INPUT DYNAMIC RANGE: REACHING NEW HEIGHTS

Denise M. Keenan, M.A.
Widex Office of Research in Clinical Amplification (ORCA)

INTRODUCTION

Clinicians may have encountered patients who indicate that they cannot communicate in loud, noisy situations because speech may sound distorted. It is possible that this distortion can occur at the input stage before any other processing in the hearing aid has been applied. The input stage is when the analog signal is converted to a digital signal [A/D converter] before digital signal processing occurs. The upper limit of the input range for A/D converters in today's hearing aids ranges from 92 dB to 108 dB SPL. When the input to the hearing aid's A/D converter exceeds its upper limit, the sound is peak clipped. Alternatively, input compression may be applied to minimize saturation distortion. The distortion from peak clipping and input compression will cause audible artifacts such as crackling and popping sounds to speech sounding muffled. These artifacts will increase as the input sound level increases beyond the hearing aids' upper limit.

A new A/D converter has been incorporated in the Dream instrument which increases the upper limit of the input to 113 dB SPL while maintaining a low noise floor of 17 dB SPL. This system effectively increases the input dynamic range of the instrument. Sounds as loud as 113 dB SPL can be handled by the instrument without distortion. With a cleaner input into the hearing aid, other features such as automatic adaptive directional microphones and noise reduction may be able to function more appropriately. This would potentially improve speech understanding in louder, noisier situations where the hearing aid wearer may tend to remove their hearing aid. Some examples are situations such as sporting events, live concerts, wedding receptions, conversations on busy city streets and other louder environments.

Purpose

The purpose of this study is to demonstrate the advantage of an increased input dynamic range for speech understanding in a louder noise situation and subjective preference at a high input level.

PARTICIPANTS

- 10 participants with mild to moderately severe hearing loss; see Figure 1
- Average unaided word recognition: 81%
- Four male and six female
- Age range of 27 to 81 years; average age 64 years
- 8 participants with >4 yrs hearing aid experience; 2 new users

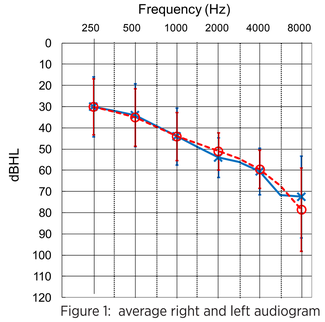


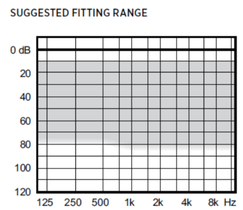
Figure 1: average right and left audiogram

METHODS

Hearing instruments

Two instruments were used for recording test stimuli: Clear 440 m-CB and the Dream 440 m-CB.

- Both instruments were set to a 50 dB flat hearing loss.
- Fully adaptive directional microphone [Locator]
- Classic noise reduction
- Input Dynamic Range:
  Clear = [highest input without distortion = 103 dB]
  Dream = [highest input without distortion = 113 dB]



Stimuli

NU-6 word lists were recorded for speech in noise testing.

- Speech shaped noise [same spectrum as the NU-6 word lists] presented at 106 dBc SPL from 90°, 180°, and 270° and speech from 0°.
- 3 different signal to noise ratios of -3, 0, and +3 dB.
- Hearing aid settings: omni with noise reduction and adaptive directional mic with noise reduction.

10 second speech and music samples [5 each] recorded in quiet for subjective evaluation.

- Speech and music samples presented from 0°.
- Two presentation levels used at -30 and 0 dB re: input level to cause distortion in the Clear (roughly 108-113 dB depending on stimuli).
- One hearing aid setting; omni with no noise reduction.

Above material was recorded in an IAC Model 1205-A sound booth using Knowles Electronics Manikin for Acoustic Research (KEMAR).

Diffuse field inverse (DFI) filter applied to all recorded materials by selecting the DFI filter on the ER-11 microphone preamp to avoid duplication of ear canal resonance (first by the coupler, second by the subject's own ear canal).

Procedures

- Participants were seen for three – 2 hour visits; one month apart.
- Participants sat in IAC Model 1205-A sound booth; internal dimensions of 10' x 10' x 6'6".
- TDH-50P supra-aural headphones worn by participants.
- Pre-recorded test materials were presented in a counterbalanced, double-blind manner.
- Practice sentence presented and dial setting adjusted in bracketing manner until speech was "loud but not uncomfortable"; began at 74 dB HL and used 2 dB steps. [average = 78 dB HL]
- Same adjusted level used for all testing; speech in noise and subjective evaluation.

RESULTS

Speech in Noise Testing

At -3 dB SNR, Figure 2, the Dream performed better than the Clear by:

- 9% with Omni and 18% Directional microphones
- 2-factor repeated-measures ANOVA revealed the improvement was significant: ($F(1,9) = 143.25$, $p < 0.001$, $\eta^2 = 0.94$, power =1)

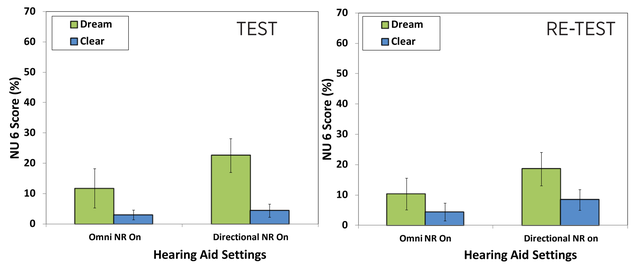


Figure 2: Average NU-6 results at -3 dB SNR; test and re-test

At 0 dB SNR, Figure 3, the Dream performed better than the Clear by:

- 14% with Omni and 23% with Directional microphones
- 2-factor repeated-measures ANOVA revealed the improvement was significant: ($F(1,9) = 61.87$, $p < 0.001$, $\eta^2 = 0.87$, power =1)

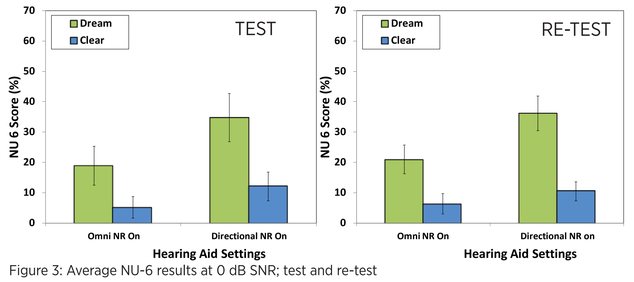


Figure 3: Average NU-6 results at 0 dB SNR; test and re-test

At +3 dB SNR, Figure 4, the Dream performed better than the Clear by:

- 13% with Omni and 23% with Directional microphones
- 2-factor repeated-measures ANOVA revealed the improvement was significant: ($F(1,9) = 71.18$, $p < 0.001$, $\eta^2 = 0.88$, power =1)

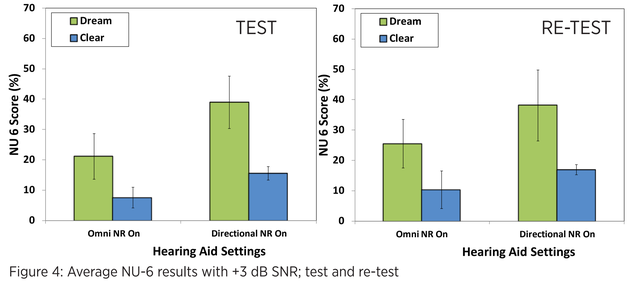


Figure 4: Average NU-6 results with +3 dB SNR; test and re-test

RESULTS (CONT.)

Results for Dream with directional mic were significantly better than Dream with omni mic:

- For -3 dB SNR: ($F(2,18) = 19.38$, $p < 0.001$, $\eta^2 = 0.68$, power =1)
- For 0 dB SNR: ($F(2,18) = 37.43$, $p < 0.001$, $\eta^2 = 0.80$, power =1)
- For +3 dB SNR: ($F(2,18) = 54.31$, $p < 0.001$, $\eta^2 = 0.85$, power =1)

Results for Clear were similar across hearing aid conditions; no significant difference between omni and directional microphones.

There was no significant difference between test and re-test.

Subjective Evaluation

- With the higher input stimuli, the Dream was chosen 82-86% of the time for test and re-test over the Clear.
- With the lower input stimuli, the preference for the Dream was very similar to the preference for the Clear. [4% difference for test and re-test]

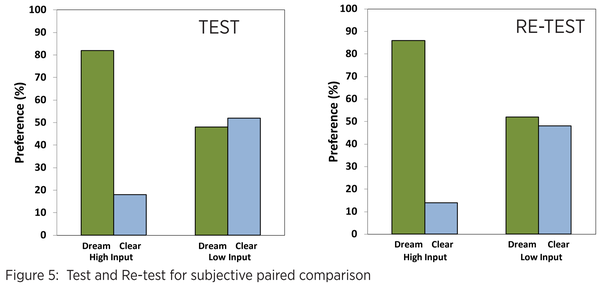


Figure 5: Test and Re-test for subjective paired comparison

CONCLUSIONS

- The speech understanding of patients in loud noisy situations using the new A/D converter with an upper limit of 113 dB SPL was better than that with a lower upper limit for the input. This may lead to improved user satisfaction under similar conditions.
- The Dream A/D converter allowed the directional microphone to be more effective. This may assist patients to improve communication in more adverse listening conditions.
- Participants had increased satisfaction in louder environments as seen by the subjective preference demonstrated in this study. This may lead to a higher acceptance of hearing aid use in similar environments.

REFERENCES

Baekgaard, L// Knudsen, NO// Arshad, T// Andersen HP. 2013. Designing Hearing Aid Technology to Support Benefits in Demanding Situations, Part 1. *Hear Rev*, 20(3): 42-50.