Development and validation of a portable platform for auditory testing

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Goal

Here we introduce a novel Portable Automated Rapid Testing (PART) platform that facilitates the conduct of reliable, calibrated testing in a wide range of research, home, and clinical environments.

Methods

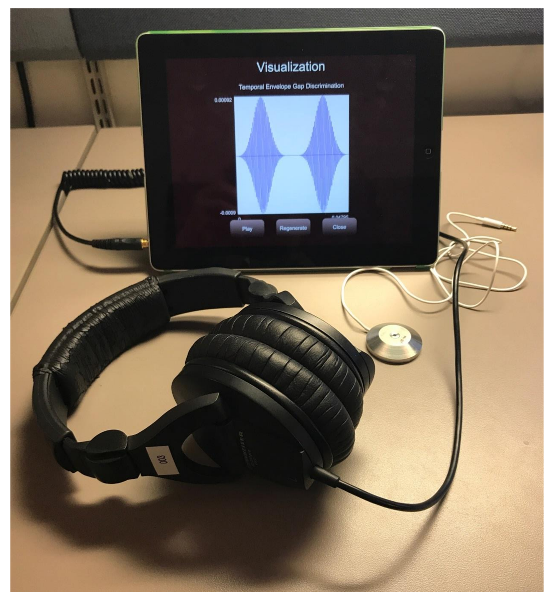


Figure 1. Testing hardware and software: iPad Pro tablet computer running PART application written in Unity, Sennheiser HD 280 Pro headphones, iBoundary microphone (for calibration)

PART leverages consumer technologies associated with the latest generation of mobile gaming, which are high-performance interactive audio-visual systems supported by the tools and community of the $100 billion gaming industry.

Three main tasks are required to achieve the goal of bringing PART to the home, the clinic, and the research environments in a way that would be easily accessible to clinicians, researchers in other fields, students, and the general public.

1. Develop mobile applications capable of administering laboratory psychoacoustics and speech-in-noise tests on a tablet computer.
2. Verify the system performed within design specifications, by acoustic analysis of the sound output and comparison of behavioral thresholds to those obtained using traditional methods.
3. Create user interfaces that facilitate the use of the system without requiring expertise in the underlying technologies.

Initial results involved the use of the Apple iPad tablet computer connected to Sennheiser HD 280Pro headphones (Figures 1,2).

Stimuli were generated with applications written in the Unity game development program. Specialized mathematical functions were created for this purpose by the programming team. For example, Figure 1 shows the visualization of two 50-ms tone bursts created using these functions and displayed on the iPad used to present the sounds. Acoustical analyses shown in Figures 4-7.

Initial calibration was conducted with the use of a Brüel & Kjær Head and Torso Simulator with Artificial Ears located in the center of the anechoic chamber associated with the VA RR&D NCRAR. Routine calibration at the test site was conducted using the iBoundary microphone as shown in Figure 2.

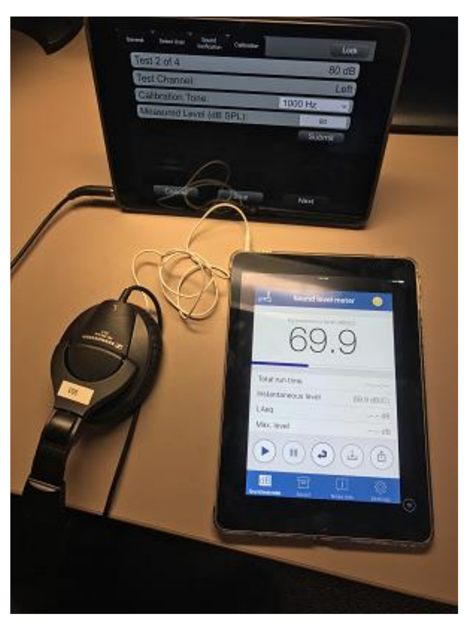


Figure 2. Routine calibration was conducted using the iBoundary microphone shown in Figure 2, and the NIOSH Sound Level Meter application, running on a second iPad. Initial calibration of the system and the NIOSH SLM application was conducted using the B&K system.

Results

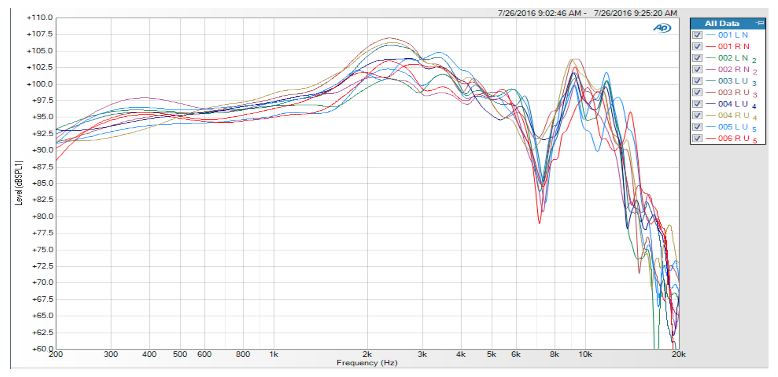


Figure 3. Output of 5 sets of Sennheiser HD280 Pro headphones, measured with Audio Precision digital analyzers.

Differences across transducers were within 7.5 dB across headphones and differences across frequency were below 15 dB up to 6 kHz.

Results show the capability of presenting signals at high levels between 200 and 12000 Hz, allowing for equalization functions to be applied as needed.

This verifies the usability of these transducers for psychoacoustical experiments.

Evaluation of a series of 50 ms Gaussian-enveloped 2000-Hz tone pulses increasing in level from 60 to 105 dB, produced by the PART system (Sennheiser HD 280 Pro headphones connected to an iPad Pro).

Data shown in Figures 4-7 demonstrate that the linearity, temporal precision, harmonic distortion, and dynamic range are sufficient to allow high-quality signals to be presented to the listener.

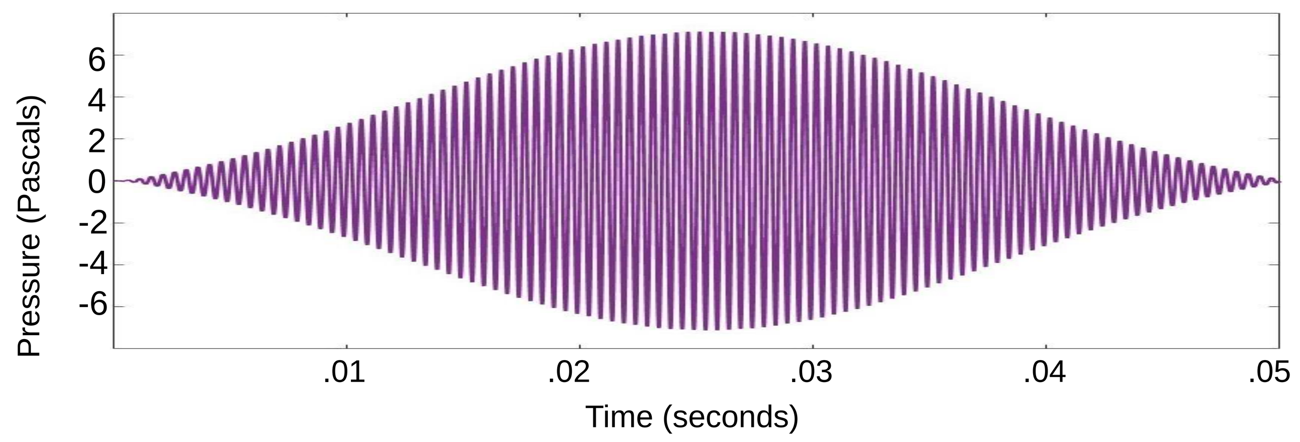


Figure 4. Single pulse recorded from PART system at maximum pressure (pressure vs time)

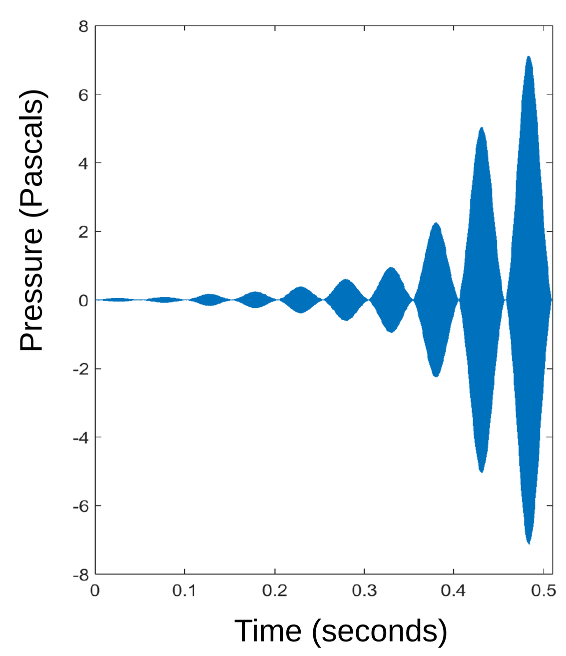


Figure 5. 10 pulses (pressure vs time)

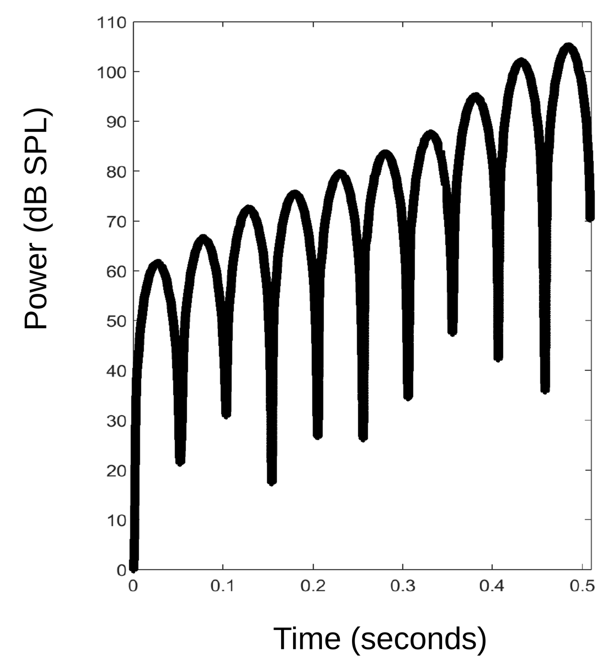


Figure 6. 10 pulses (power vs time)

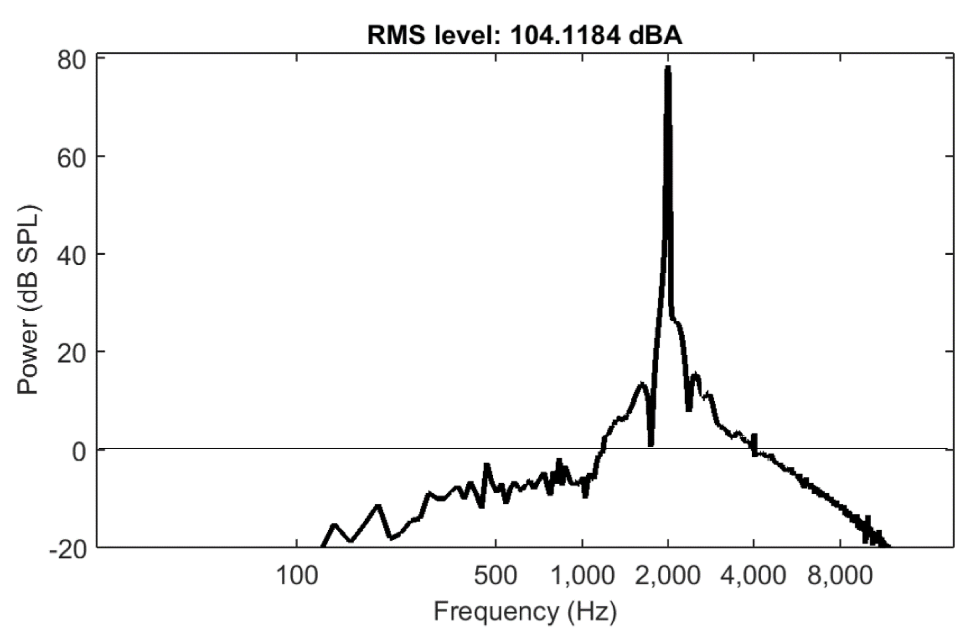


Figure 7. Single pulse from PART system (power vs frequency)

Results

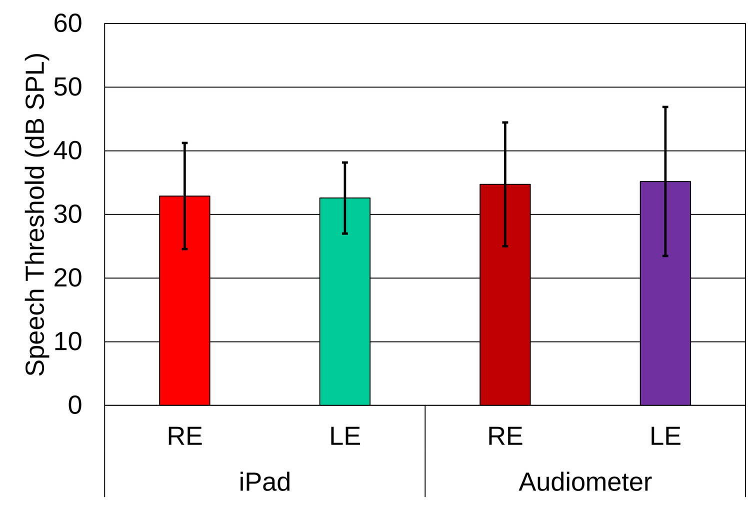


Figure 8. Average speech thresholds for 23 listeners, tested with two independent systems: iPad Pro with Sennheiser HD 280 Pro ("iPad") and with Grason-Stadler Audiometer and Etymotic ER3 earphones ("Audiometer").

Figure 9 Average SRT across left and right ears for 23 listeners, tested with the two systems. $R^2 = .772$

Behavioral verification involved comparison of intelligibility of speech through the iPad system playing closed-set speech and a calibrated audiometer.

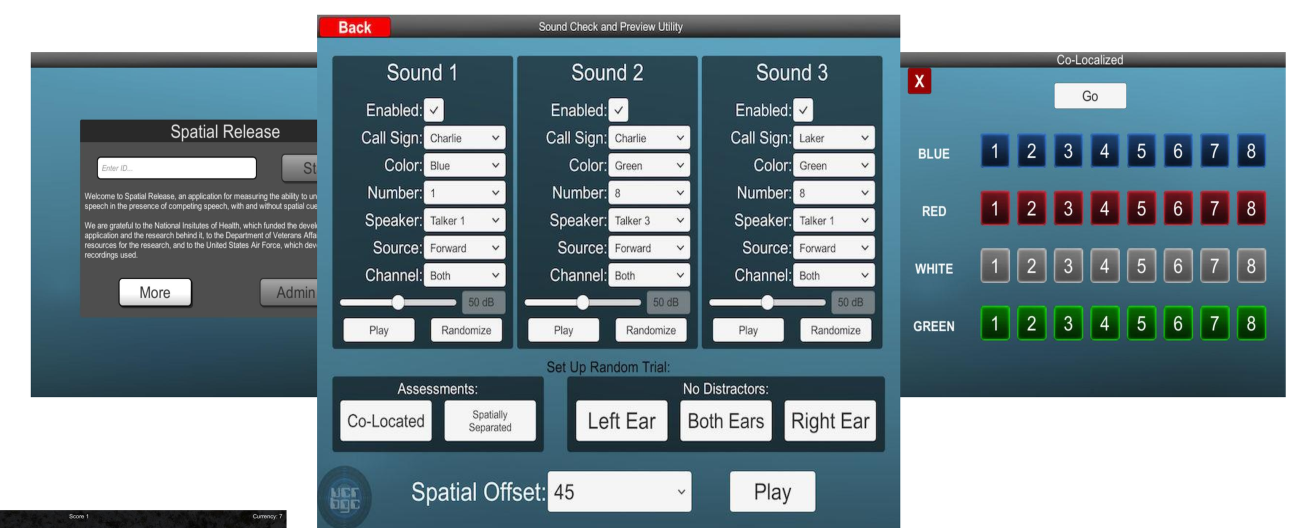
Correlations across the two methods are shown in Figure 9 for the average of the two ears for each listener.

Differences in the materials used and tracking procedure may account for slightly lower thresholds in the iPad for those with normal hearing. For those with impaired hearing (SRTs above 42 dB SPL), the lack of contralateral masking in the iPad test may be responsible.

Results confirm that the iPad is capable of producing high-quality signals at the levels necessary for measuring threshold (and thus supra-threshold) abilities of human listeners. Modifications to testing procedures be required to fully equate methods.

Usability testing is currently under way, along with comparisons of results across sites and with published data from the literature. Below are examples of the tests being developed and the interfaces being explored.

Figure 10. "Spatial Release" implements a well-studied test of spatial release from speech-on-speech masking. It includes a fully-functional virtual auditory display and is available on the iTunes store.



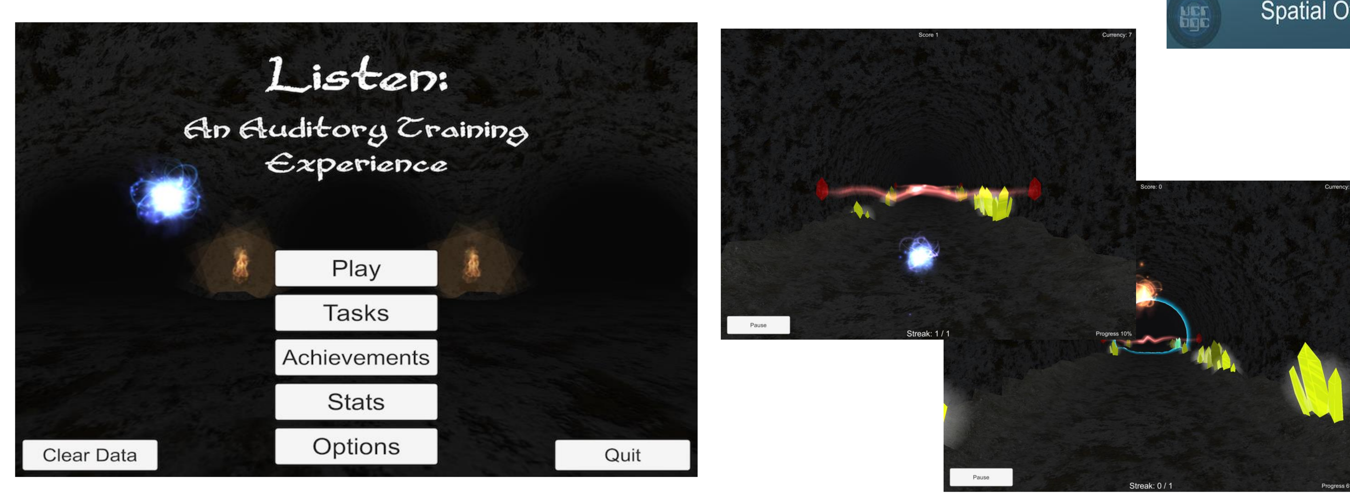


Figure 11. "Listen: An Auditory Training Experience" combines an engaging auditory game experience with training in spectrotemporal modulation sensitivity and spatial awareness, and is available on the iTunes store.

To explore the full range of interfaces, download all of the released applications for free at https://bgc.ucr.edu/games/ or use this QR Code:

Summary

These results confirm the practicality of developing auditory testing applications for the iPad platform.

Acknowledgements

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