ACOUSTIC METRICS FOR CLASSROOM PERFORMANCE – A LITERATURE REVIEW

Setareh Shams and Ramani Ramakrishnan
Department of Architectural Science, Ryerson University, Toronto, ON, rramakri@ryerson.ca

1. INTRODUCTION

Speech intelligibility, reverberation time and ambient sound are three commonly used acoustic metrics to assess the performance of classrooms. This literature review was undertaken by an undergraduate research project to enumerate all possible metrics that can be used to assess completely the classroom performance from an acoustic perspective. The review has attempted to evaluate the sufficiency of the three conventional metrics. The validity of applying other metrics was also assessed. Finally, the effectiveness of such metrics and their impact on subjective experiences were also studied. The results of the literature review are presented in this paper.

2. CONVENTIONAL METRICS

2.1 Speech Intelligibility and Reverberation Time

Majority of the papers studied often state reverberation times or speech intelligibility as the most accurate means of measuring how well students listen in classroom environments. There were always debates about which of these two commonly studied factors actually represented the acoustical conditions.

Barron and Lee, at least for concert halls, concluded that reverberation time determines early decay time, early-to-late sound index, and total sound-pressure level with volume [1]. Hence, reverberation time is one of the most important descriptors of perceived quality of a space and acoustic metrics.

Bradley indicates that speech intelligibility is the best choice for basing ideal acoustical conditions. When speech intelligibility is nearly perfect in classroom conditions, there is little impact on noise to academic achievement [2].

Despite his preference towards speech intelligibility, Bradley also uses both parameters in conjunction as a means of obtaining more accurate results for measuring classroom acoustic [3]. Reverberation time is not the sole descriptor of room acoustic conditions. There exists an important relationship between reverberation time and speech intelligibly that is also governed through various parameters, and both affect the outcomes of one another. Increased reverberation times can negatively impact speech intelligibility, and they can also increase speech intelligibility through increasing levels of early arriving speech sounds. Consequently, reverberation time has to be at an optimum so as to make the teachers voice as intelligible as possible. However, increased reverberation, will affect the speech-to-noise ratios as well. Therefore, a metric that combines predicators of both speech intelligibility and reverberation times such as the useful-to-detrimental sound ratios can be used.

Bradley states that there are numerous predicators of speech intelligibly that must be considered as well [4]. Some of these include signal-to-noise ratio, speech transmission index and useful/detrimental sound ratios. The most accurate was determined to be the 0.08-s useful/detrimental ratio (U_{80}). When using speech intelligibility as a metric, there are also individual factors that must be considered that can affect its validity. The most important of these factors include speech-to-noise ratios, reflected sounds, and the age of the listener [5]. Furthermore, as previously mentioned, reverberation time also has an important affect on speech intelligibility. As a result, it is critical to have reverberation times that are not very low while having some reflected sound in order to increase speech intelligibility. Bradley's results concluded that decreasing reverberation times influenced those of a younger age in their speech intelligibility, and therefore it is important to consider age in further studies.

2.2 Metrics and Age

Many papers also assert the importance of focusing data on age-specific subjects. Some data studied did not necessarily consider the significance of age and its relationship to acoustics. For instance, Neuman and Hochberg state that studies involving classrooms have focused on determining optimal reverberation through testing adults as opposed to children [6]. Because children adhere to different acoustical environments, the data that was thus determined in a way becomes rather inaccurate. Their study showed that in the same reverberant conditions, children scored less than adults, proving that children perceive sound in different and shorter reverberation times than adults do.

According to Bradley, different acoustical criteria are required, depending on the grade and age of students. For instance, in classes with Grade 1 students, because they are more easily distracted, teachers would adjust their voice levels based on the ambient noise level. Consequently, ambient noise is something that needs to be highly controlled in such cases [7].

Therefore, it is absolutely vital for researchers to be aware of their target age when studying conditions in a room and carrying out tests in order to obtain the most useful and effective results.

3. RESEARCH ISSUES

Though finding effective parameters in research can be difficult, the way in which tests are executed is also of great importance, where lack of attention to detail can hinder test results. One of these issues in research methods is monaural vs. binaural hearing. According to Bradley, test results can be accurate if children are tested in realistic classroom conditions with both ears [8]. Often, tests that are conducted by researchers neglect the importance of this. Furthermore, under experimental conditions, there is a lack of criteria that children experience in realistic classrooms, such as distractions, their own noises, and so on. The tests are conducted in unoccupied classrooms and fail to incorporate the subjective experiences of students. There are considerable differences between a room that is occupied and one that is not, and researchers must keep such issues in mind when conducting studies.

Bradley thus agrees that there is a greater need for acoustical conditions when classrooms were occupied and in operation [3]. His studies are completed in more realistic conditions during actual teaching conditions, and as a function of signal-to-noise ratios.

Hodgson and Nosal argue that often times, when calculating optimal reverberation times, experimenters forget to include the effects of noise [9]. Bradley argues that noise is much bigger overriding problem than poor room acoustics, especially when there is an absence of reverberation. Consequently, reverberation times have to be designed in such a way that they minimize the effects of background noise on the listener. In their paper, in order to determine optimal reverberation times, Hodgon and Nosal use the speech intelligibility metric of U_{50}. Experimental procedures often represent background noise in a more unrealistic manner. Therefore, Hodgson and Nosal state that "a physically realistic treatment of noise incorporates both the nearby noise source and the effect of reverberation on noise." Research conducted by Houtgast concludes the same issues. In his paper, Houtgast considers noise (from exterior) and how it affects intelligibility for students under the effects of reverberation [10].

Finally, Palovic points out that it is often difficult to make direct comparisons between results, because different researchers use different parameters when dealing with speech intelligibility [11].

4. SUBJECTIVE ANALYSIS

Subjective experiences are vital aspects that students undergo on a daily basis in classrooms. Studying them often exposes researchers to different and more detailed perspectives on classroom acoustics. However, the majority of papers studied neglect the true subjective experience of the listeners in the classrooms. Tests that were conducted were based on the technical and scientific approach to results. Many simply performed straightforward tests such as the Word Identification by Picture Identification, Fair-banks rhyme test, recordings of nonsense syllables, and so on. These tests focused solely on obtaining results that dealt with various acoustical parameters through the use of acoustical equipment, as opposed to how students truly perceived sound in a space. The results were then taken and compared to other quantitative results and analyzed through means such as graphs and charts. The only studies that mention subjective experiences were by Lochner and Burger, in which they tie subjective judgments to reflection patterns [12].

4.1 Subjective parameters

According to their study, Lochner and Burger believe that the execution of subjective judgments in a space is vital to how effective acoustical qualities in a room are carried out [12]. However, they also state that determining the physical units that can accomplish this in the most effective way possible is very difficult. In other words, finding the proper metric to evaluate subjective experiences is a big challenge. Nonetheless, they believe that the most accurate way is through reflection patterns in a room, and that "the quality of speech and music in a room is a function of the reflection pattern." They carried out tests with different observers using subjective articulation tests in varying reflection conditions, and used the observers' results to conclude speech intelligibility in relation to reflections. However, in the end, these speech intelligibility scores serve as a quantitative measure, and route right back to the issue of the difficulty of obtaining qualitative characteristics from such quantitative measurements.

A few other studies only briefly mention how some parameters can indicate subjective experiences. Steeneken and Houtgast used subjective intelligibility measurements in order to obtain the relation between speech transmission index values (an objective physical measure of speech transmission) and intelligibility scores [13], which again rely on quantitative measures to determine subjective measures. Bradley states that though reverberation time has been a strong indication of acoustical conditions in a room, early decay times have become more useful in terms of subjective evaluations [7]. They indicate the level of clarity as well as speech intelligibility in a room. Finally, Bradley also mentions that according to a study by Reichardt and Lehman that the "early/late-arriving sound-energy ratio for a 0.08-s early sound limit (C_{80}) has gained considerable acceptance as a correlate of subjective judgments of musical clarity" [14]. All these studies simply mention a brief measure that potentially has the ability to assess subjective analysis, yet they fail to actually present concrete results using qualitative analysis.

Though all of the research refer to how various metrics can direct us into the subjective experiences, but no quantitative basis had been presented. Thus, it is important that subjective experiences become a critical segment of experimental procedures. It becomes valuable to include how students truly perceive acoustics in a space subjectively, and finding a parameter to effectively do so becomes the next challenge.

5. REFERENCES

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