EVALUATION OF A TRANSIENT-NOISE REDUCTION ALGORITHM: SPEECH PERFORMANCE AND COMFORT

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INTRODUCTION

Transient noise sounds are a frequent source of complaint from hearing aid wearers (Keidser et al, 2009). These sounds are characterized by a very short (<1 s) duration and a rapid increase in sound pressure level to a peak value within fractions of a millisecond. In situations where transient noises are repeated, an intuitive action of the wearer to reduce annoyance is to lower the overall gain on the hearing aid through the use of the volume control (VC). While this step may ensure wearer comfort this could result in under-amplification and compromise the performance of the hearing aid for all sounds. Likewise, if the wearer complains to the dispensing clinician of the transient noise problem, it is likely that the clinician lowers the gain of the hearing aid for a more comfortable output. An effective transient noise reduction (TNR) algorithm could reduce the annoyance of transient sounds without compromising wearer amplification.

A pre-peak detection based transient noise reduction (TNR) algorithm was designed to improve wearer comfort. The algorithm was designed to detect and attenuate unwanted transient sounds efficiently and effectively without negatively attenuating any speech sounds. The algorithm detects transient sounds and presents them at a level that the hearing aid wearer can tolerate, without removing them or making them unnaturally soft. The current study was conducted to demonstrate that the TNR algorithm retains speech intelligibility while improving wearer listening comfort in repeating, transient noise environments. In addition, we investigated the effect of the TNR algorithm on wearer preferred gain in the presence of repeating transient noises and its impact on speech identification.

SoundSoftener

A TNR algorithm called SoundSoftener (SS) includes: a pre-peak detection, 15-channel processing, and a speech vs. noise transient detector. The algorithm monitors signal levels at the front-end of the signal processing chain of the hearing aid. This enables the algorithm to send a message to the compression system about a detected transient sound before the sound arrives at the compressor. The advance knowledge of an incoming transient allows the compressor to react to the transient sound instantaneously with no delay. This alert is activated in the compressor across all 15 independent processing channels so that each channel can be ready for action almost instantaneously (<0.5 ms) when a transient sound occurs in the specific frequency region. Gain adjustments are made individually in each 15 channels according to the individual hearing loss. The SS algorithm does not remove the transient sound completely, but maintains it in an identifiable form at reduced amplitude (maximum of 12 dB attenuation). The speech detector ensures that the system does not mis-identify speech transients as noise transients and attenuate them by mistake.

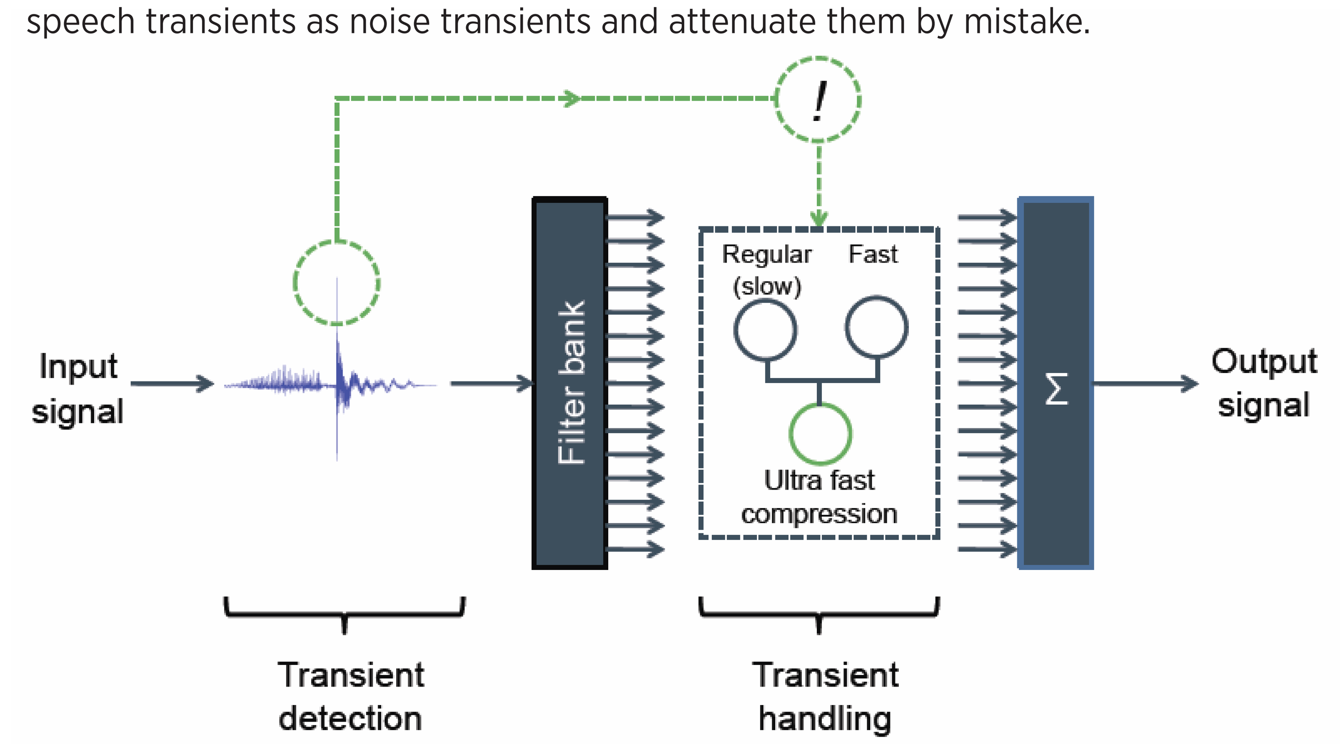

Figure 1. The integration of the TruSound Softener in the signal pathway. Peak-detection carried out before filter bank allows near instantaneous attenuation for transient noise sounds.

SUBJECTS

Thirteen listeners aged 65 – 83 yr (mean = 73 yr) with bilateral sensorineural hearing loss (PTA = 50.65 dB HL) participated in the study. On average, the participants had worn hearing aids for 10.3 yr (SD = 6.4 yr). One participant did not own any hearing aids.

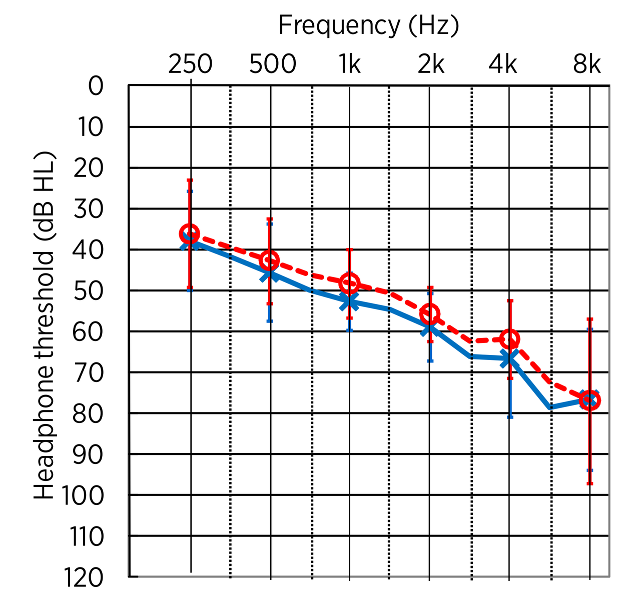

Figure 2: Averaged headphone thresholds for right (red) and left (blue) ears.

METHODS

Hearing instrument

Each subject was fitted binaurally with Widex Clear440-9 BTE hearing aids using foam inserts and #13 tubing.

Hearing aid features: 15-channel wide dynamic range digital hearing aid. 32 kHz sampling rate of the A/D stage with 20-32 bit resolution. Maximum power output (MPO) of 124 dB SPL, and frequency response from 100 Hz to 7200 Hz (ANSI, 2003). Slow-acting compression with attack time of up to 2 sec in each of the 15 channels.

Hearing aid settings: Noise reduction: off; Microphone: omnidirectional; Feedback cancellation: SuperGain. This hearing aid includes wireless binaural inter-ear features, but these features were deactivated in the current study.

Hearing aid programs: SS-on: TruSound Softener on (with 12 dB attenuation); SS-off: TruSound Softener off.

Stimuli

We recorded our own stimuli so we can have information on the exact nature of the stimuli, and to allow us to select sounds with short rise times.

Eight transient noise sounds with short rise times and varying levels were were recorded (see Table 1 for description). An example of the waveform for the sound 'Concrete block' displaying a rise time of 1 ms was shown in Figure 3. Sounds were presented at their natural recorded levels in quiet.

Speech materials used during gain adjustment were spoken by a native English-speaking female at a conversational level. The speech passage was presented at a 68dB SPL input level. The speech passage was 10.6 seconds in duration. Two transient noise sounds ('Keys' and 'Metal rails') presented at their natural levels were embedded in the speech passage. These two transient noise sounds were selected because the difference between the SS-On and the SS-Off programs was determined audible during an informal listening test with a normal hearing listener.

Table 1: Description of the transient noise stimuli including the measured SPL levels and the rise times.

Stimulus	Natural level $SPL_{A, imp}$ (dB)	Rise time* (ms)
Water glasses	102	3
Glass jar	101	4
Metal can	97	7
Keys	92	<1
Metal rails	92	1
Concrete block	89	1
Porcelain cup	88	4
Pen	67	<1

* from 20 dB below peak to peak

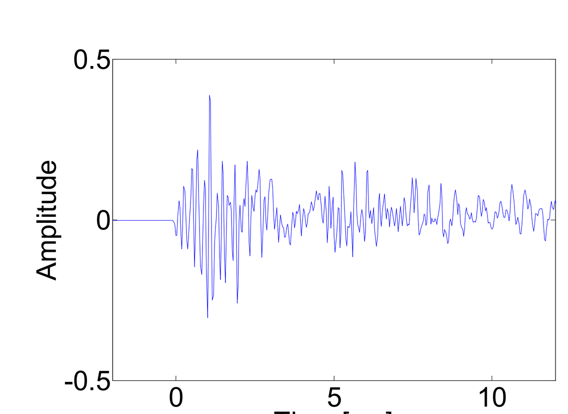

Figure 3: Waveform of the transient noise sound 'Concrete block'.

PROCEDURES

Speech identification performance was measured with the Office of Research in Clinical Amplification (Widex) Nonsense Syllable Test (ORCA-NST). The speech was presented at a 50 dB SPL input level from 0° in quiet without transient noise.

Subjective preference was measured with a paired comparison task. The recorded transient noise sound stimuli were presented at their natural levels in quiet. Participants were instructed to select the SS setting that had less impulse sounds and that they found more comfortable to listen. The participants indicated their preference for the two programs using a four-option scale ("Setting A definitely more comfortable," "Setting A somewhat more comfortable," "Setting B somewhat more comfortable," and "Setting B definitely more comfortable").

Wearer overall preferred gain with the SS algorithm was measured by presenting two transient noises interspersed within a looped conversational speech passage. The participants were instructed to select an overall gain that allowed them to hear as much of the speech as possible while tolerating the transient noise sounds. The test administrator adjusted the overall gain based on the subjects' response using a bracketing approach. Afterwards, the effect of the SS algorithm gain adjustment on speech identification was measured using the ORCA-NST presented at a 50 dB SPL input level in quiet.

RESULTS

Subjective preference

The participants selected "SS-Off definitely more comfortable" in 3.8% of the responses, "SS-Off somewhat more comfortable" in 28.1% of the responses, "SS-On somewhat more comfortable" in 50.6% of the responses, and "SS-On definitely more comfortable" in 17.5% of the responses (Figure 4). When one combined the number of responses for the criteria "SS-(On/Off) definitely more comfortable" and "SS-(On/Off) somewhat more comfortable," SS-On was selected in 68.1% of the responses, and SS-Off was chosen in 31.9% of the responses. A one-way ANOVA showed that the effect of SS algorithm was significant ($F(1,206) = 83.67$, $p < 0.001$, power>0.99).

Effect on phoneme identification

The average phoneme identification scores measured before any gain adjustment were 69.1% with SS-On and 68.5% with SS-Off. This difference was not statistically significant ($t(12) = 0.745$, $p > 0.05$). This demonstrated that the TNR algorithm did not compromise speech sound identification in quiet. This suggests that the speech detector feature implemented in the SS algorithm ensured that important speech cues with transient characteristics, such as the release bursts of stop consonants, would not be affected.

Wearer selection for overall gain

Wearer preferred insertion gain with SS-on and SS-off in the presence of transient noise sounds were shown in Figure 5. With SS-Off participants selected on average 8.6 dB lower insertion-gain compared to the default IG values. With SS-On participants selected on average 5.7 dB lower insertion gain compared to the default IG values. In summary, participants selected on average of 2.9 dB more gain with SS-On than with SS-Off.

Speech identification after gain adjustment

The average phoneme identification performance scores measured with the SS-On and SS-Off programs after the gain adjustment were reported in Figure 6. The phoneme identification scores were 57.1% with SS-on and 45.0% with SS-off. Post-hoc analysis showed a significant difference between performance with SS-on and SS-off after the gain adjustment ($t(12) = 4.193$, $p<0.05$ power = 0.97). Thus the higher user gain with the SS algorithm ensured a better speech understanding performance by 12.1%.

RESULTS (CONT.)

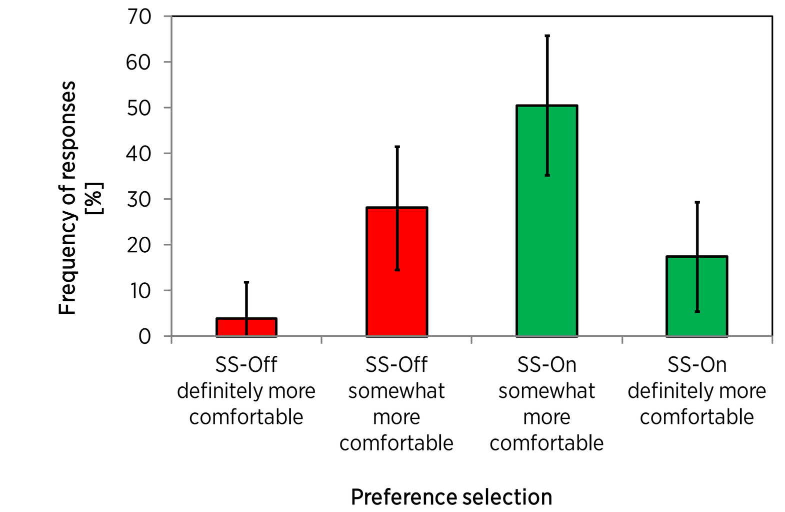

Figure 4. Average frequency of wearer preference for SS-On or SS-Off for transient noise sounds presented in quiet.

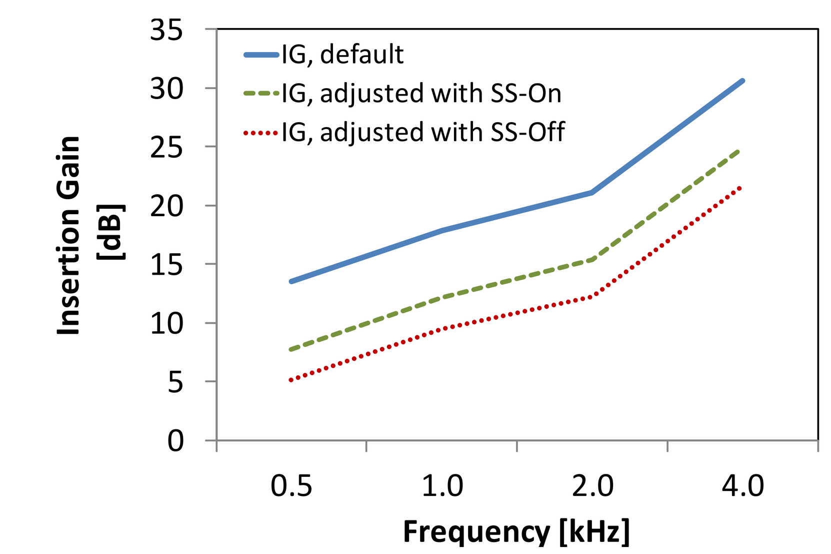

Figure 5. Insertion gain values (IG-Normal) averaged across all participants at fitting and after the overall gain adjustment with the SS-On and SS-Off programs.

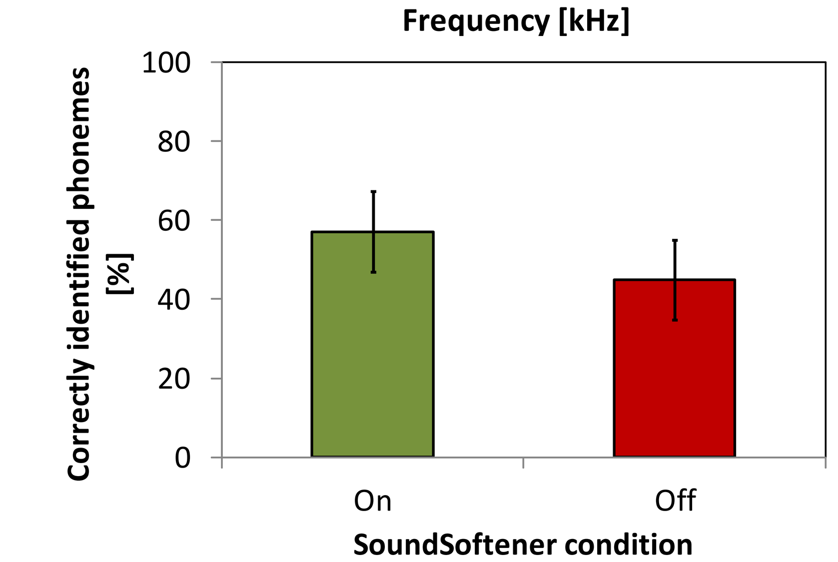

Figure 6: Average phoneme identification scores on the ORCA-NST after gain adjustment with SS-On and SS-Off. Error bars indicate +/- 1 SD.

CONCLUSIONS

In real-life hearing aid wearers may turn down the VC on their hearing aids in the presence of annoying transient noise sounds. Unfortunately many would not readjust the VC up after the transients. Furthermore, some could ask their audiologist to fine-tune the hearing aid to a lower gain level to prevent the unpleasant experience with the transients. This can compromise the performance of the hearing aid for all sounds. The pre-peak detection based TNR algorithm used in this study appears to be a good solution in maintaining listening comfort without compromising speech intelligibility. This algorithm ensured more consistent audibility across listening environments through less gain reduction in the presence of transient noise sounds. This could preserve the phoneme identification ability by as much as 12.0%. These benefits were achieved without negative impact on speech transients. Because of the potential benefits that such a feature may offer, its inclusion into a hearing aid as a necessary feature should be considered.

REFERENCES

Keidser G, Convery E, Kiessling J, Bentler R. (2009) Is the Hearing Instrument to Blame When Things Get Really Noisy? Hear Rev 16(8):12-19.

Kuk F, Lau C, Korhonen P, Crose B, Peeters H, Keenan D. (2010) Development of the ORCA Nonsense Syllable Test. Ear Hear 31(6):779-795.