Technology in Educational Settings It May Already Be In Your Pocket or Purse!

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"Technology in Educational Settings" is the theme for the Educational Audiology Association's Summer Conference in Scottsdale, Arizona in June, 2013. The program will be filled with valuable information, particularly because of the large increase in web-based tools that have been designed to address the needs of students, teachers, and educational audiologists. Yet, audiologists might be surprised to know that one of the most useful technology tools may already be in our possession: the smartphone or tablet computer, both of which have become ubiquitous in their penetration of the consumer technology market. Today, there are powerful applications (apps) for smartphones and tablets that address almost any task or query for information. This article will review the current ANSI Standard for classroom acoustics as well as focus on apps for smartphones and tablets designed for the measurement of classroom acoustics.

Introduction

In recognition of the fact that undesirable acoustics can be a barrier to listening and learning in the classroom, the first American standard was published in 2002 and revised in 2010. The first part of the revised standard, American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools (ANSI/ASA S12.60-20), is a refined version of the 2002 standard. The major performance requirement for furnished but unoccupied classrooms is basically unchanged from the 2002 standard. The one-hour average, A-weighted background noise level cannot exceed 35 dB (55 dB if C-weighting is used), and for averaged sized classrooms with a volume less than or equal to 10,000 cubic feet, the reverberation time (RT60) cannot exceed 0.6 seconds (35/55 dBA/C and 0.7 seconds if the volume is greater than 10,000 but less than or equal to 20,000 cubic feet). Among other changes are improvement of the requirements for exterior walls and roofs in noisy areas, consideration of activities close to classrooms, clarification of the definition of a "core learning space," addition of the limit of 45 dBA for sound in hallways, clarification and simplification of measurement procedures and addition of the requirement that if an audio distribution systems is deemed appropriate it should provide even coverage and be adjustable so as not to disturb adjacent classes.

The second part of the revised standard, American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 2: Relocatable Classroom Factors (ANSI/ASA S12.60-2010), includes performance requirements for portable classrooms. The current standard sets a 41 dB(A) limit for background noise in unoccupied classrooms, which would be lowered to 38 dB(A) in 2013 and 35 dB(A) in 2017. Reverberation time (RT60) in unoccupied relocatable classrooms must not exceed 0.5 second in classrooms with volumes of 10,000 cubic feet or less and 0.6 second in classrooms with volumes of 10,000–20,000 cubic feet. Both parts of the standard are available without charge from the Acoustical Society of America store (http://asastore.aip.org).

In order to estimate compliance of classroom with the ANSI (2010) standard, it is necessary to accurately and reliably measure the unoccupied noise levels and octave band reverberation times that are present in a given classroom enclosure. Obtaining accurate data regarding these parameters allows us to document compliance (or lack thereof) with the ANSI standard and affords powerful tools with which to share this information with parents, teachers, and others. These measures are not intended to replace complete acoustical analysis by certified acousticians. Instead, they are simply tools for audiologists to gather and share essential information related to the acoustical challenges students face daily in their learning environments.

There are many acoustical measurement applications (apps) that are downloadable for both Apple iOS and Android smartphone platforms. Many of these are basic sound level meters. Of these, few appear to have been designed by audio professionals for use by audiologists, or could possibly be considered equivalent to standalone, Type II sound level meters (SLMs). Others are lacking options, such as A-weighting, spectral analysis, or measures of reverberation time. While the available apps may be somewhat limited, the well-designed apps are useful and may be combined with sophisticated features that exceed our area of interest. Note that all apps are simply manipulating and displaying data that has been input to the device either via wifi, internal storage, or internal microphone. The headset input, or in the case of Apple iOS devices, the 30-pin/Lightening docking input or docking charger input may be used for input as well. Real time, direct input is our area of interest, and a review of the advantages and limitations of the various direct input methods is necessary before examining specific measurement techniques as the input method impacts the accuracy of our measurements. The following discussion is limited to Apple iOS devices (iPhone 4/4S/5, iPod Touch, and all iPad versions) as this technology, collectively, has the deepest market penetration. It is safe to assume, however, that other platforms, such as Android, have similar characteristics.

As expected, the microphone of a mobile phone, will not compare to that of an instrument-grade sound level meter. With that said, the frequency response of the iPhone/iPad's built-in microphone is fairly consistent from unit to unit. However, it has a steep, low frequency roll-off beginning at about 250 Hz of nearly 24dB/octave. App designers compensate for, or are able to override this feature to improve accuracy at low frequencies.

Another option is to use an optional microphone that connects to iPhones or iPads via the 30-pin/Lightening docking connector. However, the docking connector on older devices, such as the iPhone3GS, iPod Touch 3, and other models has an analog input. This means that the conversion from an analog signal to digital data suitable for analysis, manipulation, and display was done inside the Apple iOS device. The quality of this conversion may impact the quality of the acoustic measurements, and while analog-to-digital converter technology has reached a fairly mature state, phone manufacturers must manage costs appropriately, choosing converters that were likely not designed specifically for acoustical measurement purposes. Newer devices, such as the iPhone 4S/5, iPod Touch 4 and iPad2, have digital input docking connectors. This allows manufacturers of external hardware (and their associated software apps) for use with the Apple iOS to optimize the conversion process, thereby ensuring that the device receives an appropriate signal for analysis.

One might think that moving from (1) using the internal microphone as a source to (2) using a separate piece of hardware that houses a dedicated microphone, converter, and power supply may simply add cost without providing significant benefit. Purchasing a dedicated measurement microphone from one manufacturer that connects with a quality piece of conversion/routing hardware from another, which in turn interfaces with a smartphone via the digital input of the docking connector can cost nearly as much as the purchase price of a good Type II SLM. However, there are two advantages to this approach, which include flexibility and data sharing. The separate hardware approach allows the audiologist to choose the complexity of the options, hardware, and other applications. Some educational audiologists may wish to simply have an accurate SLM/reverberation analyzer on their smartphone while others may desire to invest in more sophisticated measurements. A more important advantage is the ability to immediately share measurements with others. It is possible, with the appropriate software, to have your measurements be displayed on another phone in real time. Another, more practical, example of data sharing is sending a screen shot of the metric(s) of interest together with a short narrative explaining the results as a supplement to the full report. Summarizing and sharing data, therefore, becomes streamlined.

Conducting Measurements with a Software Application (app)

Educational audiologists will begin the processes of documenting the acoustical properties of a classroom with apps by considering the hardware that will be used for the measurements. As discussed previously, the tradeoffs of using iPhones or iPads right out of the box in place of a dedicated piece of analysis hardware must be weighed. It is in the opinion of the authors of this article that off the shelf iPhones/iPads can produce adequate acoustical measurements for the purposes of an educational audiologist to share information for the purposes of counseling.

Second, calibration procedures for the chosen software apps must be considered. Simply purchasing, downloading, and installing the app does not ensure adequate preparation to conduct the measurements. It is necessary to calibrate iPhones/iPads and software using a reference SLM. Comparative calibration using a Type II SLM often yields reliable and valid results. Although audiologist will not be able to couple the phone's microphone to a calibration device to document its accuracy and adjust as needed, the alternate procedure of comparing the iPhone's SPL reading with that of a calibrated SLM while measuring a steady noise source, then adjusting the calibration settings in the app's "settings" menu affords fairly accurate calibration results. Instructions for calibrating the app are generally available on the developer's website. The audiologist should be mindful during these measurements that the location of the microphone on iPhones is on the bottom and on iPads is on the top. As a result, calibration and measurements with iPhones may be more accurate if the phone is placed upside down.

If the audiologist has chosen an external microphone/hardware system that connects to the iOS device via the 30-pin/

Lightening dock connector, it can be professionally calibrated and the procedure documented by the third party handling the task. The result of this calibration procedure is a true, Type II sound level meter in a smartphone with the additional capability of being able to send and share the results you have obtained.

Finally, the audiologist will begin measurements using the apps that best suit his or her needs. The following figures will provide an overview of the app bundle AudioTools by Studio Six Digital. The developer of this bundle is an audio professional, having manufactured several other high quality standalone measurement systems. The authors of this article use AudioTools for both iPhone4/4S and iPad2. Figure 1 shows a screen shot from an iPhone with the AudioTools app open and ready for function selection. In Figure 2, the basic analog SLM app was selected; it is reading 44.2 dBA. This measurement represents the sound level in a home with light background music playing. This measurement is and easy to read, store, and share using a screen shot.

While SLM screen shots are clear and somewhat informative, a much more powerful metric would be to measure and graph the SPL over time (i.e., a sound study graph). This tool would provide a useful application directly related to measuring the acoustical aspects of a classroom according to the ANSI S-12.6 2010 Standard. Figure 3 shows a sound study conducted in an unoccupied classroom. It is time stamped, and average sound level (LEQ) is noted in the top, right corner. This screen is a far more illustrative graph to share with educators, audiologists, and parents/staff compared to the simple SLM screen shot as it shows SPL over time, as well as documentation of the date, the time the measurement was taken, and the duration of the measurement. In this example, about 3 minutes, 30 seconds of data was collected, with approximately 1 minute, 18 seconds shown in the screen shot. It is important to note that this particular classroom nearly meets the ANSI standard for unoccupied classrooms of 35 dBA. If several sound studies are made at various locations in the classroom, as recommended by the ANSI standard, and screen shots are taken in each location, a powerful set of data is obtained regarding the unoccupied noise levels of the classroom.

Measures of reverberation time are essential as well. In the bundle of AudioTools apps is an "Impulse Response" app. By measuring impulse response, the audiologist can measure the RT60 of the classroom. There are a several ways to conduct this measurement, and Studio Six Digital has helpful tutorial for in depth instruction. A simple impulse signal, for example a handclap or balloon pop, is usually all that is needed as a signal source to allow the Impulse Response feature to extrapolate accurate RT60 measures for the octave bands specified in the ANSI Standard.

The first step to conduct this measurement is to obtain an Energy Time Curve by recording the impulse noise and the subsequent energy decay over time. Figure 4 shows the Energy Time Curve (ETC) obtained in the same classroom in which the unoccupied sound study data shown in Figure 3 was collected.

Figure 1. AudioTools App selected on iPhone. **Note**: To store and share your measurements, take a screen shot with your iPhone. To do this, hold the "home" button, and press the on/off button on the top. The phone will make a camera shutter sound; the resulting "photo" is now on photo roll.

Figure 2. iPhone with Analog Sound Level Meter App running.

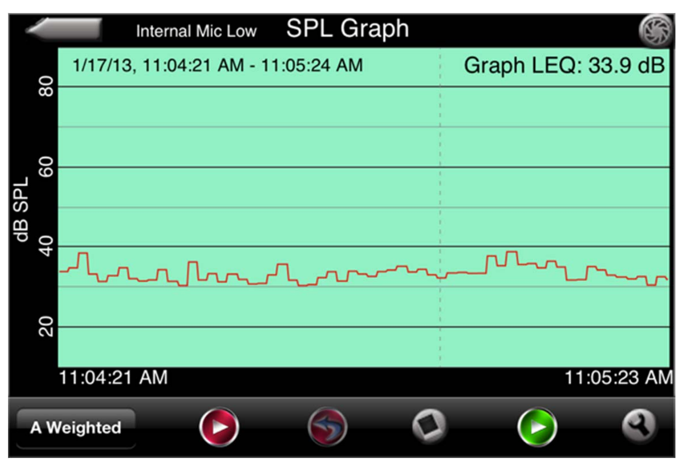

Figure 3. Sound study graph of an unoccupied classroom.

While it does display the energy decay over time within the enclosure, it does not provide the RT60 measures needed for comparison to the ANSI standard.

By clicking on the “ETC” icon in the lower right corner, a menu appears allowing the user to select RT60 measurements. Figure 5 shows the octave band RT60 measurements for the same classroom. Of note is that this is a fairly non-reverberant enclosure. In fact, this room meets the ANSI standard for reverberation. The absence of measures in octave bands at lower frequencies is likely related to the intensity of the impulse sound source, and the decrease in reverberation time as frequency increases is expected.

Using the tools in this app bundle provide the necessary data to compare the acoustical characteristics of a given classroom with the ANSI standard. As shown in the figures, the necessary measurements were obtained accurately, quickly, affordably, and in a manner that allows sharing the information in an email with other audiologists, teachers, and staff members. By simply dragging and dropping the screen shots into the body of an email or into a report, the data can be provided in full color to the desired recipients along with a narrative explanation.

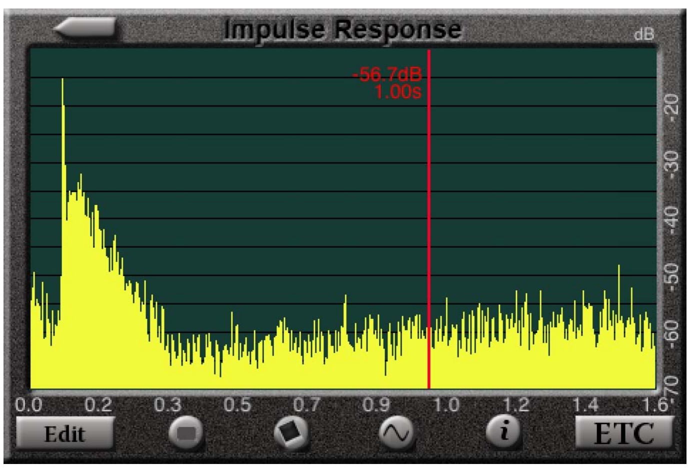

Figure 4. Energy time curve of an unoccupied classroom.

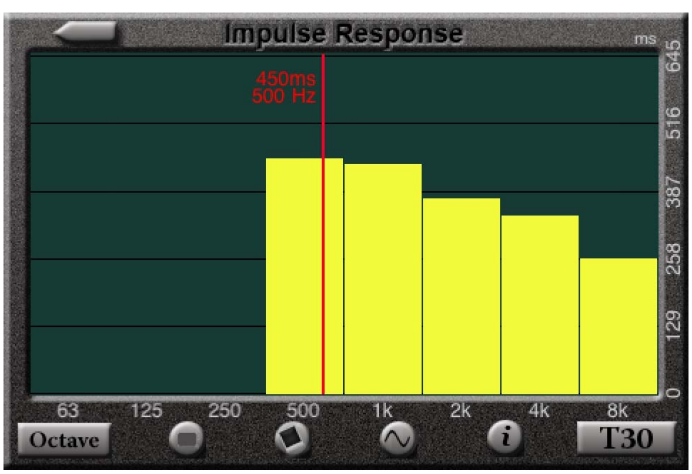

Figure 5. RT60 measures displayed in octave bands.

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