STATISTICAL ANALYSIS OF CLASSROOM QUESTIONNAIRES AND ACOUSTICAL PARAMETERS

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1. INTRODUCTION

The acoustical conditions of a classroom may have a profound impact on the ability of occupants of that space to teach and learn. Within the activities of teaching and learning there seem to be several sub-categories of activities; these are lecturing, group work and independent work such as writing exams. For the first two, being able to communicate verbally is important, whereas for individual work a distraction-free environment is more important. This report will focus on the issue of effective verbal communication.

University classrooms have several acoustical attributes that are not common to other spaces. First, in a classroom the talker is, in general, farther from his or her audience than the distance at which he or she would normally endeavor to communicate in most other settings. Second, the communication is normally in the form of a monologue; consequently most signals generated by the audience can be classified as noise. Third, the noise sources of the classroom are commonly closer to the receiver than the talker. Finally, university classrooms tend to be large spaces.

On account of the unusual needs of classrooms it follows to develop methods to evaluate and predict the acoustical performance and optimize their designs. In order to accomplish this, it is necessary to have an objective measure of the acoustical quality of a classroom. The method used in this work to create an objective measure of the quality of a classroom was to first consider the subjective quality of the classroom as reported by its users. This was done through a survey-based metric, the Perceived Listening Ease (PLE) questionnaire [1]. The details of both the administration of the PLE survey form and the calculation of the PLE score will be described below. For the purposes of this summary it is only necessary to understand that a PLE score is calculated from questionnaire responses is believed to represent the best estimate of an occupant's subjective assessment of the acoustical quality of a space. The average PLE score of a space is consequently used as an estimate of its objective quality. This implicitly assumes that an individual PLE score is drawn randomly from a distribution whose mean is dependent on the classroom for which the PLE score was calculated. The primary objective of this report is to explore the relationship between the physical-acoustical attributes of a classroom and its mean PLE score, in order to evaluate the usefulness of PLE as a measure of classroom quality and, given that PLE is useful, to evaluate the performance of classrooms. It is also of interest to find a forward prediction model for the performance of a classroom which can be used to optimize the design.

2. METHOD

2.1 Data collection

The information used in this report was gathered from questionnaires distributed to students attending classes, and physical measurements taken in the classrooms.

The student questionnaire consisted of 73 questions. These questions were divided into three sections. These were the demographic information of the student, the student's evaluation of the listening environment in the classroom, and the student's evaluation of the course and its presentation. The questionnaires were completed during class time in the classroom that each questionnaire evaluated.

The physical measurements were taken in the classrooms during their unoccupied state. Simple physical measurements such as surface area and volume were derived from building schematics where possible and measured otherwise. The direct acoustical measures included background noise level (BNL), early decay time (EDT), reverberation time (RT-20) and early-late energy fraction (C50); these measurements where taken for each octave from 125 Hz to 8000 Hz. A list of the definitions of the physical measurements is given in Table 1. The measurements were made using the calibrated MLSSA or Win MLS systems and an omni-directional loudspeaker source. These measurements were repeated at nine locations on a 3-by-3 grid in each classroom.

2.2 Participants

Seventeen classrooms were considered in the study. Fourteen of these were seven pairs of pre- and post-renovated rooms. Two were identical rooms, one of which had been renovated; however only the renovated information is available. The final room was a newly constructed classroom. From the instructors of the seventeen classrooms contacted, 65 agreed to participate in the study. Each instructor participated with at least one class; however several instructors gave permission for surveys to be administered to multiple classes that they instructed. The result is that 82 class sections, with 4882 students, participated in the study.

The average age of students participating in this study at time of survey was 20.9 years of age. The number of student participants who identified themselves as male was 2847 (58.4%), the number of females was 1937 (39.8%); 98 students did not answer the question. Of the students surveyed, 1804 (37%) reported being in the Arts and 1555 (31.9%) reported being in the Sciences; the remaining 1522 students reported various specializations. The average year of study for undergraduate students at time of survey was 2.4 years. There were also 32 graduate students who responded to the survey. The number of ESL students in the study was 2076 (42.6%); the number of native English speakers was 2656 (54.5%). The students reported their usual location in the classroom as one of 30 possible locations on a 6-by-5 grid. For reasons of convenience and integrity it was necessary to truncate this down to four possible locations. These were in the front third of the room, the middle third of the room, the back third of the room, or when a respondent stated that they had no preferred location in the classroom. Students were distributed in these locations as follows: 1965 (40.3%) students sat in the front, 1767 (36.2%) in the middle, 716 (14.7%) in the back and 434 (8.9%) gave no preference. Only 136 (2.8%) students reported having a hearing impairment.

The global average PLE score was 62.6; the global standard deviation of PLE scores was 17. The average score for male respondents was 63.5, for female respondents it was 62.0. The average response from hearing-impaired respondents was 59.6, from non-hearing-impaired respondents it was 62.7. Similarly, students who suffered from repeated ear infections also rated the PLEs of classrooms lower; these students had an average PLE score of 60.6; students who did not have multiple ear infections had an average PLE of 62.7. For ESL students the average PLE response was 60.6; for native English speakers the average score was 64.4.

3. STATISTICAL ANALYSIS

3.1 Covariate selection

On account of the large impact of the demographic information on PLE score it was necessary to block for the demographic information of the respondents, and then to model the residuals against the physical-acoustical measurements of the classrooms.

An iterative holdout procedure was used to select the covariates. The selected variables were, the student's assessment of the air quality, lighting, seating and temperature of the classroom; the student's assessment of the instructor's accent, articulation and volume; whether the student is a native English speaker; the student's assessment of the course's difficulty and interest and; does the student do the pre-assigned work for the course.

3.2 Physical attributes selection

The multivariate model for the residuals of the demographic information and the physical attributes of the classrooms was selected using a step AIC procedure. The selected variables are shown in Table 2. A ".2" indicates that a variable was squared before the linear modeling process was preformed. The ".V" and ".VS" indicate an interaction with volume and the two way interaction between volume and surface area respectively.

4. SUMMARY OF FINDINGS

The first significant finding is that the effect of renovations on the PLE scores of the classrooms is almost always positive (increased acoustical quality). Another important observation is that rooms that have good acoustical qualities also have good non-acoustical qualities. This seems to imply that a person's perception of the acoustics of a space is linked to their perception of non-acoustical attributes.

With regards to comparisons that can be made between the PLE scores of the different classrooms, the distribution of the PLE scores for each of the classrooms appear to only differ in median values. Notably, the shape of the distributions, and the variances of the PLE scores for the different classrooms are similar.

In consideration of the relationships between PLE and the physical attributes of the classrooms, amongst the most important findings is that mid to high frequency (between 2000 and 4000 Hz) ventilation noise has a negative linear relation with PLE. Another important point is that most C50 octave band vales have a negative quadratic relation with PLE. This indicates that some reverberation is preferable in classrooms. It is only the low-frequency octaves (between 125 and 250 Hz) that have a linear relation; for these frequencies, the slope of the regression line is positive. The total amount of sound absorption in a classroom has a positive relation with PLE when considered as an interaction of surface area. There is some discord between this result and the one for C50 values, as they seem to indicate two different conclusions. It should be noted that this is not a result of there being an insufficiently large distribution of sound absorption across the classrooms to observe an optimal amount; if this were the case, then it would be unlikely that the effect would be observable in the case of the C50 values. A more likely explanation is that a student's evaluation of the reverberation of a classroom is linked to other attributes of a classroom, such as shape, which were not blocked for in this study. This theory is supported by the relationship of EDT with PLE; EDT is only important in small classrooms and has an optimal value of approximately 0.9 seconds.

In consideration of the physical attributes that were adjusted for the occupied state of the classrooms, some of the more important results are: Total background noise level has a negative linear relation with PLE; this is pleasantly consistent with the effects observed for ventilation noise. The component of speech intelligibility that is not explained by occupied EDT predicts PLE score; strangely this component is in some way linked to signal-to-noise; however signal-to-noise does not appear to be a strong predictor. The contradiction created by these two points is a strong indicator that the method that was used to adjust the signal-to-noise values for the presence of a speech reinforcement system was not adequate.

The component of PLE that is explainable by physical attributes of the classrooms is explainable by many physical attributes of the classrooms. This is unfortunately not useful for predicting the performance of classrooms; however it does imply that a careful study of the acoustically relevant physical attributes of spaces share some underlying components that are perceived by people and impact their assessments of the spaces.

Table 1. A list of the physical acoustical variables and their descriptions.

Variable	Description	Variable	Description
AlphaEDT	The total number of square meters of sound absorption based on EDT.	Total BGNL	Total background noise level of occupied classroom.
Ao	Total sound absorption, adjusted for number of occupants.	SRS	Is a Speech reinforcement system used in the classroom.
Attendance	Estimated number of students attending the class at time of survey.	V	The classroom volume
f.m	Is the instructor male of female?	VN	Ventilation noise level.
Floor	The classroom floor area	**Extention**	**Description**
Registered	Number of students registered in the class.	.o	Indicates that the variable has bean adjusted for the occupied stat of the classroom.
S	The classroom surface area	.Mid.Freq	The average of the 500, 1000 and 2000 Hz values.
SI	Speech intelligibility	.Average	The average of all values.
SNA	Signal to noise ratio	.Global	The average over frequancys of all values.
Upseat	Are the seats upholstered	.1000.Hz	The ocatave band for which a given measument was taken
STI	Sound transmission index	A.Weight	The total A weighted noise level

Table 2. A list of the physical-acoustical variables and their coefficients used in the PLE prediction model.

Variable	Coefficients	95%CI(LB,	UB)	Standard Error	T-value	P-value
(Intercept)	4.3965	-1.718	10.511	3.11959	1.409	0.159
Attendance	-0.0137	-0.032	0.004	0.00912	-1.505	0.132
C50.500.Hz	0.7903	0.469	1.111	0.16381	4.825	0.000 ***
C50.500.Hz.2	0.1151	0.062	0.168	0.02706	4.255	0.000 ***
EDT.125.Hz.VS	-27.2742	-32.874	-21.674	2.85713	-9.546	0.000 ***
EDT.2000.Hz	-6.1873	-10.240	-2.135	2.06748	-2.993	0.003 **
EDT.2000.Hz.2.VS	4.8229	3.017	6.629	0.92131	5.235	0.000 ***
EDT.250.Hz.2.V	3.2022	2.346	4.058	0.43684	7.330	0.000 ***
EDT.500.Hz	6.8294	3.859	9.800	1.51566	4.506	0.000 ***
f.m	1.6055	0.585	2.626	0.52066	3.084	0.002 **
VN.2000.Hz	-0.2867	-0.490	-0.083	0.10389	-2.760	0.006 **

REFERENCES

[1] Kennedy, L. Dillon Edgett, M. Hodgson, N. Lamb and R. Rempel, "Subjective assessment of listening environments in university classrooms", J. Acoust. Soc. Am. 119(1) 299-309 (2006).