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Smartphone-based sound level measurement apps: Evaluation of compliance with international sound level meter standards☆

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ABSTRACT

Smartphones have evolved into powerful devices with computing capabilities that rival the power of personal computers. Any smartphone can now be turned into a sound-measuring device because of its built-in microphone. The ubiquity of these devices allows the noise measuring apps to expand the base of people being able to measure noise.

Many sound measuring apps exist on the market for various mobile platforms, but only a fraction of these apps achieve sufficient accuracy for assessing noise levels, let alone be used as a replacement for professional sound level measuring instruments.

In this paper, we present methods and results of calibrating our in-house developed NoiSee sound level meter app according to relevant ANSI (American National Standards Institute) and IEC (International Electrotechnical Commission) sound level meter standards. The results show that the sound level meter app and an external microphone can achieve compliance with most of the requirements for Class 2 of IEC 61672/ANSI S1.4-2014 standard.

1. Introduction

Excessive noise is a public health problem and can cause a range of health issues: noise exposure can induce hearing impairment, cardiovascular disease, hypertension, sleep disturbance, and psychological, social and behavior problems. The World Health Organization (WHO) estimates that 466 million people have disabling hearing loss [1]. Occupational hearing loss is the most common work-related illness in the United States; the National Institute for Occupational Safety and Health (NIOSH) estimates that approximately 22 million U.S. workers are exposed to hazardous noise [2].

The number of smartphone users will reach 2.87 billion by 2020 [3]. The power of modern mobile devices is comparable to the power of desktop computers. Performance results obtained by Geekbench [4], which is a popular cross-platform performance benchmark tool, show that iPhone 7 performs about as well as Intel Core i5 processor.

Android and iOS are the two major platforms for mobile operating systems worldwide and account for almost 99.7% of the mobile smartphone market today [5], with 85% and 14.7% market share respectively, and are thus the two natural choices for mobile applications development. Using a mobile device, which has a built-in audio input as a sound measuring device is not new. Mobile applications (apps) such as NoiseTube [6], SoundPrint [7], and iHEARu [8] are some of the examples of apps where users can use their smartphones to report the noise levels and geolocation using the devices' audio and GPS (global positioning system) capabilities for mapping noise levels in cities or rating restaurants and entertainment venues based on their ambient noise environment.

Although Android smartphones dominate the worldwide market share, iOS continues to be the preferred development platform for audio-based and sound measurement applications. This is mainly due to the fact that all iOS mobile devices share a common audio architecture called Core Audio and because there are typically no more than 15 current variations of iOS mobile devices (including variants with different screen size) with 86% running the most recent version of iOS and 97% of these devices running an iOS that is no more than 2 years old [9]. In contrast, the Android market is much more fragmented with many different manufacturers producing a vast number of mobile devices ranging from the less capable, low-end to powerful, high-end devices and often relying on many different suppliers for microphones and audio processing tools and chipsets, furthermore, only 11.5% of Android devices run the most recent version of Android [10].

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Fig. 1. Sound level meter calibration system Brüel & Kjær Type 3630.

A laboratory-based study by Kardous and Shaw [11] have shown several iOS apps can have a mean difference of 2 dB compared with a type 1 sound level meter system across different iOS devices over a range of pink noise from 65 to 95 dBA in a reverberation room at the NIOSH Acoustics Laboratory. Their follow-up study [12] with external calibrated microphones showed even greater agreement with apps having ±1 dBA difference from the reference sound level meter. They also reported that none of the Android apps they tested met their testing criteria. They concluded that some iOS apps may be considered accurate enough for limited professional noise measurements. Another study by Murphy and King [13] examined 100 mobile phones (different models and operating systems) with several sound measuring apps. Their results show that there is a significant inter-device variability (standard deviation 6.81 dB) and on average, the measured level deviated 2.93 dBA from the true value on iOS devices and 2.79 dBA on Android devices. They concluded that mobile devices are not quite ready to replace sound level meters and that overall accuracy is often dependent on the age and condition of the smartphone and internal microphone.

Robinson and Tingay [14] evaluated several Android and iOS sound measurement apps on different "available" devices using workplace noise sources. Their results showed an average difference of 12 dB from the levels measured by a type 1 sound level meter. They pointed out several shortcomings of smartphones and noise measurement apps and concluded that one of the major limitations for using sound level meter apps on any smartphone for making an accurate measurement is the internal Micro-Electro-Mechanical-System (MEMS) microphone, the inability to calibrate such microphones using common calibration tools such as acoustical calibrators. Aumond et al. [15] examined the accuracy of mobile devices for measuring urban noise pollution. They conducted a total of 3409 noise measurements using 60 mobile phones at 28 selected locations in Paris, in parallel with fixed noise monitoring stations and a sound level meter. By processing the abundance of noise data gathered by 60 participants, they have mitigated the effect of inter-device variability and concluded that mobile phones could be a useful noise measurement tool. Although their research was performed on Android-based devices only (HTC-One X), they demonstrated that the noise levels measured with calibrated mobile phones correlate strongly with noise monitoring station and sound level meter measurements (root mean square error smaller than 3 dBA).

The most important issue with using smartphones and sound measurement apps to date is that none comply with international sound level meter standards such as IEC 61672-1:2013 [16] or ANSI S1.4-2014 [17] (a nationally adopted IEC 61672 standard), and as a result, they cannot be relied on to make regulatory-accepted environmental or occupational noise exposure assessments. This study aims to address this issue by subjecting a sound level measurement system consisting of our in-house developed iOS sound level meter app; an external, commercially-available, Class 2 compliant microphone; and an iOS-based smartphone to the Class 2 requirements of the IEC 61672 standard. In this paper, we present the results of the calibration and compliance testing of the first portion of our study - the requirements for periodic test specified in IEC 61672-3 [18]. This is the first study of its kind to address the compliance of smartphone-based systems with international standards for sound level meters.

2. Methods

2.1. Experimental setup

IEC 61672-1 states that "A sound level meter may be a self-contained hand-held instrument with an attached microphone and a built-in display device. A sound level meter may be comprised of separate components in one or more enclosures and may be capable of displaying a variety of acoustical signal levels."

The calibration of the sound level meter consisting of an iPhone 6 (running operating system iOS 10.3), NoiSee app (version 2.0.) [19] and an external microphone (MicW type i436 [20]) was performed on a professional sound level meter calibration system Brüel & Kjær type 3630 (Nærum, Denmark) (Fig. 1). The system consists of equipment listed in Table 1. This system is designed to comply with all relevant international standards and is used by major calibration laboratories and commercial calibration centers worldwide. The calibration system also allows for developing a custom software plugin enabling it to control (i.e. to start, stop and reset a measurement) and to read the required parameters from any sound level meter. We have used C#

Table 1
List of equipment used in the professional calibration system.

Equipment	Model	Manufacturer
Generator	Pulse generator	Brüel & Kjær
Amplifier divider	3111 Output Module	Brüel & Kjær
Adaptor	WA0302A, 12 pF	Brüel & Kjær
Calibrator	4226	Brüel & Kjær
Voltmeter	DMM34970A	Agilent
Weather station	2290-4	Ahlborn

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