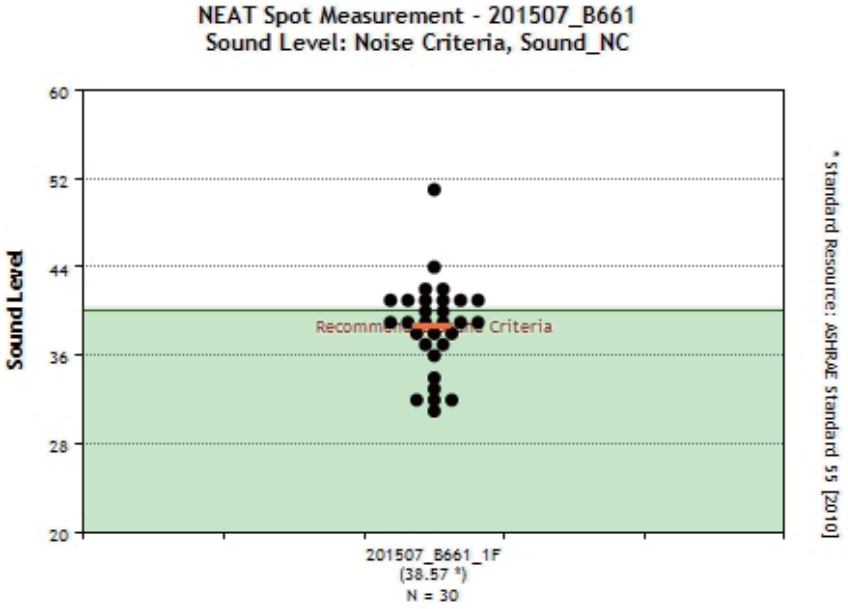


Sound Level: Noise Criteria

SOURCE DATA

201507_B661_1F: 38, 41, 39, 39, 41, 41, 39, 37, 38, 37, 44, 41, 42, 51, 39, 32, 38, 41, 32, 34, 31, 39, 32, 33, 36, 42, 40, 39, 40, 41

Mean: 38.57, Min: 31, Max: 51
Percentage Within Comfort Zone: 66.67%

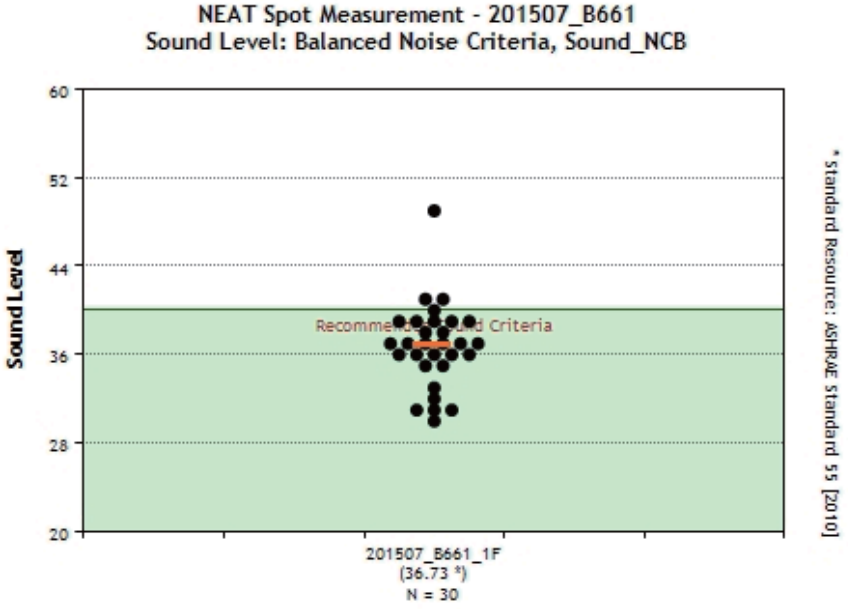


Sound Level: Balanced Noise Criteria

SOURCE DATA

201507_B661_1F: 37, 39, 37, 37, 38, 41, 39, 35, 37, 36, 41, 39, 39, 49, 36, 31, 36, 37, 31, 33, 30, 37, 31, 32, 35, 39, 36, 38, 36, 40

Mean: 36.73, Min: 30, Max: 49
Percentage Within Comfort Zone: 90%



BUILDING 661

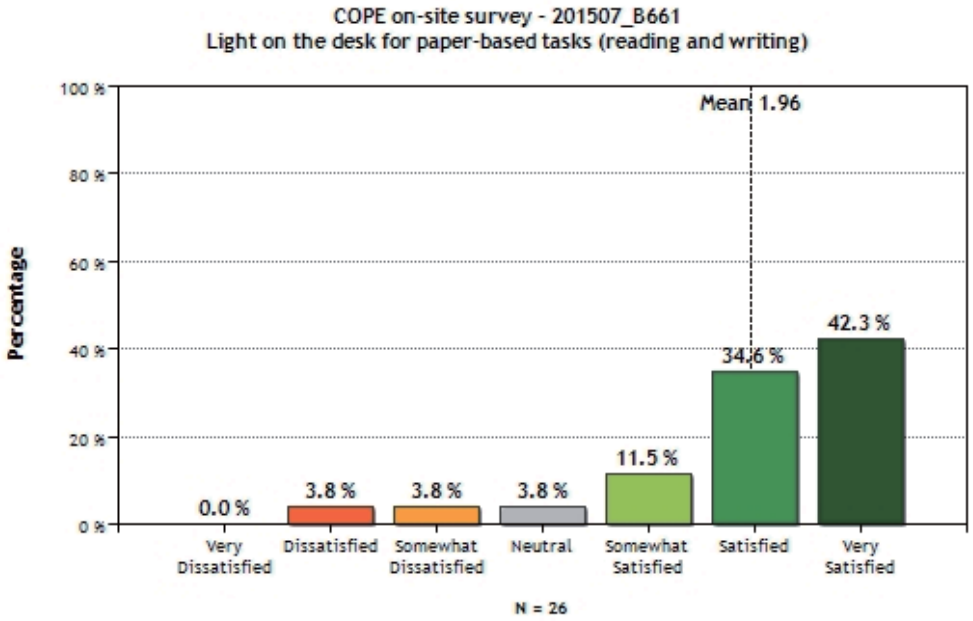
USER SATISFACTION SURVEY

2015

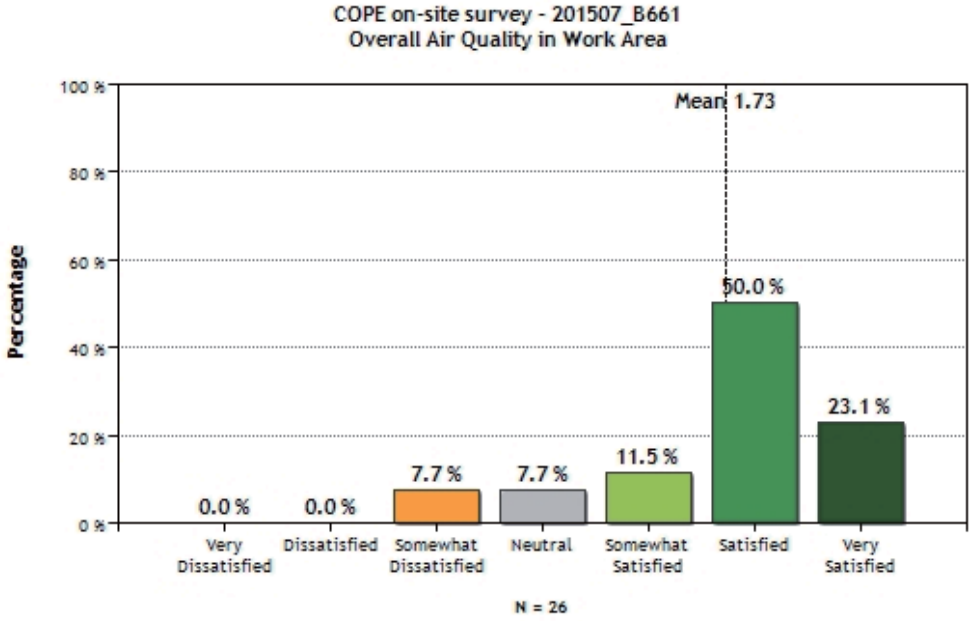
Center for Building Performance and Diagnostics

Carnegie Mellon University

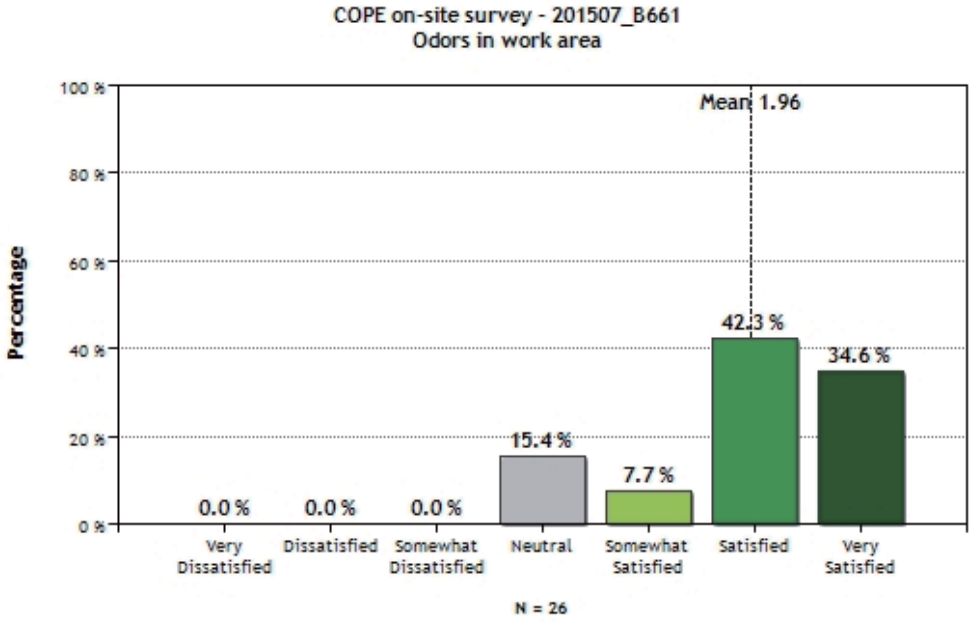
1. **Light on the desk for paper-based tasks (reading and writing)**



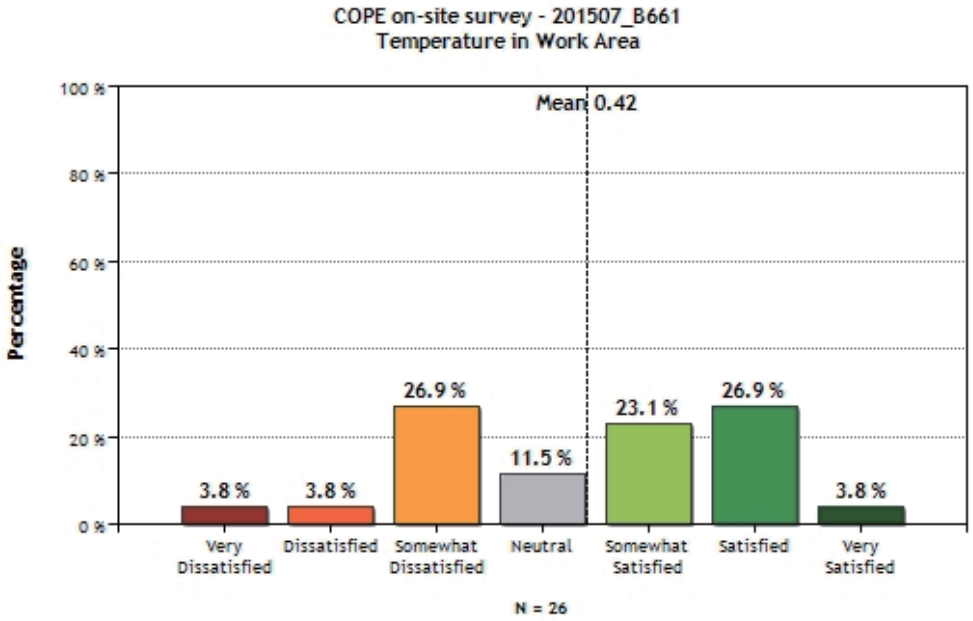
2. **Overall air quality in work area**



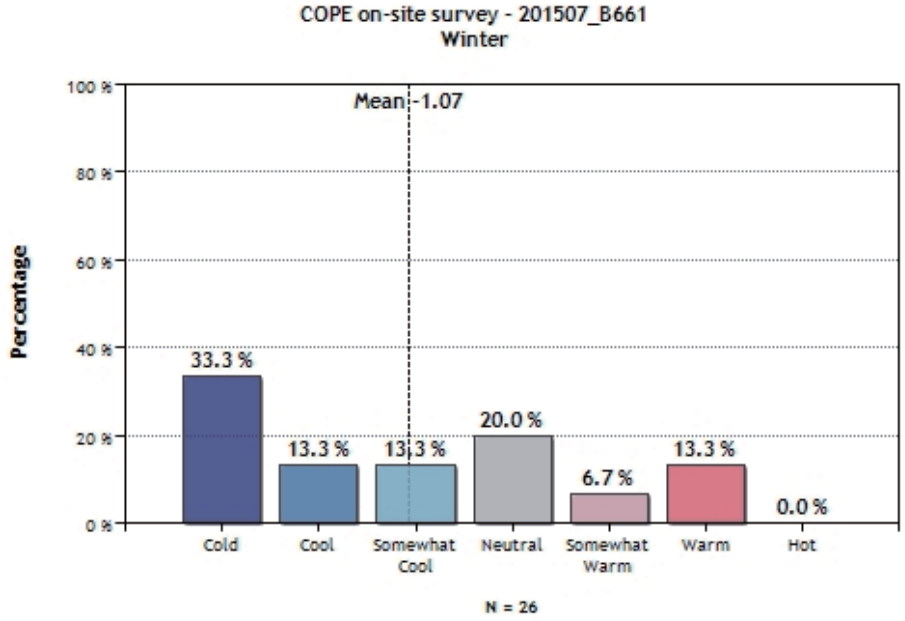
2a. **Odors in work area**



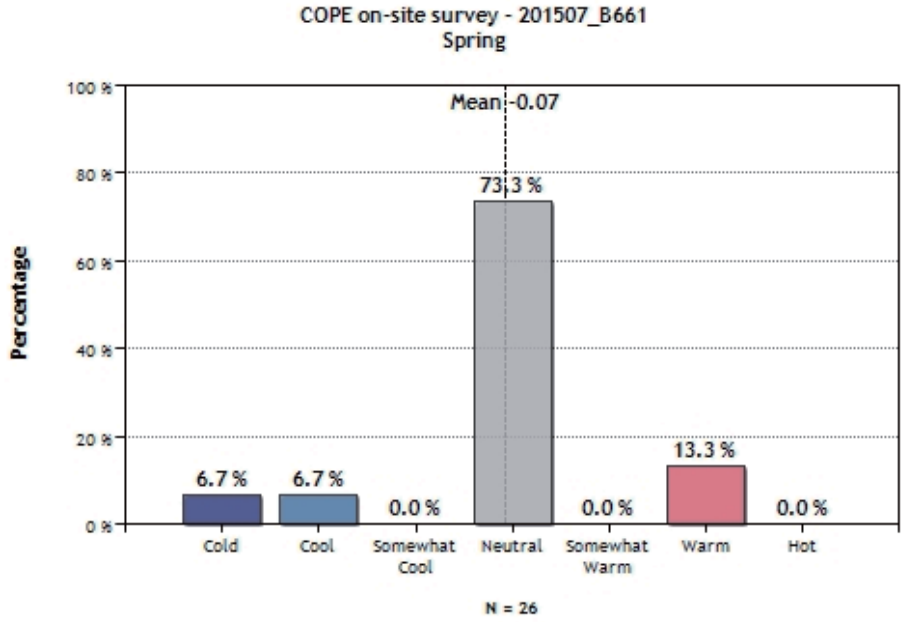
3. Temperature in work area



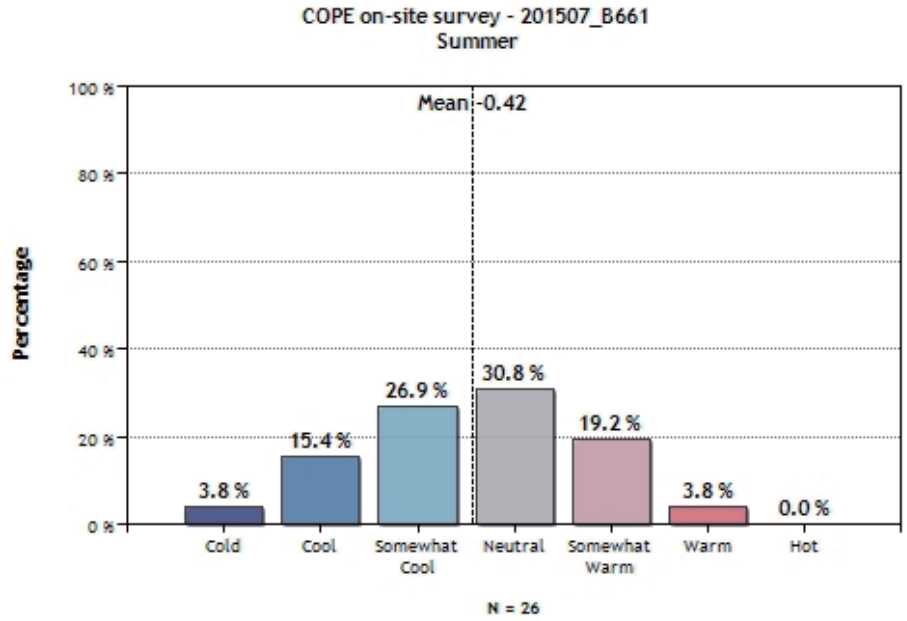
3a. Winter



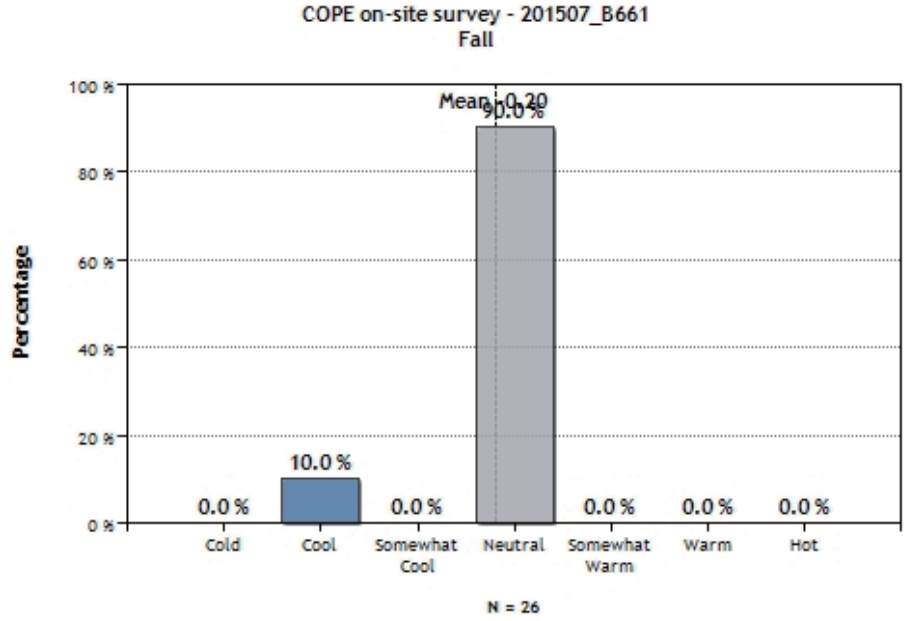
3b. Spring



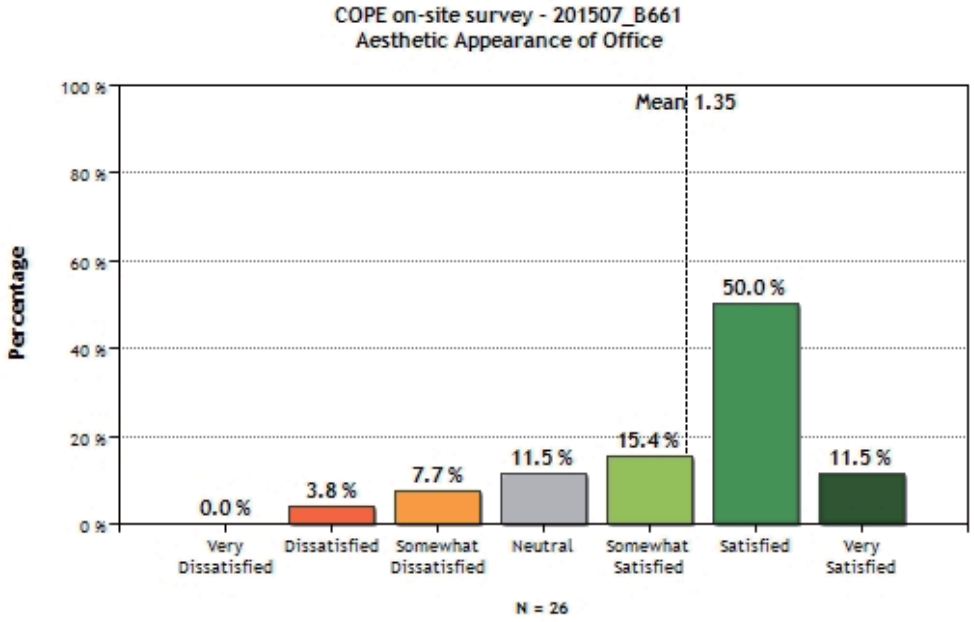
3c. Summer



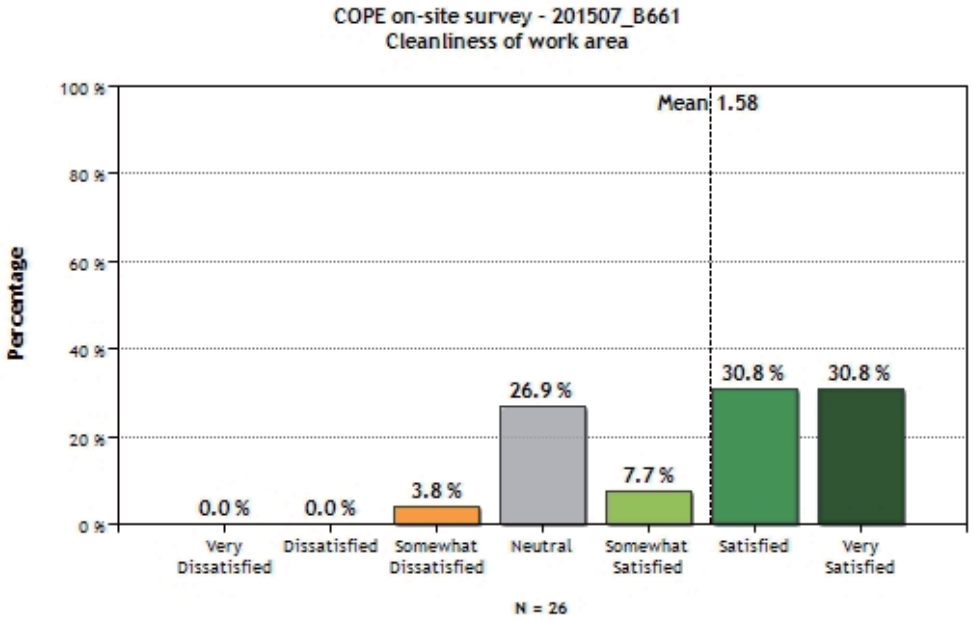
3d. Fall



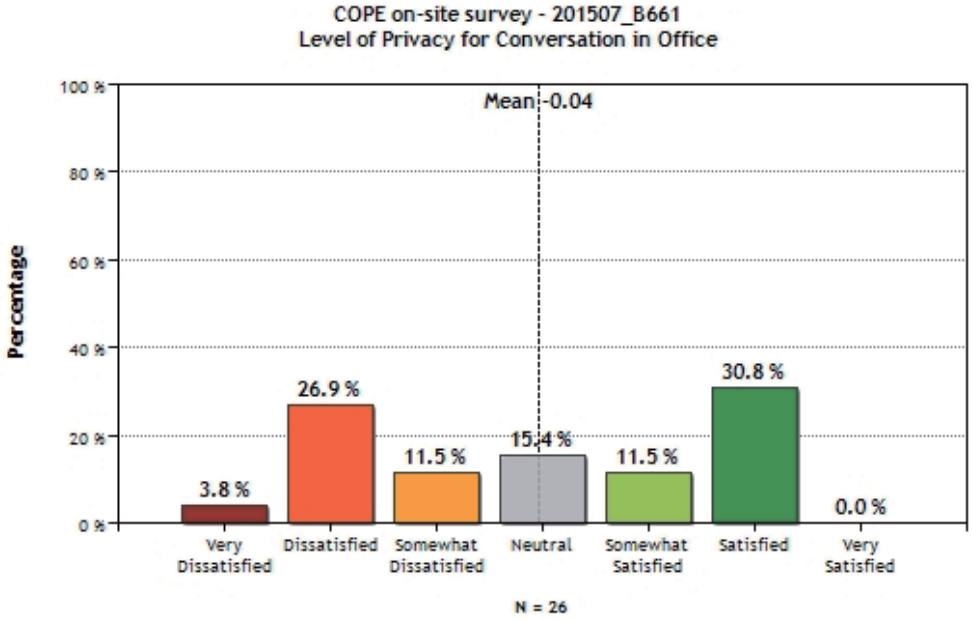
4. Aesthetic appearance of office



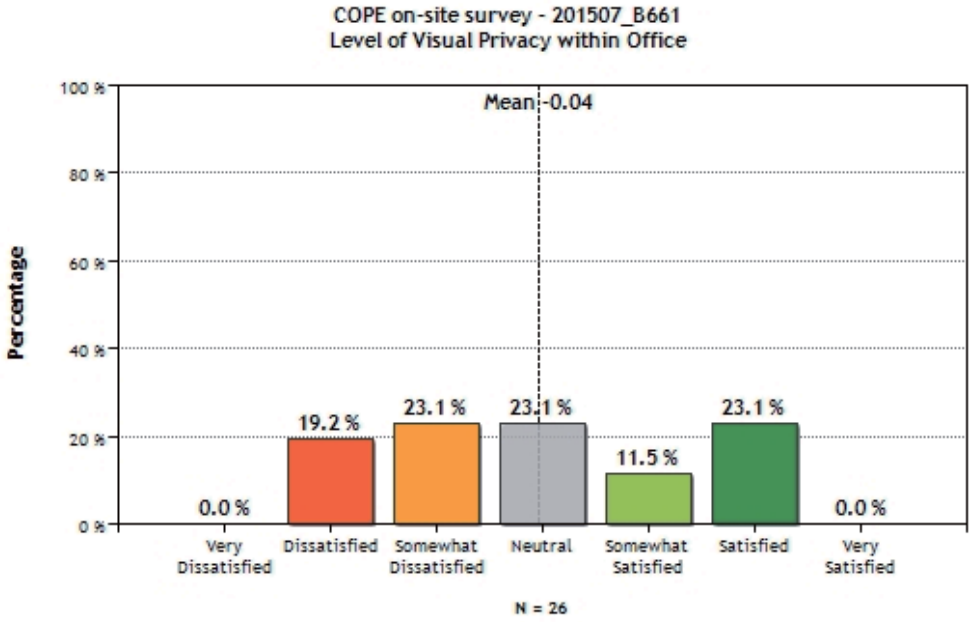
4a. Cleanliness of work area



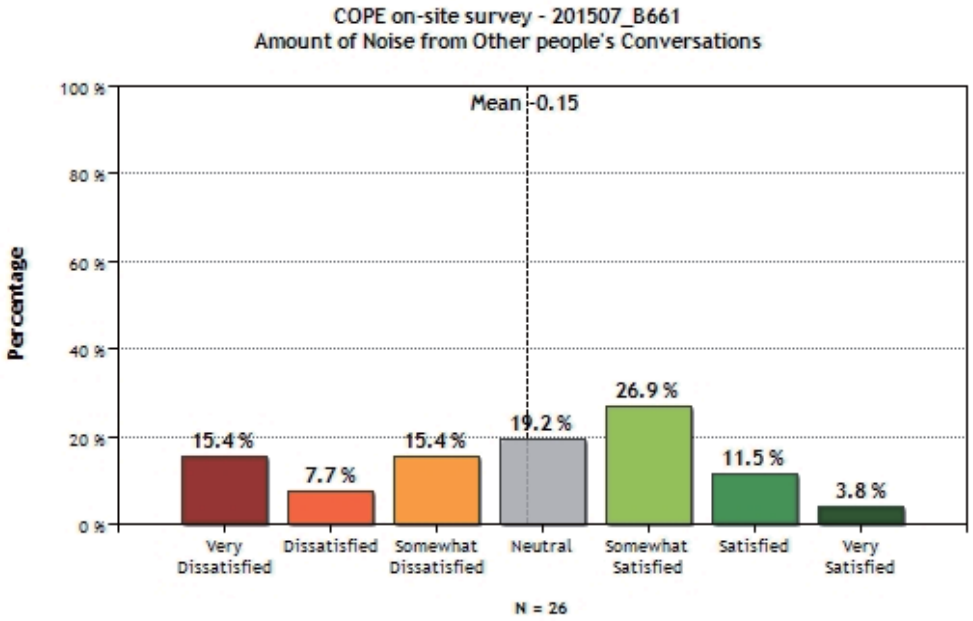
5. Level of privacy for conversation in office



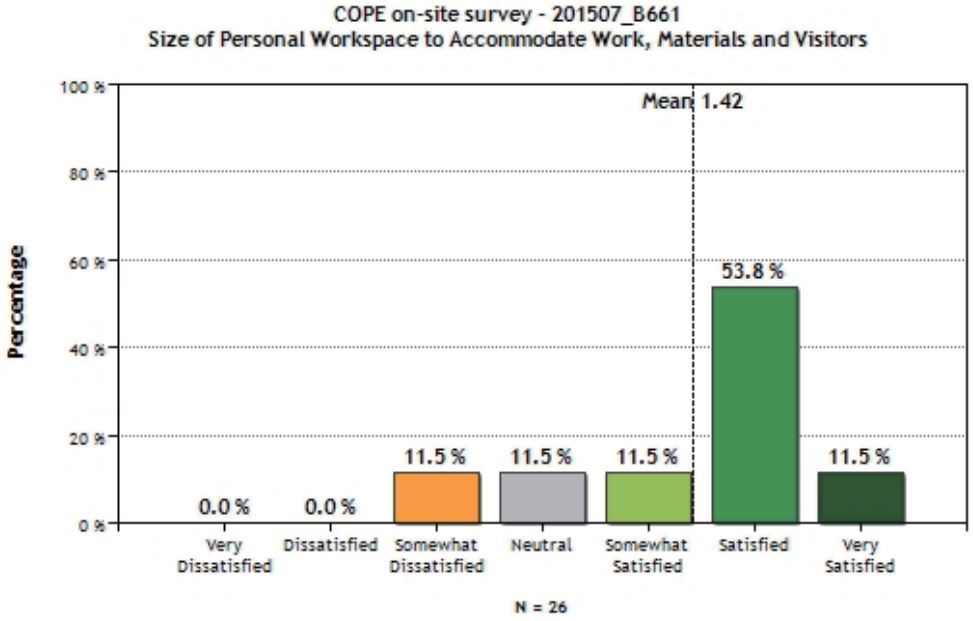
6. Level of visual privacy within office



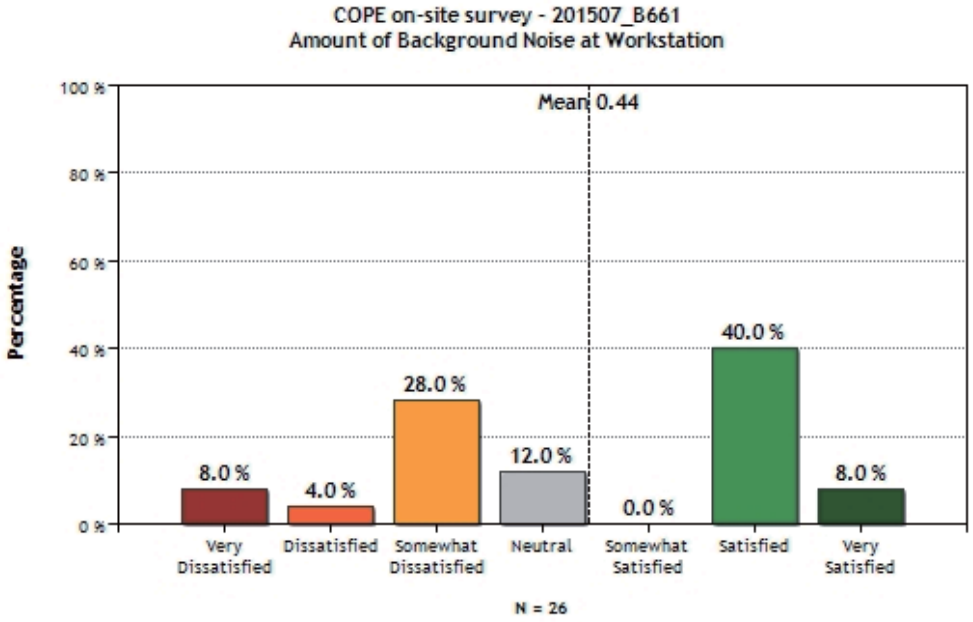
7. **Amount of noise from other people's conversations**



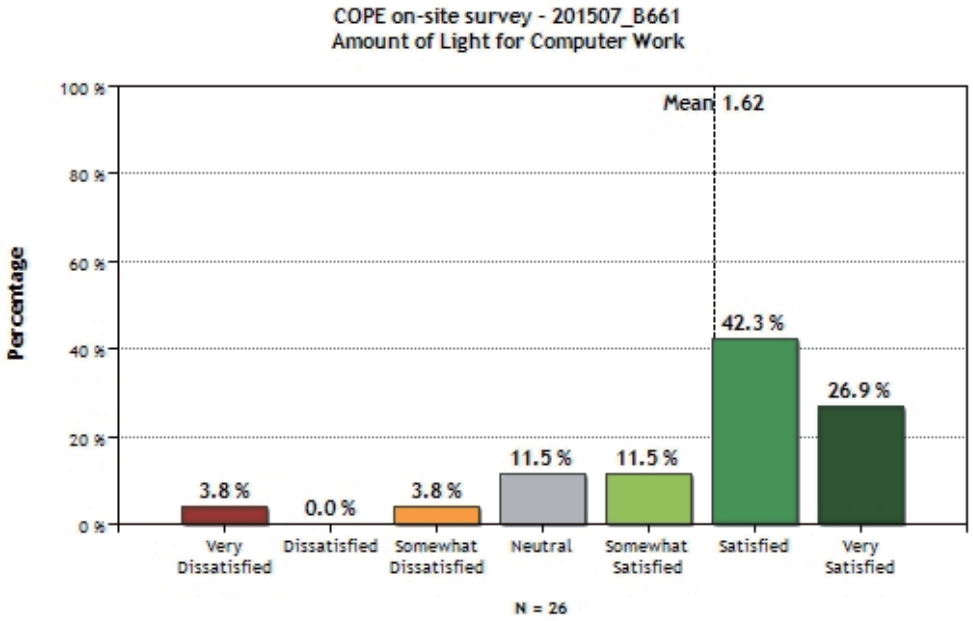
8. **Size of personal workspace to accommodate work, materials and visitors**



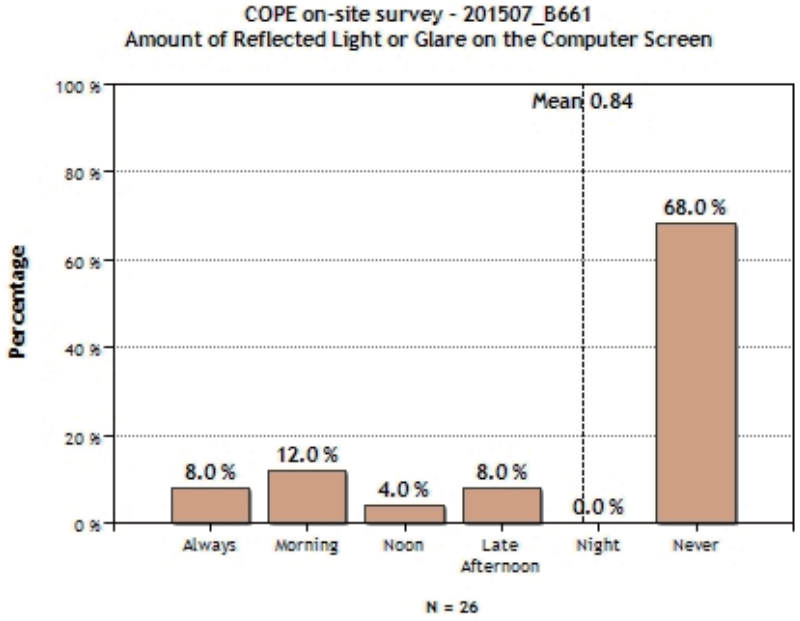
9. **Amount of background noise at workstation**



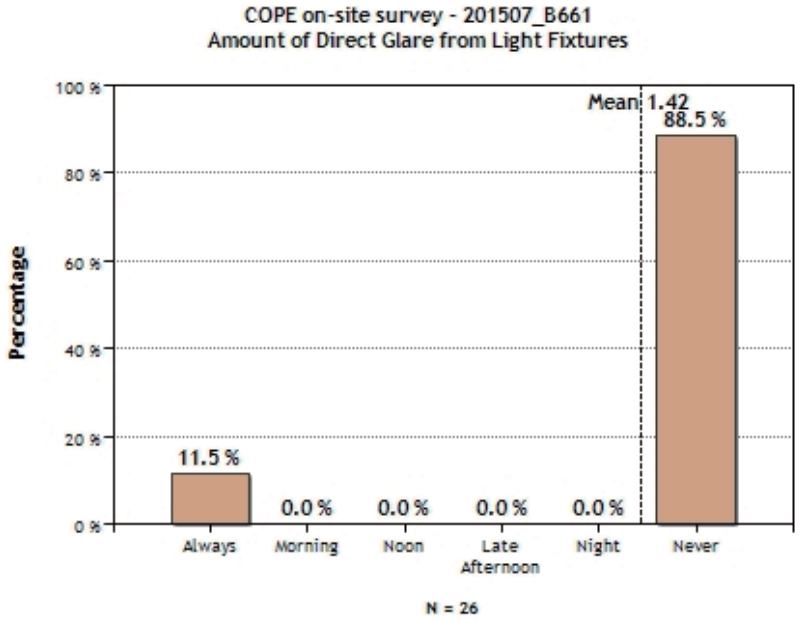
10. Amount of light for computer work



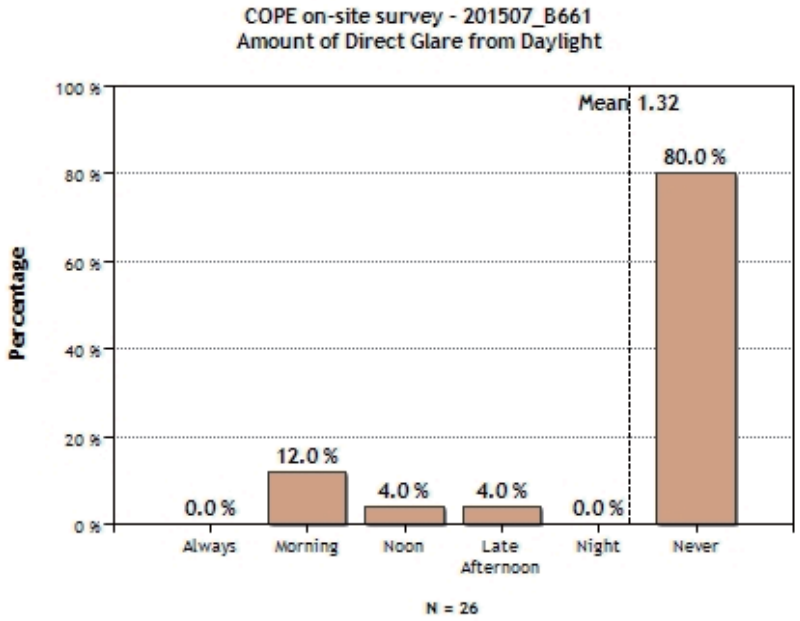
11. Amount of reflected light or glare on the computer screen



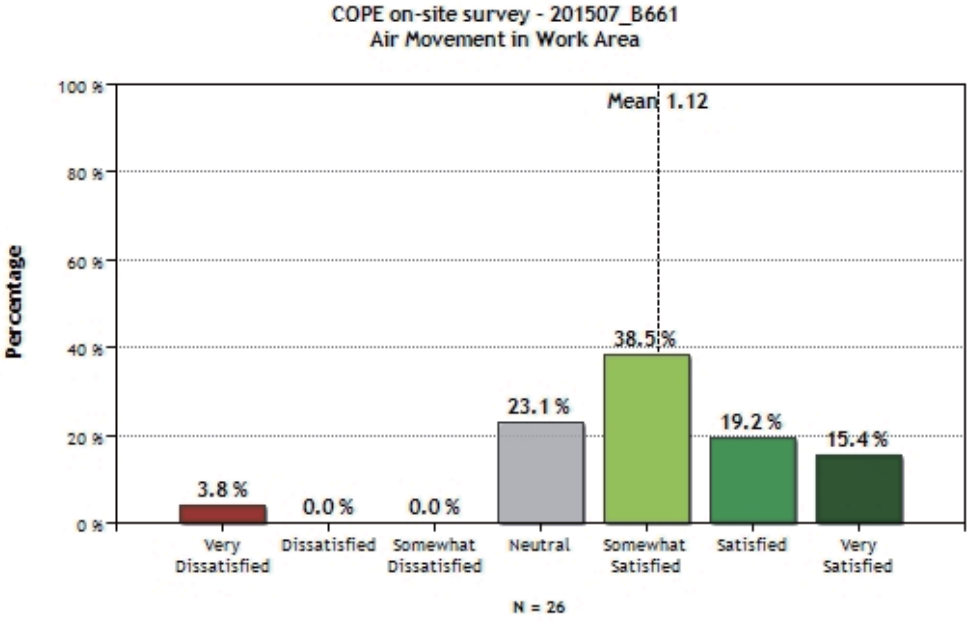
12. Amount of direct glare from light fixtures



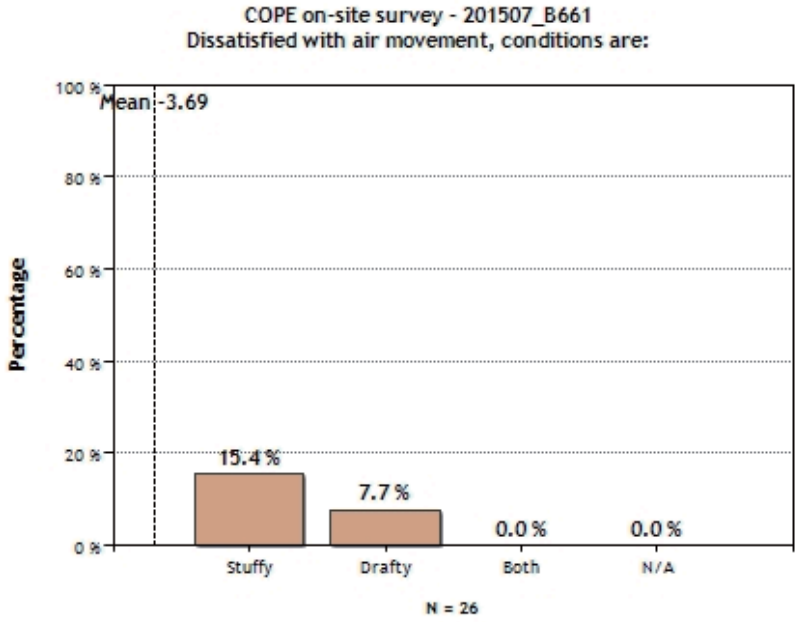
13. Amount of direct glare from daylight



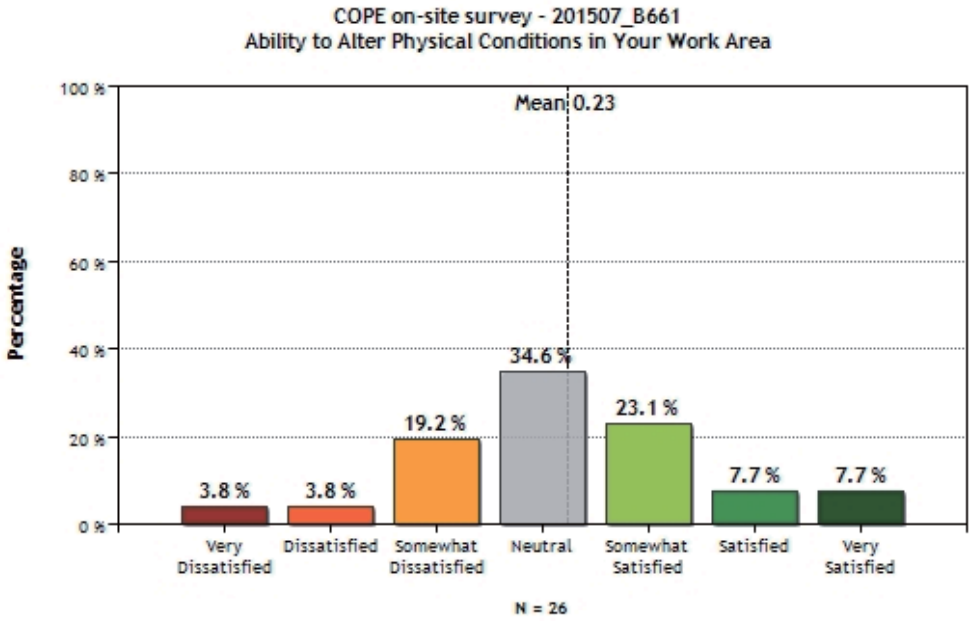
14. Air movement in work area



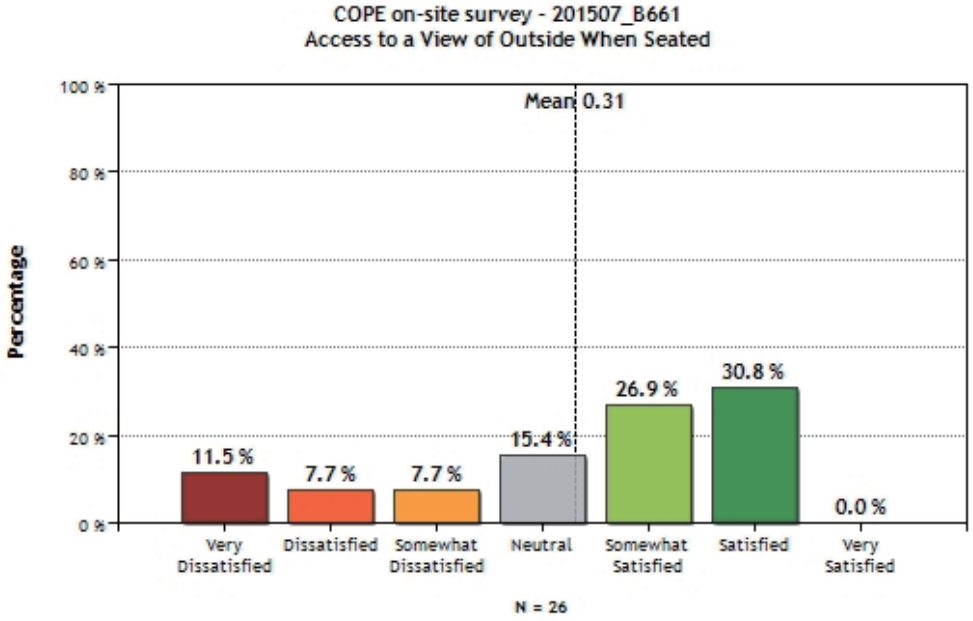
14a. Dissatisfied with air movement, conditions are:



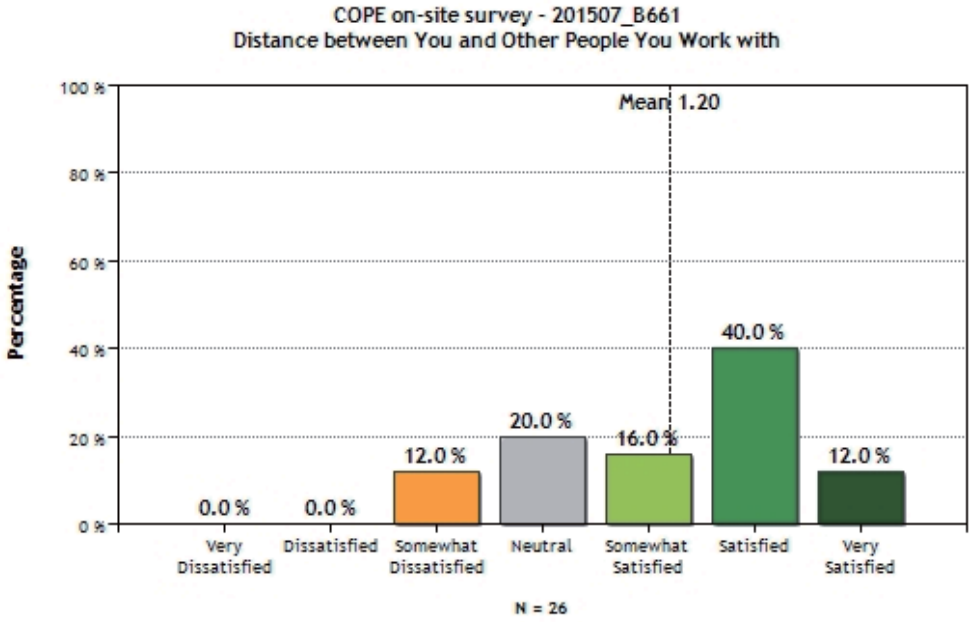
15. Ability to alter physical conditions in work area



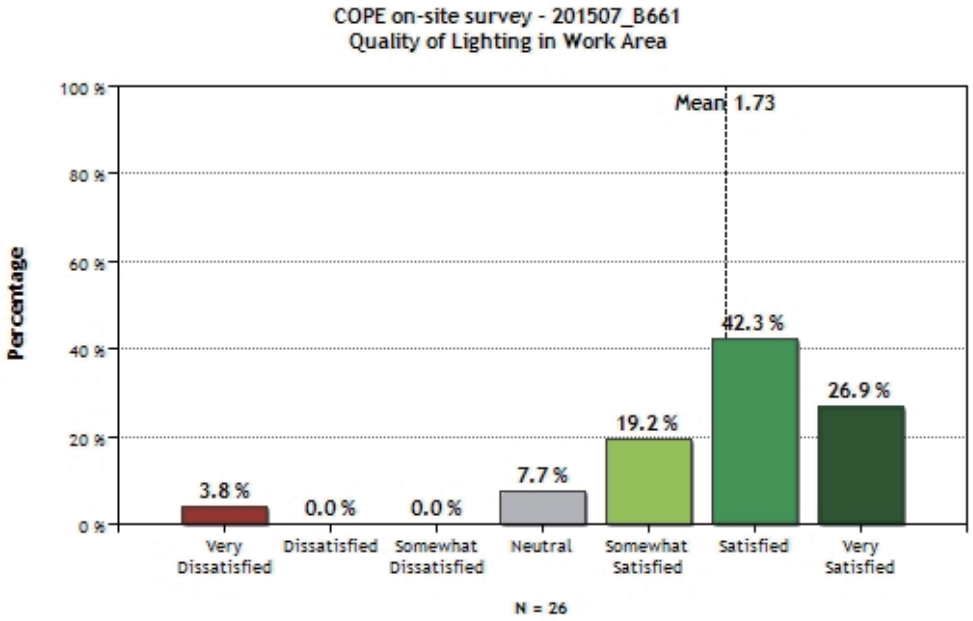
16. Access to a view of outside when seated



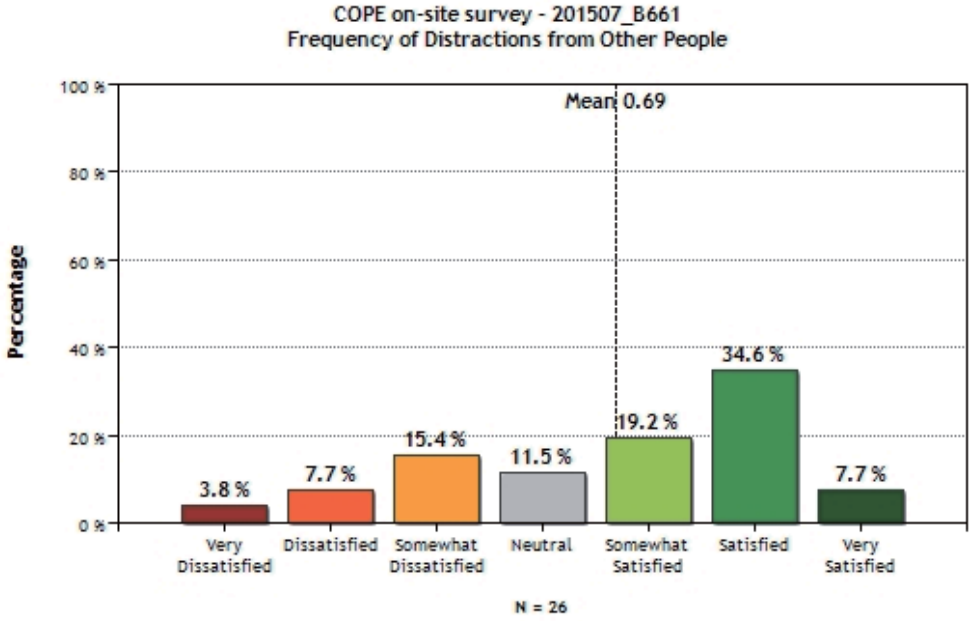
17. Distance to co-workers



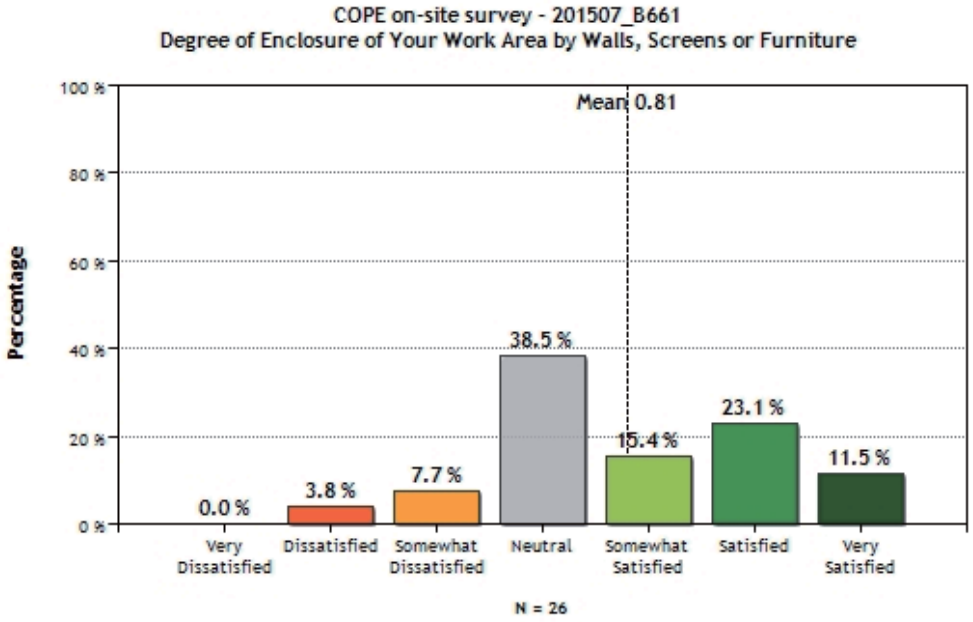
18. Quality of lighting in work area



19. Frequency of distractions from other people



20. Degree of enclosure of work area by walls, screens or furniture

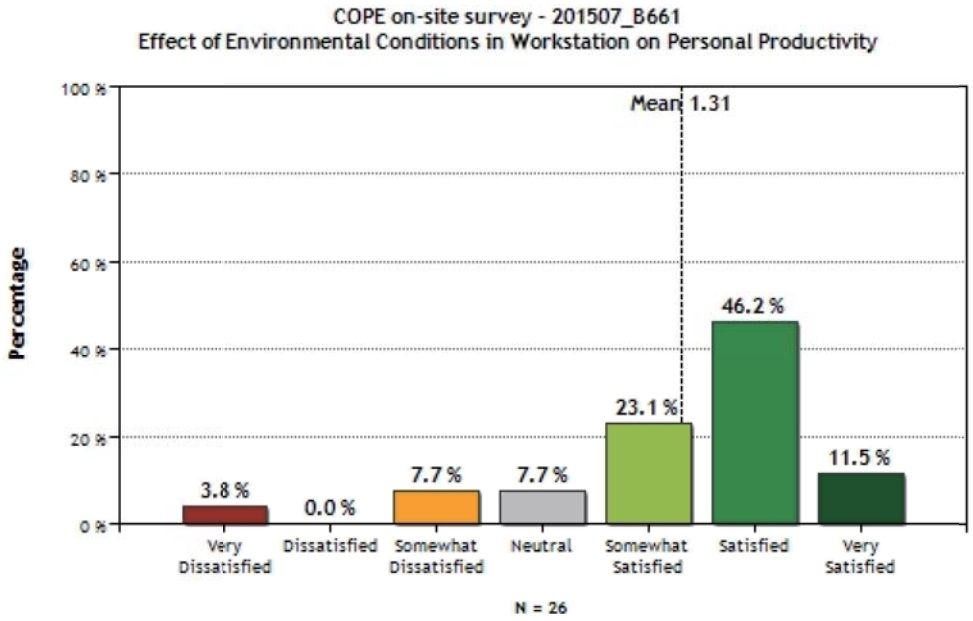


Ranking of Importance by Occupants

	201507_B661_1F
Temperature	2.32
Air Quality/Ventilation	3.92
Lighting	5.08
Noise Levels	3.16
Privacy	3.88
Size of Workspace	4.75
Window Access	4.84

1 : Temperature
2 : Noise Levels
3 : Privacy
4 : Air Quality/Ventilation
5 : Size of workspace
6 : Window Access
7 : Lighting

28. Effect of environmental conditions in workstation on personal productivity



29. Overall indoor environment in workstation