Evaluation of Objective and Subjective Benefit of a Novel Frequency-Lowering Algorithm

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Introduction

A common goal for most hearing aid fittings is to restore access to speech information that has been lost as a result of hearing loss. At the most elementary level, this has traditionally been achieved by applying appropriate levels of gain across the channels of a hearing aid to restore audibility for speech level inputs while maintaining comfort for louder level inputs. Despite advances in loudness and perceptual fitting approaches, in some cases, the hearing loss is so severe in certain frequency regions that it is not possible to achieve audibility within that frequency region of the cochlea. Therefore, frequency lowering technologies were developed to restore access to high-frequency speech information such as consonant sounds. In addition, a useful byproduct of this technology is a reduction in the potential for feedback due to increased high-frequency gain requirements. Currently, three distinct types of frequency-lowering technology are available in hearing aids: 1) conformal frequency compression, 2) linear frequency transposition and 3) spectral envelope warping.

In this study, subjects with varying degrees of hearing loss were fit with custom or receiv er- based (RIC) hearing aids and one novel frequency-lowering algorithm (Spectral iQ; Starkey Hearing Technologies). Spectral iQ uses real-time spectral envelope warping to reproduce high-frequency spectral information in a lower frequency range, thereby improving audibility. Over a six-week clinical evaluation, objective performance and subjective outcomes were measured with a variety of laboratory and field tests, including a final consonant identification test and subjective outcome measures evaluating perceived sound quality and speech understanding. Specifically, objective tests and subjective measures focused on:

- Speech recognition in noise
- Participant per ceived sound quality

Methods

Participants

- 20 adults with varying degrees of seni o ronential hearing loss. The average audiogram is shown in Figure 2.
- Participants (3 female, 17 male) were 57 to 73 years with a mean age of 68.8.
- All participants were experienced users of hearing instruments, although none had prior experience with frequency lowering technology.
- Participants were fit bilaterally with Compl icoil in-the-canal (ICIC), In the Canal (ITC), In-the-Ear (ITE), and Receiver-in-the-Canal (RIC) devices.

Hearing Aid Fitting

- The primary goal of spectral envelope warping technology is to provide access to high-frequency speech cues in participants with steeply sloping, moderately-to-profoundly high-frequency hearing loss. This algorithm creates a nonlinear frequency mapping which can be used to improve speech in noise and intelligibility. The algorithm, illustrated in Figure 1, identifies high-frequency spectral peaks and replicates the envelope of this high-frequency information around a lower frequency. The newly identified spectral envelope is mixed with the amplified pathway. The replicated stimulus is only presented while the corresponding high-frequency energy is present; otherwise, the unfiltered pathway is maintained.

- Adjustments to the spectral envelope warping algorithm (Spectral iQ) can be made through Starkey Hearing Technologies’ Inspire programming software (see Figure 2). Two major parameter adjustments can be performed: 1) Translated bandwidth: the range of frequencies over which the algorithm will look for spectral peaks to translate and the bandwidth of frequencies it will translate the peaks into and 2) Translated gain: which adjusts the amplitude of the translated signal.

Results

- The S-Test was administered using two 48-word lists per condition. Participants were required to identify the spoken word at having a “Yes” or “No” ( 2/3) consonant either present or absent in a non- alternative forced-choice procedure. The speech and a speech-shaped background noise were presented at 60 dB nHL and 60 dB nHL, respectively.
- The CASPA test was administered at 65 dB SPL.
- The Speech Test Signal to Noise Ratio (SPLS) was presented at 60 dB, 65 dB, and 70 dB, and signal-to-noise ratio was determined during a period of quiet. Values with spectral envelope warping expected to be impacted by noise (6 to 1) were not evaluated. Speech was scored in percent correct at vowel, consonant, phoneme, and word level.

Discussion/Conclusions

- Objective benefit was measured during laboratory trials with subjective outcome measures developed by the authors.
- Significant objective benefit was measured during laboratory trials with subjective outcome measures developed by the authors.

- Presence in participants reported improved speech understanding and sound quality as assessed using Field trials with subjective outcome measures developed by the authors.

- Participant responses on the 5-point scale were significantly improved with spectral envelope warping on at three preferred settings (pp<0.001). Participants’ preferred settings were collected for each participant prior to the field study. Participants were allowed to have their conventional hearing aid settings in the laboratory but were instructed to use their preferred settings in the field.

- Frequency lowering technology utilizing spectral envelope warping, in combination with appropriately amplified hearing instruments, significantly improved objective speech understanding as measured by the S-Test.

- Participants reported enhanced subjective speech understanding on subjective outcome measures when utilizing spectral envelope warping relative to conventional processing.

- Participants did not report deleterious effects on their perceived sound quality or sound quality when spectral envelope warping was on, as reported on subjective outcome measures.

- Frequency lowering technologies have been developed to provide hearing-impaired listeners access to high-frequency speech cues critical for speech understanding. One of the newest types of frequency-lowering technologies is spectral envelope warping (Spectral iQ) from Starkey Hearing Technologies.

Summary

- Spectral envelope warping identifies spectral peaks in the high-frequency region of the signal and replicates that part of the signal at a lower frequency. Significant objective benefit was measured during laboratory trials of final consonant identification (S-Test) when this algorithm was turned on versus when it was allowed off. In addition, participants reported improved speech understanding and no deleterious effects on sound quality as shown on subjective outcome measures.

References