ACOUSTICAL EVALUATION OF UBC NON-CLASSROOM LEARNING SPACES

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1. INTRODUCTION

At the University of British Columbia (UBC), students share ideas, do homework, read, write, study, compute, discuss live or on cell-phones, or otherwise interact with fellow students to the benefit of learning in spaces such as lobbies, hallways, eateries, cafés, labs, libraries and common rooms. These areas are non-classroom learning spaces (NCLS). The main objective of this research project was to evaluate non-classroom learning spaces located in buildings at UBC, to determine the quality of their acoustical environments and how to improve their designs. Spaces were chosen for study based on the following criteria: be used by students for learning purposes; have capacity for at least 40 users; have a constant flow of users. In the end, 23 spaces in 11 buildings were studied. They were libraries, academic common areas, coffee shops, eateries and dedicated study spaces. The evaluation assessed the spaces by questionnaire survey and physical-acoustical measurement.

2. METHODOLOGY

2.1 Questionnaire

A questionnaire was developed for the study. Its length had to give a response time of 5-7 minutes. Both acoustical and non-acoustical questions were included, as follows:

- Non-acoustical: respondent demographics (sex, number in group, wearing of earplugs/headphones, current learning activities); perceived overall quality of the NCLS environment; perceived quality of non-acoustical aspects of the environment (lighting, air, temperature, furniture).
- Acoustical: perceived overall quality of the acoustical environment; effects of aspects of the acoustical environment; awareness of the acoustical environment; positive and negative consequences of the acoustical environment.

2.2 Physical-Acoustical Parameters

The following physical-acoustical parameters were measured:

- Noise levels. Equivalent-continuous noise levels in the 63-8000 Hz octave bands were measured. In the unoccupied spaces total, A-weighted and NC levels were determined. In the occupied spaces, total, A-weighted and NC(B) levels were determined;
- Reverberation time at mid-frequencies (**RT_{mid}**);
- Speech Intelligibility Index (**SII_n**), calculated at a receiver position from the normal-voice speech level, occupied noise levels and unoccupied RT_{mid}'s. SII_n at 1 m (SII_n1) was used to assess speech intelligibility. SII_n at 4 m (SII_n4) was used to assess speech privacy.

2.3 Acceptability Criteria

The evaluation criteria chosen for this study were adopted from various sources [1, 2, 3]:

- **RT_{mid}.** The spaces evaluated in this project are not classrooms, and are larger than those considered in classroom standards, sometimes considerably larger. Moreover, students experience the occupied space, and student absorption reduces the RT of the unoccupied space. Thus, for the non-classroom learning spaces in this study, RT<1.0 s was considered acceptable, and values less than 0.7 s were considered excellent;
- **SII_n.** Speech intelligibility was considered acceptable for SII_n1 values of 0.5-0.75; above 0.75, it was considered excellent. For speech privacy, SII_n4 values ranging from 0.10-0.20 were acceptable; values below 0.1 were considered excellent;
- **NC_u.** Continuous noise (mainly generated by mechanical services) in an unoccupied learning space should be in the range NC 25-30. Values below NC 25 were considered excellent;
- **NCB_o.** Continuous noise in an occupied learning space should not exceed NC(B) 40; values below NC(B) 35 were considered excellent;
- **$dBA_{u,o}$.** Values of total, A-weighted level up to 40 dBA were acceptable for unoccupied learning spaces, and up to 47 dBA for occupied learning spaces.

2.4 Test Protocol

Four visits were made to each space. For visits 1, 2 and 3 (occupied NCLS), noise levels were measured and the questionnaire administered in the periods 9:30-11:00, 12:00-14:00 and 14:00-16:00. For visit 4 (unoccupied NCLS), all physical measurements were performed.

3. RESULTS

3.1 Questionnaires

850 questionnaires were analyzed. The average results for each space were calculated, and spaces with better or worse quality identified. Average responses for each question were also calculated. Following are the main results: the learning activities reported most often were thinking and reading; lighting, air, temperature and furniture comfort generally enhanced learning—the acoustical

environment interfered with it; people moving and talking was the aspect of the acoustical environment that most impaired learning, followed by intermittent noise; distraction was the most reported negative consequence of the acoustical environment, followed by annoyance; difficulty hearing and talking were reported least; feeling relaxed was the most reported positive consequence of the acoustical environment, followed by feeling productive; conversational privacy was reported least; 22% of respondents reported that they chose their study location because of the acoustical environment; in most cases they chose a quiet location.

3.2 Statistical Analysis

Correlation

In order to observe if there were any apparent relationships between the questionnaire responses and the measured physical-acoustical parameters, Pearson's correlation coefficients between all data pairs were calculated. Values >0.2 in absolute value were considered significant and their apparent implications deduced.

Considering first only the questionnaire responses (note: 'satisfaction' refers to the perceived extent to which learning was interfered with or enhanced): no responses were correlated with the time of day or respondent sex; overall satisfaction with the learning environment was associated with increased satisfaction with people talking and moving, continuous noise and intermittent noise; overall satisfaction with the learning environment was associated with increased experiencing relaxed, energized and productive; overall satisfaction with the learning environment was associated with decreased distraction; satisfaction with lighting was associated with feeling productive satisfaction with air quality was associated with feeling relaxed; satisfaction with furniture comfort was associated with feeling relaxed and productive; satisfaction with the acoustical environment was associated with increased satisfaction with people talking and moving, continuous and intermittent noise and reverberation; satisfaction with the acoustical environment was associated with decreased annoyance, distraction, stress and difficulty hearing; satisfaction with people talking and moving, continuous and intermittent noise and reverberation were mutually correlated; satisfaction with people talking and moving, continuous and intermittent noise and reverberation were associated with decreased annoyance, distraction and stress; experiences of annoyance, distraction, stress, fatigue, difficulty hearing and difficulty talking were correlated; experiences of conversational privacy, and of feeling relaxed, energized and productive were correlated.

Second, considering only the physical-acoustical parameters: all noise levels and SII_n values were correlated; RT_{mid} was only correlated with SII_n4.

Finally, considering both the questionnaire responses and the physical-acoustical parameters: when noise levels were lower, students were more likely to be involved in reading; when noise levels were higher and SII_n's lower, people were less satisfied with the overall learning environment and with furniture comfort, were more likely to be involved in discussion, to work in groups, to report more difficulty hearing, slightly more difficulty talking, and to feel less productive, and were more likely to choose their study location because of the acoustical environment.

Regression analysis

Various multivariable linear-regression models were developed to predict the response to the question, "How well does the environment *in general* in this learning space interfere with or enhance your ability to use this space for your activities?" on a scale from -3 (interferes a lot) to +3 (enhances a lot) (variable *env_gen*). First, using only the other questionnaire responses as predictors, an optimal model which had an adjusted-R^2 of 0.48 was found. Second, using only the physical parameters as predictors, an optimal model which had an adjusted-R^2 of 0.19 was found. The best model, with an adjusted-R^2 of 0.53, was developed using both the questionnaire responses and the physical-acoustical parameters: $env\_gen = 0.151\ light + 0.126\ furn + 0.264\ people + 0.174\ prod + 0.401\ acoust - 0.014\ BNA_u + 0.348\ RT_{mid} + 2.188\ SII_n4$, in which *light* quantifies the perceived quality of the lighting, *furn* quantifies the perceived comfort of the furniture and *people* quantifies satisfaction with people talking and moving (on the same scales as *env_gen*); *prod* quantifies the reported feeling of productivity on a scale from 0 (not at all) to 5 (a lot), *acoust* = 1 if respondents chose their study location because of the acoustical environment and 0 if not. BNA_u is the total, A-weighted unoccupied noise level, RT_{mid} is the unoccupied mid-frequency RT, and SII_n4 is the normal-voice SII at 4 m.

4. DISCUSSION

According to the above regression model, occupant satisfaction with overall environmental quality can be improved by improving the lighting and furniture comfort, ensuring that people talking and moving are not a disturbance, decreasing noise levels and increasing speech privacy. The positive coefficient of the RT_{mid} term suggests that environmental quality can be increased by increasing the mid-frequency RT; however, it also increases with SIIn4 which decreases with increase RT, so the effect of reverberation is not simple.

REFERENCES

[1] ANSI S12.2-1995. American National Standard Criteria for Evaluating Room Noise. Acoustical Society of America, New York, 1995.

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