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Extended Abstract

COMPARISON OF THE RESULTS OBTAINED WITH SIMPLIFIED IEQ TOOLKIT AND ROBUST INSTRUMENT IN POE FIELD STUDIES

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Abstract:
Recently mobile Indoor Environmental Quality (IEQ) evaluation has gained increasing interest. Hundreds of mobile apps have been developed in the market which run on smartphones and tablet PCs to support simplified IEQ assessment. Simplified IEQ tools that combine simple measurement instruments with user surveys can provide a statistically significant insight into IEQ conditions at a fraction of the cost of complex field instrumentation, while still providing the first tier of evaluation critical to field evaluation of indoor environments.
We pilot tested simplified IEQ toolkit with the comparison of the robust sensors. Six simplified thermal, air, visual and acoustic sensors were tested in the post occupancy evaluation in the office building in Pittsburgh, PA. For a comparison, National Environmental Assessment Toolkit (NEAT) developed by Center for Building Performance and Diagnostics (CBPD) at Carnegie Mellon University (CMU) and Brüel & Kjær 2250 acoustic meter were utilized. The result showed that there's no significant difference in CO_2, air temperature, and acoustic level. However, the relative humidity (%) and illuminance level (lx) measurements from the simplified IEQ assessment were not adequate in terms of sensor accuracy and consistency.

Introduction and Background:
IEQ evaluation is critical to defining retrofit actions for improving the indoor environment to enhance human health and performance. The National Environmental Assessment Toolkit (NEAT) developed by the Center for Building Performance and Diagnostics (CBPD) at Carnegie Mellon University (CMU) has been used for IEQ evaluation to measure the indoor thermal quality, air quality, lighting, and acoustic performance in work environments [1]. Despite the inclusiveness and accuracy of measurements, the NEAT instruments are expensive, labor intensive, and require expertise to operate the sensors, log the measured data, and conduct data analysis. Simplified IEQ measurement tools on tablet PCs such as iPad and iPhone can help IEQ assessment become a critical phase in the design and commissioning of buildings, as the assessment can provide constant feedback at each stage of the design and construction process. Compared to NEAT, the simplified IEQ toolkits were developed to evaluate IEQ out of consideration for cost-effectiveness and robustness [2].

Approach / Experimental:
Post Occupancy Evaluation (POE) was conducted in an office building in Pittsburgh, PA using both robust and simplified IEQ sensors. Total IEQ conditions of twenty-one workstations were tested using both simplified and robust IEQ toolkits on the 28th of February 2013 (Table 1).

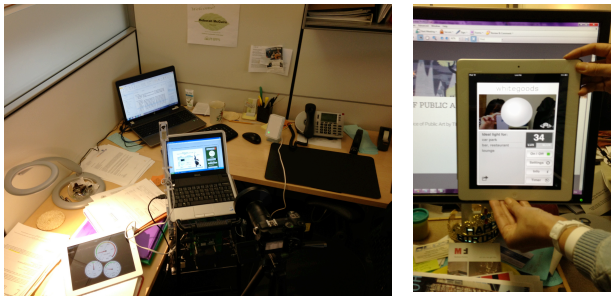


Figure 1 IEQ Spot measurements using NEAT cart and Simplified Toolkit

Six simplified IEQ sensors with selected apps were tested in the field as shown in Table 1. In this paper, the results of 1) CO_2 concentration, 2) air temperature at 1.1 m, 3) relative humidity, and 4) background noise level data were analyzed. Lighting results were not including because the measured illuminance levels obtained in two different apps on iPad 3 were inconsistent such that comparison would be inadequate.

Table 1 Sensor comparison (simplified vs. robust sensors and accuracy)

Sensor	Simplified Toolkit		Robust Toolkit	
	Manufacturer & Accuracy		Manufacturer & Accuracy	
CO_2	AQM [3]	±5 %	Telaire [1]	±5 %
Air Temperature	AQM [3]	±1˚C	National | LM35DZ [1]	±0.5˚C
RH	AQM [3]	±5%	Honeywell | HIH-3602 [1]	±2 %
Acoustics	RTA [6]	n/a	Bruel Kaejer | 2250 [7]	±1 dB
Illuminance1	Whitegoods [4]	n/a	Minolta T-10 [8]	±3 %
Illuminance2	LuxMeter [5]	n/a		

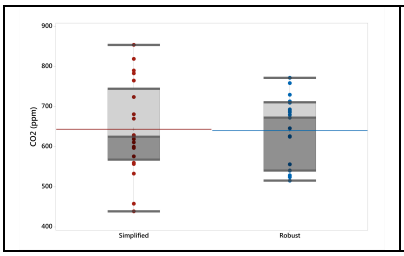
ANOVA F-test was used to analyze the differences between the two means of measured results. SAS 9.3 software was utilized to compare IEQ sensor evaluation for the IEQ field measurement.

Results and Discussion:

1. Air Quality

1) CO_2 level

Figure 2 shows the result of the comparison of CO_2 level using simplified and robust sensors. There was no statistically significant difference between two sensors (P=0.909). Hence it may be feasible to measure CO_2 level with simplified sensors.



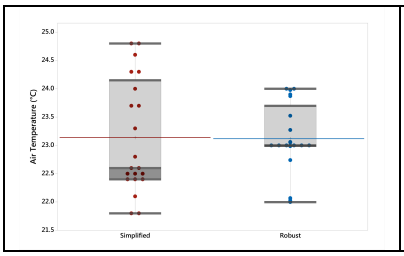
Summary Statistics
Total: n = 42
Mean:
Simplified: 643.7 ppm
Robust: 640.2 ppm
P-Value = 0.909

Figure 2 Comparison of CO_2 level using simplified and robust sensors

2. Thermal Quality

1) Air temperature

Figure 3 shows the result of the comparison of air temperature using simplified and robust sensors. The mean temperature values at 1.1 m from two sensors have no significant difference from each other (P=0.938), which indicates that the simplified toolkits should be highly reliable for air temperature measurements.

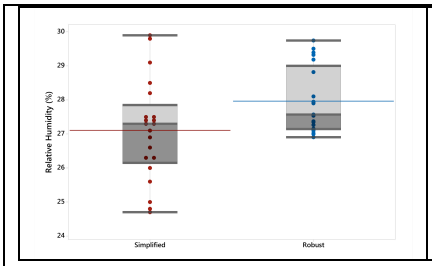


Summary Statistics:
Total: n= 42
Mean:
Simplified: 23.138 ^{O}C
Robust: 23.118 ^{O}C
P-Value = 0.938

Figure 3 Comparison of air temperature using simplified and robust sensors

2) Relative Humidity

By comparing the measured relative humidity, two mean values measured by simplified and robust sensors were statistically different given the threshold of α=0.05 (P=0.030). Having investigated the specifications of the sensors for the accuracy of the sensors, we noticed that the accuracy of the NEAT sensor is ± 2%, while the accuracy of the Air Quality Monitor in the simplified IEQ toolkits is ± 5%. Therefore, the simplified sensor cannot guarantee to provide reliable results in scientific field studies of relative humidity.

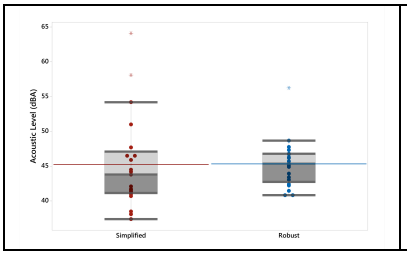


Summary Statistics:
Total: n = 42
Mean
Simplified: 27.105 %
Robust: 27.965 %
P-Value = 0.030*

Figure 4 Comparison of relative humidity using simplified and robust sensors

3. Acoustic Quality

The result of the f test indicated that there was no statistically significant difference between the two acoustic sensors (P=0.960), and the background noise can be diagnosed using the simplified sensor (Figure 5).



Summary Statistics:
Total: n= 42
Mean:
Simplified: 45.25 ppm
Robust: 45.34 ppm
P-Value = 0.960

Figure 5 Comparison of acoustic quality using simplified and robust sensors

Summary and Conclusions:

The comparison of the results obtained with simplified IEQ toolkit and robust instruments in POE field studies were presented. The results showed that the simplified IEQ toolkits were adequately accurate in terms of CO_2 level (ppm), air temperature (^{o}C) and acoustic level (dBA) assessment, but it cannot offer an informative result in measuring relative humidity (%) and illuminance level (lx).

It is expected that the simplified IEQ toolkit is able to provide occupants' preliminary perception of IEQ in workstations, and if some issues were detected, robust toolkits should be used for in-depth analysis.

Acknowledgements:

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References:

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[7] Brüel & Kjær: http://www.bksv.com
[8] http://sensing.konicaminolta.us/products/t-10a-illuminance-meter/