DEVELOPMENT OF THE ORCA NONSENSE SYLLABLE TEST

Petri Korhonen, M.Sc. (Tech.), Bryan Crose, B.S.
Widex Office of Research in Clinical Amplification (ORCA), Widex USA

WIDEX high definition hearing

ABSTRACT

The development of a nonsense bisyllable test designed for evaluating the effects of high-frequency processing in hearing aids is presented. A list of 115 nonsense CVCVC syllables using 25 consonants and 5 vowels was designed for analysis of phoneme substitutions, insertions, and omissions in open-set phoneme identification task. The syllables used in the test implementation were produced by one male and one female speaker. Syllables were equalized for uniform presentation levels. A custom computer program for administration and automatic analysis of the results was developed. The test verification was carried out using 9 normal hearing subjects.

MOTIVATION FOR A NEW SPEECH TEST

Introduction of new features in hearing aids, such as frequency transposition processing and extended bandwidth, poses new challenges in evaluation of performance. Especially, the transmission of speech information located at high frequencies is an aspect that these new features would potentially affect. Speech tests are typically designed to determine the extent to which the hearing aid facilitates speech understanding in everyday life. This has resulted in numerous speech tests for which the selection of test material reflects the characteristics of language and may not include all the speech sounds that may be of particular interest, especially when effects of processing higher frequencies is considered. The effects of processing higher frequencies may be more sensitive for a particular set of speech sounds, and therefore, if we study only a limited set of speech sounds, these effects may go unnoticed.

When speech is processed with a frequency transposition algorithm the new lowered speech cues may be interpreted incorrectly. To analyze the potential confusions between different phonemes in speech identification task in a comprehensive manner, the test should ideally include all phonemes of interest. The word list used in the current test uses all American English phonemes and was generated without using phonetic balancing. The use of balancing would create a list which reflects the real life frequency of occurences for different speech sounds, but would not allow analysis without emphasis on particular speech sounds. In addition to careful source material selection, the source material of the current test was recorded using conditions and equipment which ensures the preservation of high-frequency cues in the final stimuli.

A computer software for conducting automated and comprehensive analysis of the results was developed to facilitate the detection of effects that might occur only with particular phonemes or phoneme classes. Automated analysis of stimulus-response error patterns will help us to understand the potential misinterpretation of acoustic cues in frequency lowering.

TEST DEVELOPMENT

A. Word list generation and selection

- A list of 115 words with 25 consonant sounds (p, t, k, b, d, g, m, n, ŋ, f, v, θ, ð, s, z, ʃ, ʒ, l, w, wh, r, j, h, tʃ, dʒ) in initial, medial, and final positions was generated using a custom software. These consonants were coupled with five vowels (I, ə, æ, ɑ, u) in CVCVC nonsense bisyllables.
- The coarticulation effects were taken into consideration by coupling each consonant with each vowel once in each position.
- The word list generation was based on random permutations of the stimuli in each position, which ensures that each consonant was be coupled with each vowel in each position once.
- Using sounds in all positions allows examination of the position effects.
- Use of nonsense CVCVC words minimizes the effects of context.
- The list was iteratively revised to ensure that none of the words or parts of them included English language words.
- The list was then iteratively revised to remove phoneme combinations that are cumbersome to pronounce.
- Phonemes which do not occur in a given word position in English language were omitted, or replaced with other phonemes.

B. Source material collection

- Four male and female American English speakers were recruited.
- Recordings carried out in audiometric testbooth (3m x 3m x 2m) using condenser microphone with frequency response of 20Hz -18kHz using 44.1kHz sampling frequency.
- Each nonsense word recorded at least three times to ensure a propper pronunciation.
- Best recording selected through subjective listening test carried out by two native American English speakers.
- One male (age 22), and one female (age 27) speakers were used in the final implementation based on the clarity of their pronunciation.
- Each word equalized for uniform level reference to peak RMS.
- Presentation of the source material is calibrated using a 1000Hz centered warble tone with the same peak RMS as the speech material.

C. Acoustic analyisis

- Signal-to-noise ratio of the recordings was measured to be 45-46dB.
- Each phoneme analyzed individually (4049-point FFT) to ensure the quality of the recordings and presence of high frequency content up to 16kHz.
- The highest frequencies for predominant acoustic cues for phoneme /s/ at 4000-8000Hz (male) and at 5600-9600Hz for female.

TEST IMPLEMENTATION

A. Test administration

- The test was implemeted to be administrated on general purpose computers (Windows PC, with high-quality sound output capability).
- Verbal responses are documented at phoneme level.
- The administration software allows presentation of different types of noises with selected signal-to-noise ratios: white noise, pink noise, babble noise, speech weighted noise. Also stimuli can be low-pass filtered using cut-off frequencies 500,Hz, 1000Hz, 1500Hz, 2000Hz, and 4000Hz.

B. Automatisation of analysis

- The software provides immediate and automatic analysis of the results.
- Composite and position specific scores are automatically computed for:
  - ◊ Consonants
  - ◊ Vowels
  - ◊ Phonetic groups created based on manners of articulation
  - ◊ Phonetic groups created based on places of articulation
- Automatic confusion matrix is generated for all phoneme positions
- Software allows instant feedback for the test administrator at the end of each test trial.
- Results are saved into a standard ASCII text file and also in Microsoft Excel format.

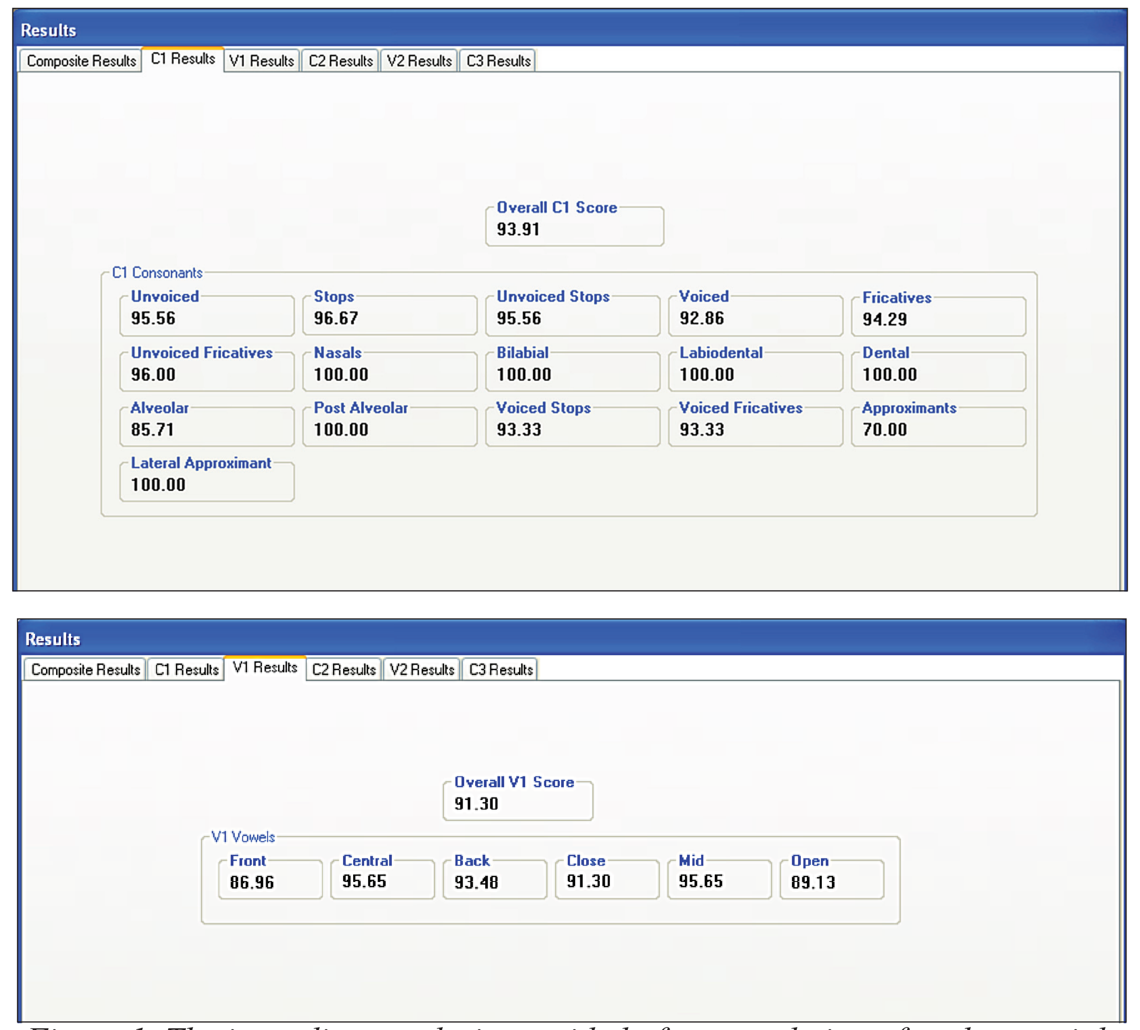
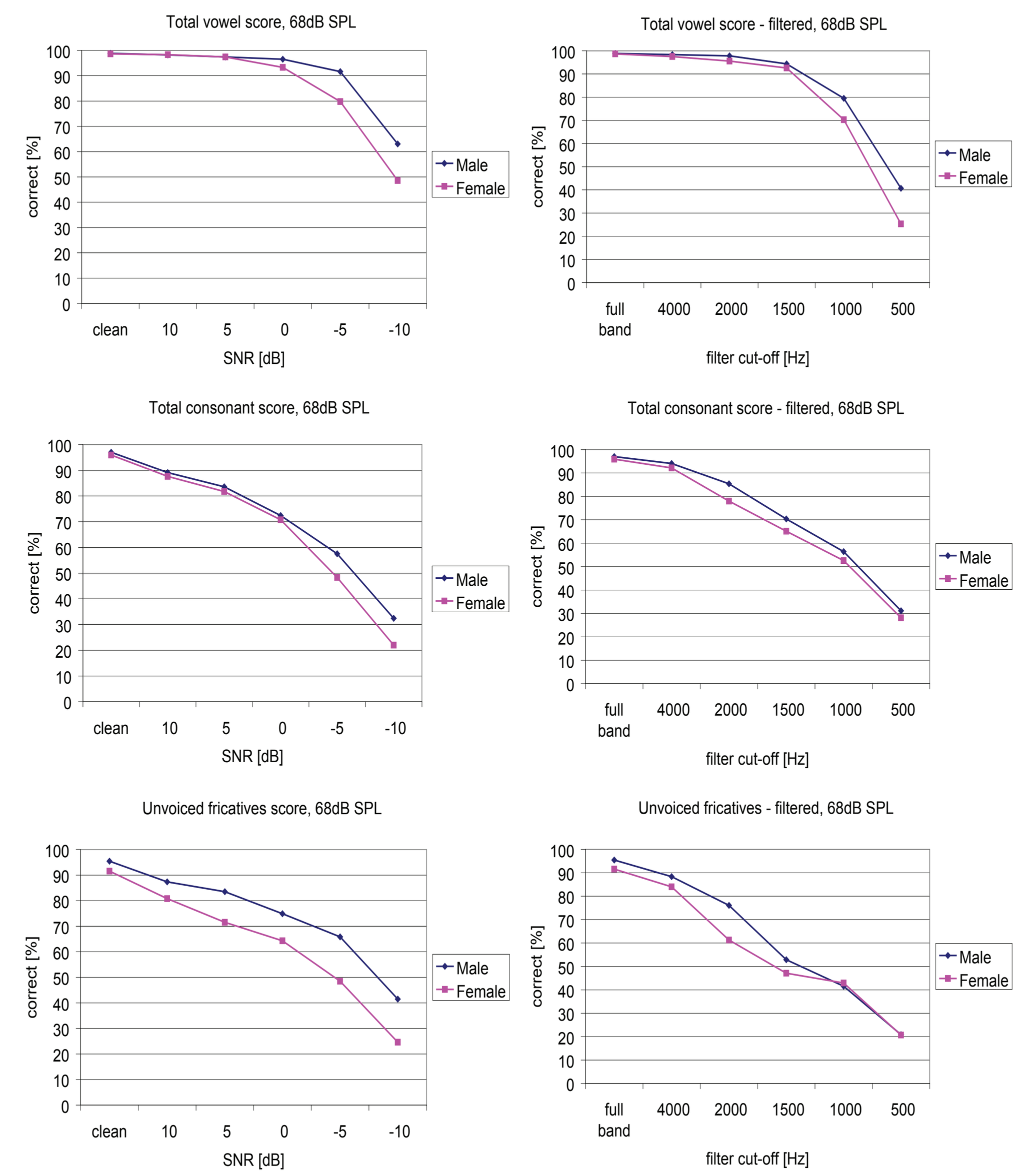


Figure 1. The immediate analysis provided after completion of each test trial.

TEST VALIDATION

Collection of normative data

- Normative data was collected using 9 normal hearing test subjects (HL less than 20dB at each ear at 500, 1000, 2000, and 4000Hz).
- Stimuli presented using a loudspeaker at 0° 1m in front of the subject in audiometric testbooth.
- Counterbalanced conditions: 50dB SPL & 68dB SPL, 68dB SPL with speech noise at SNR 10, 5, 0, -5, -10dB, low-pass filtering with cut-off frequencies 500Hz, 1000Hz, 1500Hz, 2000Hz, and 4000Hz.



DISCUSSION AND PERSPECTIVES

A list of 115 nonsense bisyllables were carefully selected to allow systematic and comprehensive testing of phoneme identification and to analyze error patterns. A custom computer software was developed for test administration and subsequent automatic analysis. Test verification was carried out using 9 normal hearing subjects. The normative test data will allow us to further narrow down the list of items to create tests suitable for different applications of the test.