

Effects of Environmental Noise Reduction Configurations on Speech & Preferences

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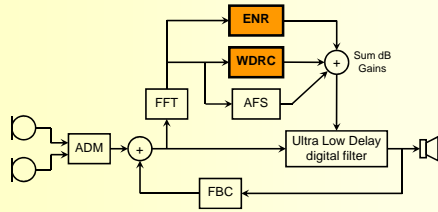
ENR algorithms typically adjust the gain with the modulation depth and/or the noise level in different ways in different aids, often with little configurability for individual preferences.

This study shows that different people prefer different ENR configurations, which have no negative effect on SRTs in noise and quiet, and improve subjective ratings of overall sound quality, listening comfort, and ease of speech understanding.

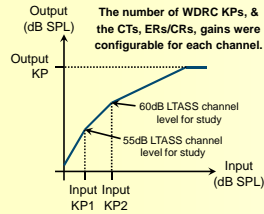
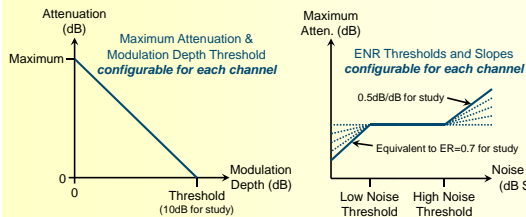
Environmental Noise Reduction (ENR) algorithms in hearing aids generally adjust the gain based on the modulation depth and/or the noise level in each channel. However, the shaping of the amount of noise reduction across channels and the variation of the amount of noise reduction with the noise level differ among manufacturers, often with little or no configurability for individual needs or preferences. In this study, highly configurable WDRC and ENR algorithms were developed for open-platform DSP hearing aids, and were used to investigate the effects of different ENR configurations on:

- Speech understanding in quiet and in noise
- Listening comfort, perceived ease of speech understanding, and overall sound quality
- Subjective preferences in real-life listening situations

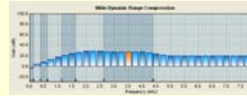
The hearing aid included an adaptive directional microphone (ADM), adaptive feedback cancellation (FBC) and suppression (AFS) and ultra-low processing delay as well as environmental noise reduction (ENR) and wide Dynamic Range compression (WDRC).



The ENR algorithm had configurable kneppoints, maximum attenuation, modulation depth thresholds, slopes, and expansion ratios for each channel.



The WDRC and ENR channel spacing was very flexible. Thirty two frequency bands were grouped into eight frequency channels.



STUDY DESIGN

Ten volunteers with moderate to severe hearing loss wore open-platform DSP BTE hearing aids with hard acrylic, skeleton earmolds vented appropriately for each hearing loss. WDRC was initially fitted to the NAL-NL1 prescription, followed by fine tuning as required. In the acclimatisation period of 1-2 weeks, the participants had two programs: ENR Off and ENR On (order counterbalanced across participants). For half of the participants the ENR On program was ENR Flat (max attenuation equal at all frequencies), and the other half used ENR SII (max attenuation weighted by speech intelligibility index) with variable strength. In the variable strength conditions, the maximum attenuation increases with increasing noise level at levels above the high noise threshold and decreases with decreasing noise level below the low noise threshold.

Questionnaire

After acclimatisation, participants compared ENR configurations (blind comparison with programs balanced across participants)

- Week 1: ENR Flat shaping/Variable strength vs. ENR SII shaping/Variable strength.
- Week 2: ENR Preferred shaping/Variable strength vs. ENR Preferred shaping/Constant strength.
- Week 3: ENR Preferred shaping/Preferred strength behaviour vs. ENR off.

Each week the participants completed a Questionnaire, covering a variety of real-life listening situations with different levels of noise. They were asked to compare the two programs in each situation and decide which program was better overall.

Speech Testing

Speech Reception Thresholds were measured with the HINT in a sound booth. For all conditions speech was presented from the front and noise was presented from the rear. The three test conditions were:

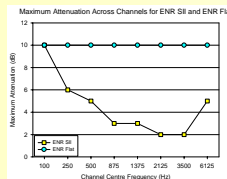
- Speech in quiet: starting level 55 dBA.
- Speech in 8 talker babble: speech starting level 70 dBA, babble playing continuously at 65 dBA.
- Speech in speech shaped noise: speech starting level 70 dBA, noise level 65 dBA starting 7 seconds before speech.

All four ENR configurations and ENR off were tested in quiet. ENR Flat/Variable, ENR SII/Variable and ENR off were tested in the two noise conditions. The order of testing and HINT lists was balanced across participants.

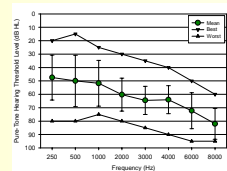
Satisfaction Ratings

Participants listened to continuous CUNY sentences at 70 dBA from the front, in the presence of two types of noise (8 talker babble and speech shaped) at 65 dBA from the rear. The aids were programmed with ENR off, ENR Flat/Variable, and ENR SII/Variable. Participants cycled through the programs and rated them on a 5 point satisfaction scale for Listening Comfort, Ease of Speech understanding and Overall Sound Quality.

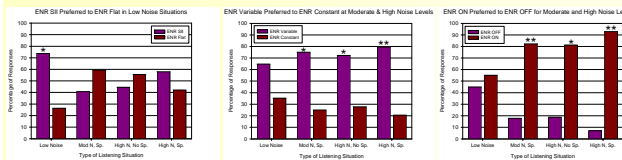
Maximum attenuation was 10 dB across all frequencies for ENR Flat, and shaped according to the speech intelligibility index for ENR SII.



The ten participants had moderate to severe hearing loss



ENR SII was preferred in low noise situations and ENR with variable strength was preferred in moderate and high noise levels. (* p < 0.05; ** p < 0.01; binomial test)



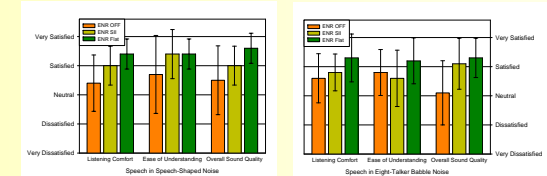
RESULTS

Analysis of variance for the rating data showed significant positive main effects of ENR on vs. off for all three rating scales: listening comfort, ease of speech understanding and overall sound quality (p < 0.01). ENR Flat was rated significantly higher than ENR SII on average (p < 0.05). This may be due to the higher max attenuation for Flat ENR at mid frequencies which provided a greater degree of noise reduction.

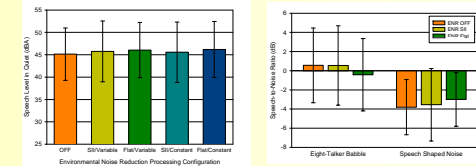
Repeated measures ANOVA for the speech reception threshold testing confirmed that the ENR algorithm had no significant negative effect on speech intelligibility compared with the ENR off condition in quiet (p = 0.435) and in noise (p = 0.897).

Chi-squared analysis indicated that preferences for ENR (on vs off) were different for low noise vs moderate and high noise conditions, consistent with the higher ratings for ENR on in the higher noise conditions.

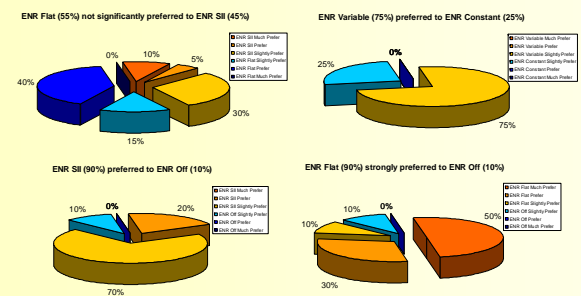
Significant positive effects of ENR on Comfort, Ease of Speech Understanding, and Sound Quality. ENR ON preferred to ENR OFF (p < 0.01), ENR Flat preferred to ENR SII (p < 0.05)



No negative effect of ENR on Speech Reception Thresholds in Quiet or Noise



Configuration of ENR parameters affected the patterns of overall preferences



CONCLUSIONS

- All configurations of the ENR algorithm improved ratings of listening comfort, ease of speech understanding, and overall sound quality.
- No negative effects of ENR were found.
- Preferences depended on noise conditions and ENR parameters.

RECOMMENDATION

- Configurable ENR parameters may provide higher levels of satisfaction for hearing aid users by allowing for differences between individuals and noise conditions.