Transient Noise Reduction

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Transient sounds, like the explosion of a firework, a glass breaking, a hammer pounding, or dishes clanging can be annoying and uncomfortable for hearing aid users. This adverse perception is largely due to the fact that hearing aids do not fully compensate for the abnormal growth of loudness experienced by hearing-impaired listeners because of their reduced dynamic range. This reduced dynamic range and the associated rapid growth of loudness is called recruitment (Moore, 2003). The Transient Noise Reduction (TNR) feature found in all Starkey® Livio® AI and Livio hearing aids acts as a fast compressor that quickly attenuates transient acoustic signals, making them more tolerable, without distorting other environmental sounds like speech.

TNR attenuates transients in a level-dependent manner: more attenuation is applied when the overall sound-pressure level is low, and less attenuation is applied when the overall level is high. This is important for two reasons: (1) acoustic transients are most disruptive for the listener in relatively quiet environments, when hearing-aid gain is high, so more aggressive attenuation prevents transients from reaching uncomfortable listening levels; and (2) acoustic transients are less disruptive in relatively loud environments, when hearing-aid gain is low, so less aggressive attenuation prevents large changes in gain during speech and other ongoing sounds, which would result in an unnatural perception.

The amount of gain reduction is determined by the broadband signal, but TNR attenuates transients in a frequency-dependent manner: more attenuation is applied at high frequencies than at low frequencies. This is important for two reasons: (1) most environmental sounds, including speech, are dominated by low-frequency energy, and have decaying energy with increasing frequency, and (2) most transients are dominated by high-frequency energy. Furthermore, gain reduction is applied using asymmetric time constants: the rise time is much faster than the fall time, such that both the quick onsets of transients and their slower offsets are effectively suppressed.

Figure 1 shows the effect of the TNR algorithm on a series of hammer strikes in a quiet background. Time is plotted along the x-axis, and the amplitude of the acoustic signal is plotted along the y-axis. The gold waveform shows the unattenuated hammer strikes with the TNR feature disabled, and the blue waveform shows the attenuated hammer strikes with the TNR feature enabled and set to the default strength setting.

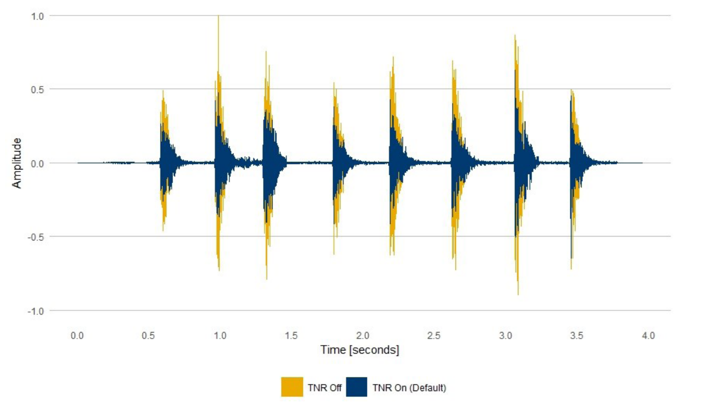

Figure 1: The effect of TNR on a series of hammer strikes in quiet.

The effect of TNR is to quickly reduce the amplitude of each hammer strike without distorting the envelope of the waveform. Perceptually, this equates to the sound being less sharp and uncomfortable, but still sounding natural.

To test the TNR feature, 15 normal-hearing listeners were asked whether different transient sounds were more annoying with TNR enabled or TNR disabled. The stimuli were presented as paired comparisons, and the order of presentations was randomized. Figure 2 shows that both hammer strikes (left pie graph) and clanging cutlery sounds (right pie graph) were rated as less annoying when TNR was enabled versus when TNR was disabled. In other words, listeners preferred the TNR feature to be enabled when listening to different transient sounds.

In a separate study, 32 hearing-impaired listeners also rated these same transient sounds as less annoying when TNR was enabled versus when TNR was disabled. Figure 3 shows that, when listening to either hammer strikes (left pie graph) or cutlery sounds (right pie graph), there was a strong preference that the TNR feature be on rather than off.

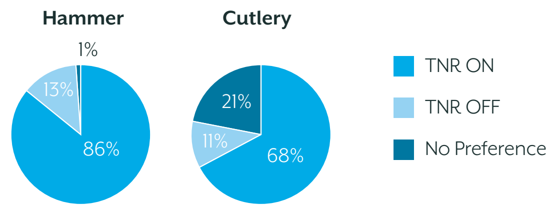

Figure 2: Preferences for TNR on vs. TNR off when listening to hammer strikes (left) or cutlery (right). Normal-hearing listeners (n = 15).

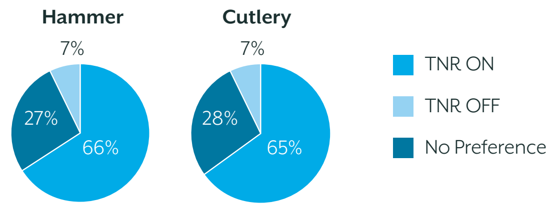

Figure 3: Preferences for TNR on vs. TNR off when listening to hammer strikes (left) or cutlery (right). Hearing-impaired listeners (n = 32).

In summary, Transient Noise Reduction is a feature that is designed to make transient sounds more comfortable for hearing aid users to listen to. Without TNR, transients can be too loud and abrasive. With TNR, transients are quieter and less annoying, but the sounds are largely preserved so that they still sound like they are supposed to sound. For example, a hammer pounding still sounds like a hammer pounding, it's simply less jarring under amplification when Transient Noise Reduction is enabled.

REFERENCES

Moore, B.C.J. (2003). "Speech processing for the hearing-impaired: Successes, failures, and implications for speech mechanisms," Speech Communication: 41, 81 – 91.