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Clinical Testing

Work Performed in the Hearing Assistive Technology Lab at UTD

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Data Collection Overview: Clinical verification could not begin until the algorithms were complete for the IOS platform. Pilot conditions were tested throughout the past four months with various coupling arrangements as the Smartphone programs became available. The final testing arrangement was specified during the past month and data collection with normal-hearing and hearing-impaired subjects began. Results show that both speech enhancement (JMAP) and noise reduction programs (WPF) on the IOS platform provides significant benefit for persons with normal and impaired hearing in speech recognition in noise.

Experimental Setup: During the first year, possible experimental designs were explored for verification studies of the algorithms developed on the smartphones. Two test setups were calibrated including stimulus presentation in a soundbooth and in a more real-world reverberant room. Because of multiple test sites, a powerful laptop was purchased and software loaded and tested for hearing aid fittings, signal calibration, and data collection. The final test arrangement for evaluation of the speech recognition in background in a real-world, reverberant environment with the smartphone algorithms is show in Figure 1.

Figure 1. Testing arrangement for evaluation of noise reduction and speech enhancement algorithms on IOS and Android smartphones.

Subjects: Three clinical verification Phases were conducted. Following pilot testing with 5 normal hearing and 3 hearing-impaired listeners, subject recruitment for clinical verification began. For Phases 1 and 2, 21 UTD students with normal hearing, were recruited to participate. There were 8 males and 13 females. For Phase 3, 10 listeners with bilateral moderate-to-profound hearing loss were recruited, 2 males and 8 females. All were experienced hearing aid users and received $50 compensation for their participation! Pure-tone audiograms for the hearing-impaired participants' better ear are shown in Figure 2 below (average thresholds shown in blue dashed line).

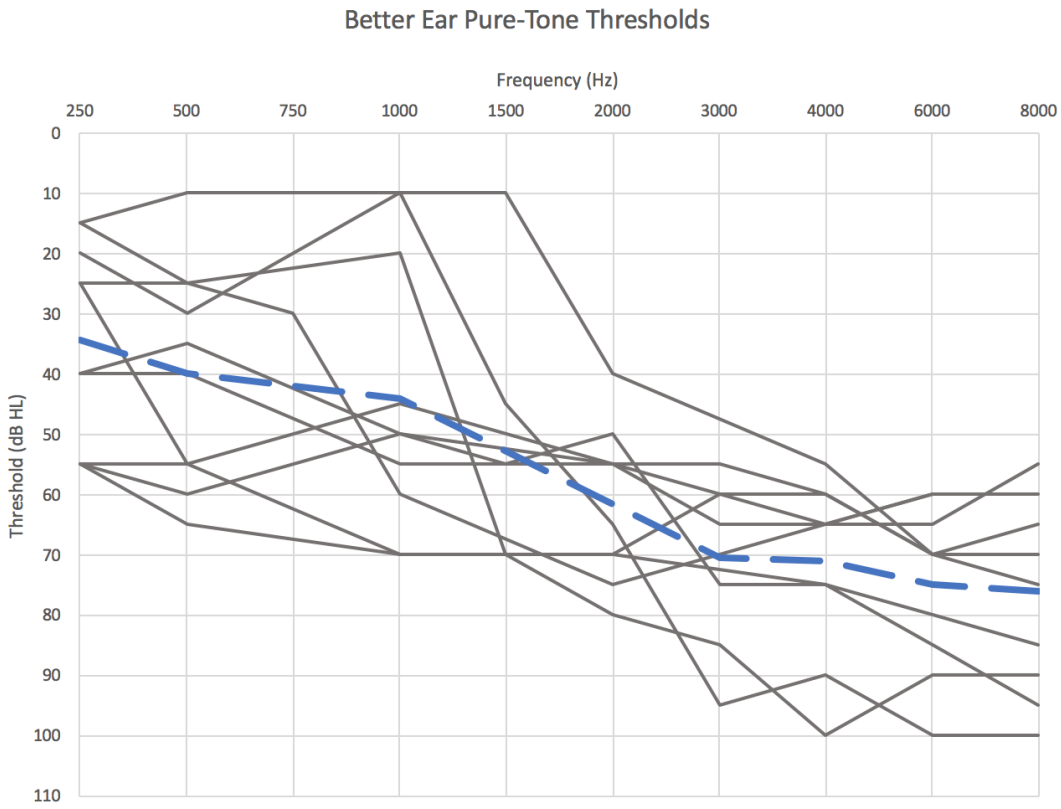


Figure 2. Better ear thresholds for the subjects in Phase 3.

Equipment: Two sets of hearing aids were used for connections with the IOS smartphone. Starkey Halo 2 receiver-in-the-canal hearing aids (HAs) were programmed using Starkey Inspire Software. The connection to the smartphone was through Bluetooth low-energy. Phonak Audeo V90 2 receiver-in-the-canal hearing aids were programmed using Phonak Target Software. The connection to

the IOS phone was via a hard-wire connection to a compilot when then sent the signal to the hearing aids via digital streaming. All hearing aids were set for no noise reduction, compression limiting, and gain/output according to NAL-NL2 fitting targets.

Stimuli: HINT sentences were presented in restaurant babble noise at various signal-to-noise ratios (SNRs) to challenge the subjects in the conditions with no Smartphone use (HA only) so that benefits with the Smartphone programs could be examined relative to the challenging condition. Following a practice list, a list of ten sentences was randomly selected for each test condition.

Test Procedures:

Phase 1: The normal-hearing listeners (N=11) were fit with with Halo 2 HAs programmed for flat 20 dB HL thresholds. The testing was conducted with the IOS smartphone and the following conditions were completed: JMAP, WPF and Live Listen. The signal-to-noise ratio (SNR) were selected so that the listener scored below 80% correct. (SNR was -5 or -7.5 dB).

Phase 2: The normal-hearing listeners (N=10) were fit with Phonak Audeo V90 HAs programmed for flat 20 dB HL thresholds. Testing was conducted with IOS smartphone and the following conditions were completed: Hearing Aid only, JMAP and WPF, all at -7.5 dB SNR. Clinical verification of the compression algorithm was tested using the Mean Opinion Scale (MOS) procedures. Subjects listened to a male and female voice speaking sentences and to a singing voice. They were asked to judge the overall clarity of the signal on a scale from 1 (low) to 5 (high). There were two versions of compression tested. Version 1 was xxxxx, while version 2 was xxxx.

Phase 3: The hearing-impaired listeners (N=10) were fit with Halo and Phonak HAs programmed for their thresholds. Testing was conducted with IOS smartphone and the following conditions were completed: Hearing Aid only, JMAP and WPF, all at 0 dB SNR. Clinical verification of the compression algorithm was tested on IOS using the MOS procedures. The MOS procedures were the same as described in Phase 2.

Results:

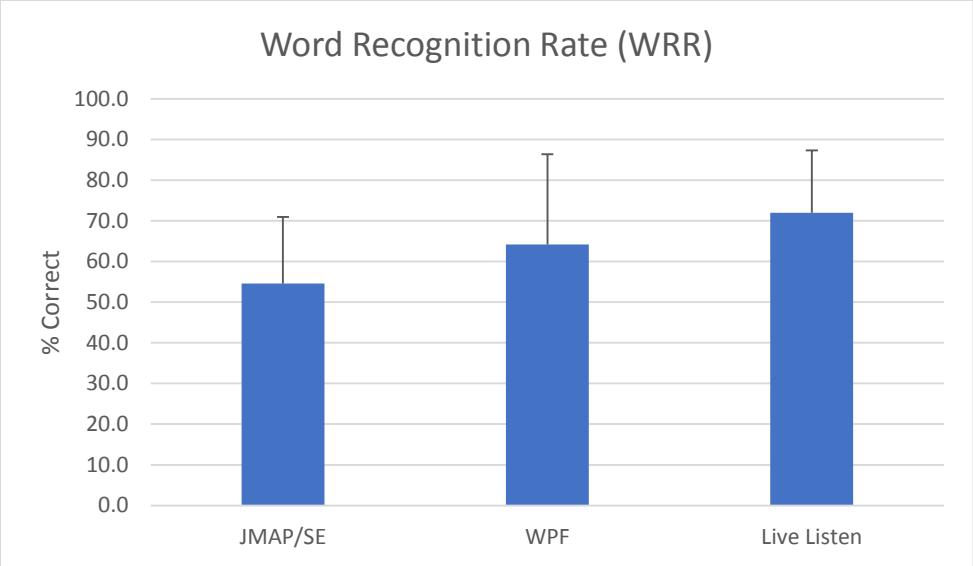
The results for the three phases of clinical verification are shown below. The testing with subjects with normal hearing in Phases 1 and 2 (Figures 3 and 4) show that the JMAP and WPF algorithms allow speech recognition scores in negative SNRs of 70 to 90%.

The results for Phase 3 are shown in Figure 5. In Phase 3, the subjects with hearing loss achieved 29 to 46% correct with the Starkey and Phonak hearing aids alone, respectively. The Smartphone algorithms for Speech Enhancement (JMAP) and for Noise Reduction (WPF) resulted in significant improvements to up 96 and 94% for Speech Enhancement and Noise Reduction, respectively. This was an overall average increase in performance of 59 (Starkey aids) and 60% (Phonak aids) when compared to the HA alone condition. There was no significant different between overall average speech recognition performance with the Starkey and the Phonak aids.

The results of the MOS testing in Phase 2 with the normal-hearing listeners showed slightly lower average scores for Version 1 of compression, 2.78 compared to Version 2, 3.83. The scores ranged from 1 to 4 and 3 to 5 for Versions 1 and 2, respectively.

The results of the MOS testing in Phase 3 with the hearing-impaired listeners showed similar average scores for the two versions of compression, 3.20 and 3.19, for Versions 1 and 2, respectively. The scores ranged from 1.67 to 4.33 and 2.33 to 4.00 for Versions 1 and 2, respectively. These results suggest that the compression algorithms running on the IOS platform were rated acceptable on average.

Phase 1:



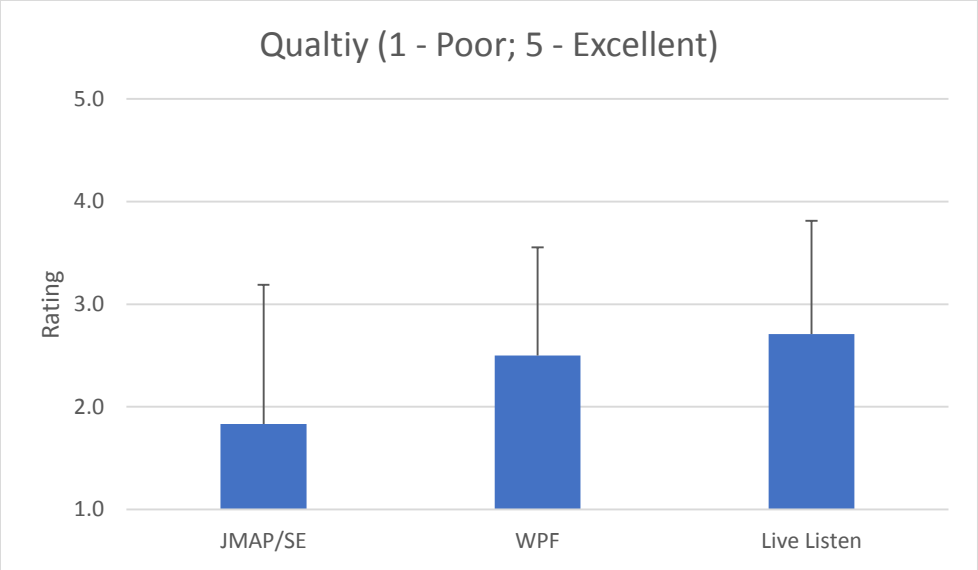
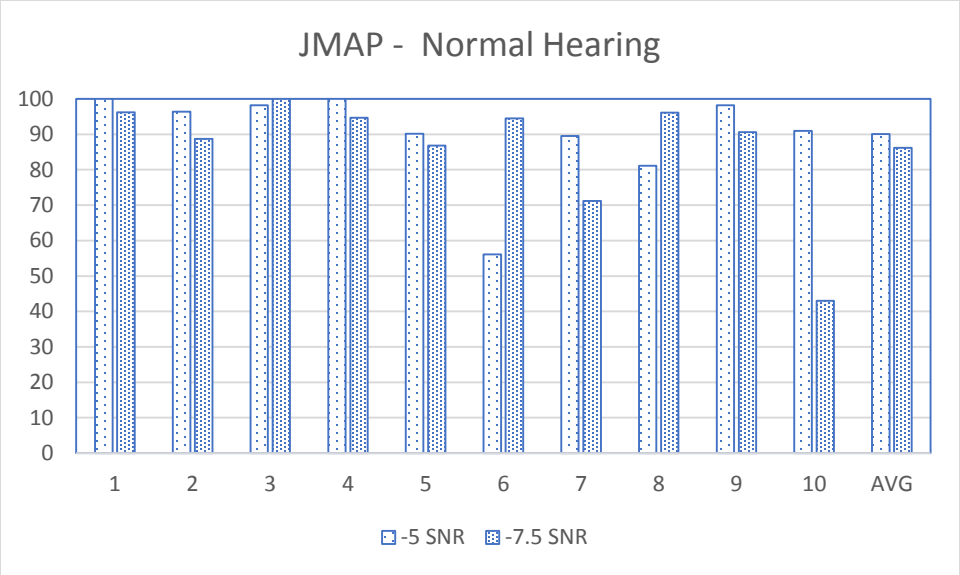


Figure 3. Speech recognition scores (top) and Quality ratings (bottom) for normal hearing college students in Phase 1 when tested with Halo 2 hearing aids and the IOS platform.

Phase 2:



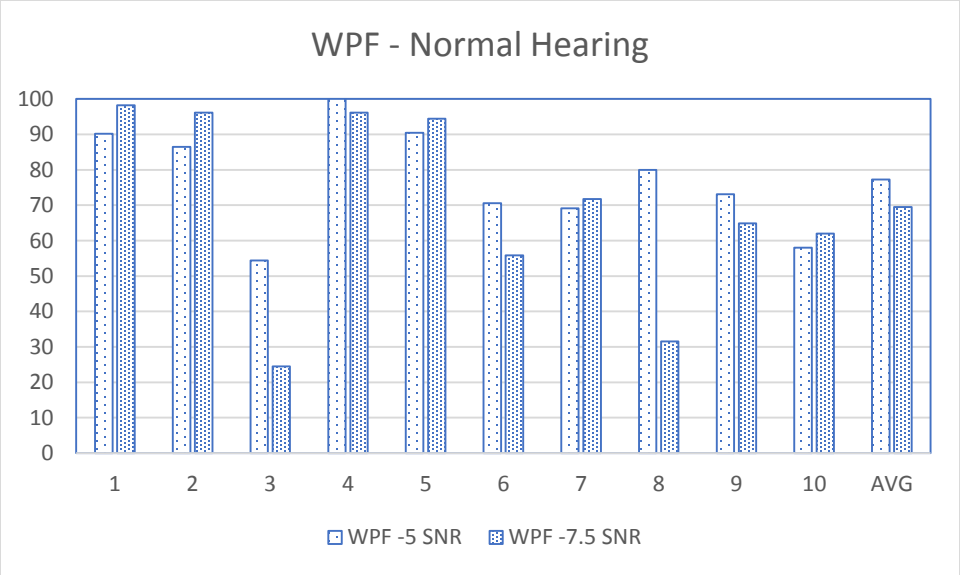
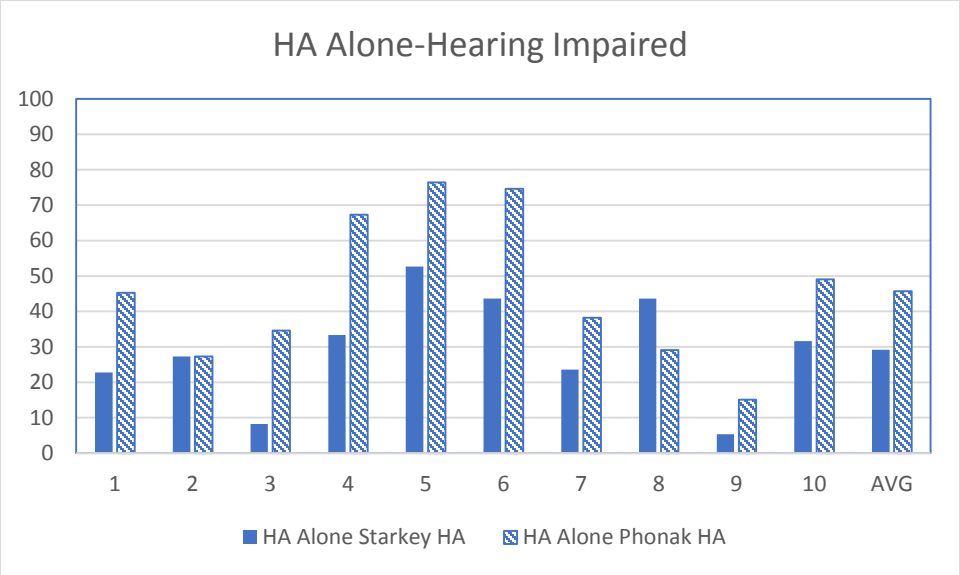


Figure 4. Speech recognition results with JMAP (top) and WPF (bottom) algorithms for two SNRs (-5 and -7.5 dB) with normal hearing college students.

Phase 3:


HA Alone-Hearing Impaired
100
90
80
70
60
50
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30
20
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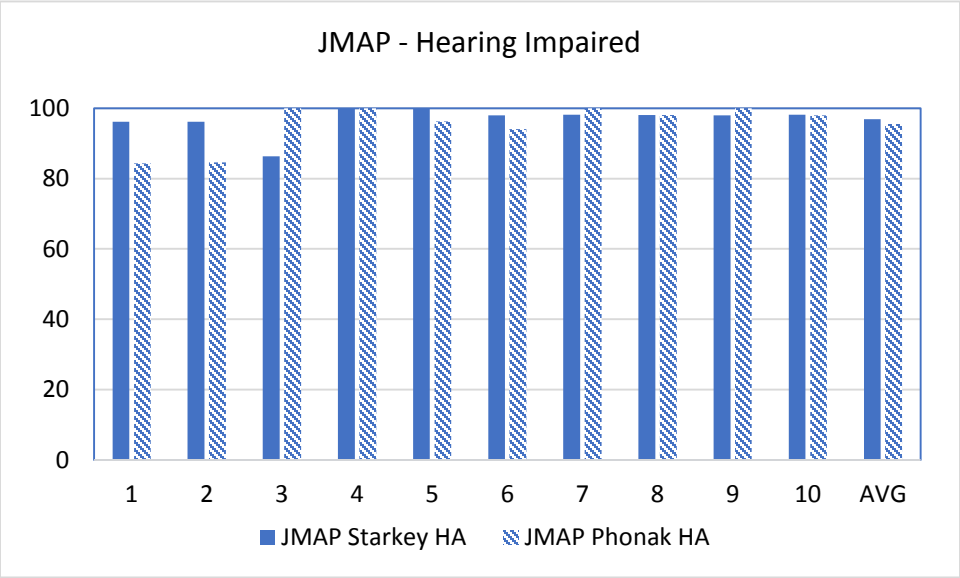
6
7
8
9
10
AVG
HA Alone Starkey HA
HA Alone Phonak HA


JMAP - Hearing Impaired
100
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AVG
JMAP Starkey HA
JMAP Phonak HA

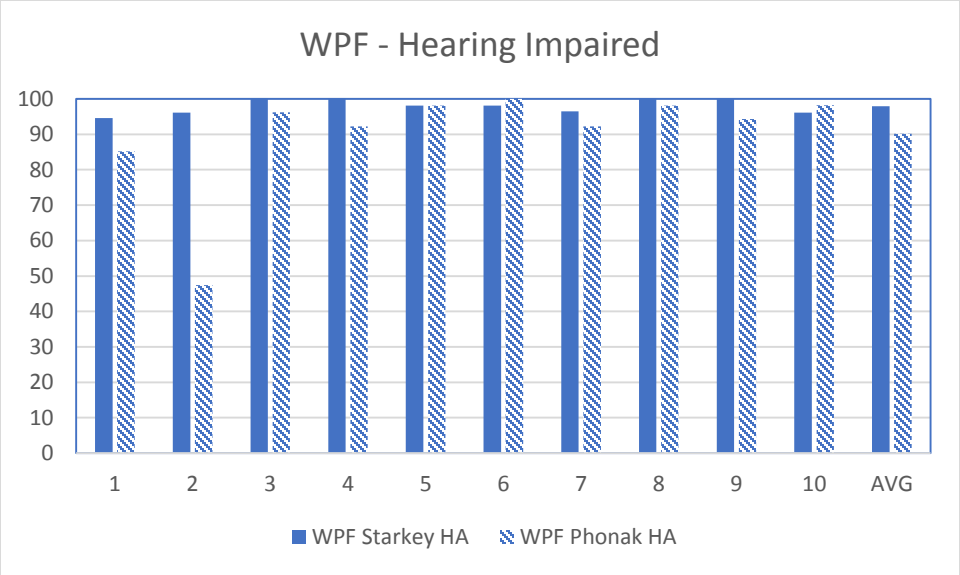

Figure 5. Speech recognition results for three conditions: HA only (top), JMAP (middle), and WPF (bottom) for persons with moderate-to-profound hearing loss when using Starkey (solid bars) and Phonak (striped bars) hearing aids.