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Testing the accuracy of smartphones and sound level meter applications for measuring environmental noise

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ABSTRACT

This paper reports on experimental tests undertaken to assess the capability of noise monitoring applications to be utilized as an alternative low cost solution to traditional noise monitoring using a sound level meter. The methodology consisted of testing 100 smartphones in a reverberation room. Broadband white noise was utilized to test the ability of smartphones to measure noise at background, 50, 70 and 90 dB(A) and these measurements were compared with true noise levels acquired via a calibrated sound level meter. Tests were conducted on phones using the Android and iOS platforms. For each smartphone, tests were completed separately for leading noise monitoring apps culminating in 1472 tests. The results suggest that apps written for the iOS platform are superior to those running on the Android platform. They show that one of the apps tested – SLA Lite – is within ±1 dB of true noise levels across four different reference conditions. The results also show that there is a significant relationship between phone age and its ability to measure noise accurately. The research has implications for the future use of smartphones as low cost monitoring and assessment devices for environmental noise.

1. Introduction and context

Smartphones have become a ‘must have’ for the majority of adult citizens in world’s developed nations. As of October 2014, 64 per cent of US adults own some form of smartphone [1]. To demonstrate the rapidity with which smartphones have infiltrated the US market, the corresponding figure for the spring of 2011 was 35 per cent [2]. Internationally, more recent research covering 32 countries estimates that 80 per cent of internet users own a smartphone. Of those, 54 per cent of phones utilize the Android operating system, 16 per cent operate the iOS and the remaining come from alternative operating systems such as Windows among others [3].

The development of smartphone technology and its impact on environmental noise studies has only recently begun to receive some attention in the academic literature. There are some studies which suggest that smartphones are capable of replacing traditional noise assessment devices such as sound level meters (SLMs) in the not too distant future. Kanjo [4] has outlined the possibility of developing a mobile phone platform for measuring noise in cities and highlights the potential of such avenues for the future. Similarly, D’Hondt et al. [5] have demonstrated the possibility of smartphone-based noise apps to be utilized by ordinary citizens as a form of crowd sourced participatory noise assessment in cities. Studies such as these suggest that the future of noise assessment, whether it is in cities or elsewhere, will likely be tied closely to developments in smartphone and other forms of innovative mobile technology that are easily and relatively affordably accessed by ordinary citizens, especially in developed nations. A key challenge for noise mapping studies, in particular, is determining the accuracy of any smartphone based approach and to shed light on the margin of error that might be associated with the substitution of smartphones for sound level meters in future real world settings.

The current paper is concerned with trends in the development of smartphones and associated applications for the measurement of environmental noise specifically. There are only a small number of studies which have investigated issues that are relevant to the current research. Perhaps the most relevant is a recent study by Kardous and Shaw [6]. They tested the accuracy of 10 iOS and 4 Android apps for measuring noise in occupational settings on 8 smartphones and one tablet. Their research found that the iOS noise app – SoundMeter, developed by Faber Acoustical – has the best agreement in A-weighted sound levels (−0.52) with reference values while three other apps for the iOS were within ±2 dB(A) of reference values. This led the authors to conclude that devices running the iOS, in particular, had significant scope to be used as

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assessment devices for occupational settings. What is also interesting is that their research found that devices running the Android operating system were inadequate for the same purpose because they were 'built by several different manufacturers and that there is a lack of conformity for using similar microphones and other audio components in their devices' [6, p.192]. The focus of previous work by Kardous and Shaw was on examining the accuracy of smartphone apps rather than the smartphones themselves. Although they did offer some insights about the relationship between phone model and measurement accuracy, the sample of phones they used for testing was somewhat limited in scope (3 iPhone models and 5 Android devices).

Similarly, the work of Nast et al. [7] tested five apps but only one phone – the iPhone 4S – thereby essentially controlling for the phone model in their analysis of noise measurement applications. Thus, their work provides no insight into the role of the smartphone hardware in producing accurate noise measurements or otherwise. Moreover, their tests did not utilize pink noise and/or white noise thereby limiting the spectral variability of the testing conditions to specific octave band analysis. Nevertheless, their results showed that for all apps tested, the results varied widely from that measured using a Type 1 SLM. The authors concluded that, with the exception of the Sound Meter App by Faber Acoustical, 'SLM apps are best used for entertainment purposes, as they are not accurate as SLMs...' [7, 253–254]. Indeed, their work pointed to large errors and nonlinearities at high sound levels, drawing into question the utility of apps for occupational purposes.

Within the foregoing context, the current paper builds on previous work which has sought to analyze the suitability of smartphones for use as a substitute for traditional SLMs. Whereas related studies has tended to place focus on the smartphone apps themselves, this research focusses not only on testing the leading apps on two leading platforms – iOS and Android – but we also test a much wider range of smartphones than has been tested in similar studies to date. In this regard, we are seeking to identify statistically significant differences in the ability of different smartphone models to measure noise accurately or otherwise using the same app while also assessing the suitability of the apps themselves and the platform being utilized to host them. The research also examines the relationship between smartphone age and measurement accuracy.

2. Methods

A representative sample of the most popular smartphones on the University of Hartford campus was acquired by asking students to volunteer their device for testing. In total 100 smartphones were tested; 65 were on the iOS platform while the other 35 were Android-based. A list of the phone manufacturers and individual models tested is presented in Table 1. For each iOS-based phone, four leading apps were tested while three apps were tested for each Android phone. This discrepancy was due to one app being taken down from the Google Play store after a small number of tests had been completed and because of this it was removed from the testing agenda. For an app to be included in the testing it had to satisfy certain criteria. These included: (1) being able to report A-weighted sound levels; (2) being able to report the sound level as a numeric value and (3) being either free or cost less than $5.00. While some apps allow for manual calibration of the inbuilt microphone prior to measurement, this was not completed for our experimental tests in order to simulate a typical real world situation. This conforms to the approach taken for similar testing studies [6,7]. Table 2 provides a full list of the apps tested for our study – 7 in total – for the iOS and Android phones, the developer and version. All of the apps tested met our selection criteria and all were commercial apps. No tests were conducted on Windows-based devices given the dominance of iOS and Android phones of the smartphone market.

Table 1
Phones and models tested and their frequency.

Brand	Number
iPhone (4, 4s, 5, 5s, 5c, 6, +)	65
Galaxy (Note 2, Note 3, s3, s3 slim, s3 mini, s4, s4 active, s5,	24
Google (Nexus 5)	2
HTC (One, One Mini 2, M8)	4
LG (VS870, g2)	2
Motorola (Droid 2, Droid MAXX, Moto X 2nd gen.)	3
Total	100

Table 2
Smartphone apps selected for testing.

Name	Developer (Price)	Web Link
Sound Level Analyzer Lite (iOS) version 1.3	Toon, LLC (€4.99)	https://itunes.apple.com/us/app/sound-level-analyzer/id886109671?mt=8
SPLnFFT (iOS) version 1.1	Fabien Lefebvre (HK€28)	https://itunes.apple.com/hk/app/splnfft-noise-meter/id355396114?mt=8
Decibel Meter Pro (iOS) version 2.05	Performance Audio (€0.99)	https://itunes.apple.com/ie/app/decibel-meter-pro/id382776256?mt=8
UE SPL (iOS) version 2.1.1	Logitech Inc. (Free)	https://itunes.apple.com/us/app/ue-spl/id332300068?mt=8
Sound Meter (Android) version 1.6	Smart Tools co. (Free)	https://play.google.com/store/apps/details?id=kr.sira.sound&hl=en
Noise Meter (Android) version 2.1	JINASYS (Free)	https://play.google.com/store/apps/details?id=com.pjw.noisemeter&hl=en
Decibel Pro (Android) version 1.4.22	BSB Mobile Solutions Tools (€4.99)	https://play.google.com/store/apps/details?id=bz.bsb.decibel.pro

For our experimental set up, we used broadband white noise in a 125 m^3 ISO 3741 [8] compliant reverberation room. This source was generated through Brüel & Kjær's Pulse Measurement System, version 18.1 and was played through a Type 4292-L OmniPower dodecahedron loudspeaker located in the center of the room. The output voltage was adjusted in Pulse to produce a uniform sound field at 50 dB(A), 70 dB(A), and then 90 dB(A). These values were initially confirmed using both a rotating microphone boom fitted with a diffuse field microphone as well as a calibrated Brüel & Kjær Type 2250 SLM. Background noise was measured on each test day and was found to be 27 dB(A) in the reverberation room. Testing was conducted over 10 separate days. The diffuse sound field generated in the reverberation room meant that the precise location and size of the smartphone in the room did not influence the results of the study in any way. However, during measurements, phones were handheld at shoulder height by the same two individuals for the entire series of testing[2]; all phone covers were removed prior to testing to avoid any interference with the microphone. We collected a single measurement for each app at each test level (background, 50, 70 and 90 dB(A)). As an experimental precaution, the room was tested immediately before and after each testing schedule to ensure that the room acoustics remained consistent across testing schedules. The adoption of a handheld approach for testing differs from previous studies which utilized a tripod [6,7]. The reason for

[2] For all tests, there was one individual testing in the reverberation room and one located outside operating the Pulse system for all tests.