The Surprising Success of Digital Noise Reduction

While DNR may not improve speech-in-noise scores, it greatly improves listening in noise.

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The literature shows the benefits of DNR include more rapid word learning rates, less listening effort, better recall of words, an improved SNR at the hearing aid output, improved ANLs, improved attention and quicker word identification and better neural coding of words. Therefore, the authors suggest the typical fitting rule in 2016 should include activation of the DNR circuit as the "go-to" setting for adults and children.

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Digital Noise Reduction (DNR) does significantly more than most of us realize. Indeed, DNR is currently vastly underused and is a vitally important feature of contemporary hearing aids. As such, the authors recommend engaging high quality, sophisticated DNR all the time for all patients—children and adults. In this paper we address these issues through examination of contemporary, peer-reviewed, and other literature (ie, published opinions from luminaries and text books) on this topic.

Frankly, we acknowledge many (perhaps most) of our colleagues don't use DNR except in the minority of hearing aid fittings. However, it appears the two most-common reasons Hearing Care Professionals (HCPs) don't use DNR on every patient is:

1) They're concerned DNR may take away speech sounds, and
2) They cannot find a direct audiologic measure to indicate and validate DNR.

This situation is not unlike the story of the man searching the sidewalk late at night for his dropped car keys. A friend walks by, stops and asks if he can help. "Sure," says the first man. "I dropped my car keys over there," pointing to the other side of the street. "If you dropped them over there, why are you looking here?" queries the good samaritan. "Well," the man with the missing keys responds, "the light is better over here."

Likewise, we contend we're not aware of the impressive and multiple successes of DNR because we've been (mostly) looking in the wrong places.

Quality of Life and Hearing Health

The consequences of hearing loss are broader and deeper than simply not hearing loud enough. In 1999, the National Academy on an Aging Society stated "Hearing loss can have a profound impact on an individual's emotional, physical, and social well-being. People with hearing loss are more likely to report symptoms of depression, dissatisfaction with life, reduced functional health, and withdrawal from social activities…"[1] Of course, these same and similar findings have been confirmed and documented by many studies in the 21st century.

In 2007, the "Final Report of the American Academy of Audiology Task Force on the Health-Related Quality of Life Benefits of Amplification in Adults"[2] stated people with hearing loss who wear hearing aids experience an improved Quality of Life (QoL) and, specifically, hearing aids reduce the psychological, social, and emotional effects of sensorineural hearing loss (SNHL). The committee reported "hearing aid use improves adults' health-related quality of life by reducing psychological, social, and emotional effects of sensorineural hearing loss, an insidious, potentially devastating chronic health condition if left unchecked."[2]

More recently, Lin and colleagues[3] stated in the *Journal of the American Medical Association* "Hearing loss is independently associated with accelerated cognitive decline and incident cognitive impairment in community-dwelling older adults…" Other retrospective studies have indicated increased auditory/sensory stimulation (ie, hearing) facilitates increased cognitive awareness (ie, listening) while potentially facilitating multiple benefits, to be addressed below.

Hearing vs Listening

To be clear, "hearing" is the perception of sound, and "listening" is the ability to assign meaning to sound. Well-fitted technologically advanced hearing aids improve not only the ability to hear, but also improve the ability to listen.

Indeed, human listening (not hearing) is a highly sophisticated cognitive ability which involves attention, neural processing speed and quality, memory, language and more. As such, human listening is what separates

humans from all other primates. Interestingly, "normal hearing" humans are not very good at hearing. That is, dogs, cats, whales, dolphins, and many other primates and mammals have hearing which is vastly superior to ours. However, our ability to "listen" (to extract meaning) is unmatched in the animal kingdom. Of course, one must first hear (detect) sounds in order to process sounds. That is, one cannot listen to that which is not heard.

Therefore, the first step when fitting amplification on patients with hearing loss is to amplify sounds appropriately, so as to make all speech sounds audible, while not making them uncomfortably loud. However, simply making sounds louder is not the entire task. One must amplify sounds appropriately using a hearing aid fitting rationale (such as the manufacturer's proprietary fitting protocol, NAL-NL2, DSL-V, etc) to create amplified sounds which provide the brain with abundant, natural acoustic information.

Noise, DNR, and Speech Perception

It is our thesis that DNR and the maintenance of natural acoustic information is highly beneficial and should be the "go to" hearing aid fitting strategy, unless there is a specific reason not to use it. Further, in the peer-reviewed literature, there is ample evidence DNR is an excellent and beneficial tool, and there exists vast support in the peer-reviewed literature for using DNR, some of which will be highlighted below.

Gatehouse and Akeroyd[4] noted the "dynamics" of the auditory world "are highly influential." Specifically, they reported the ability to sustain and switch one's attention across multiple sound sources matters a great deal, as does the ability to determine from where (in space) sounds originate, as well as their distance and motion (relative to the listener). They stated "The absence of a correspondence in the domain of sound quality and naturalness is intriguing and suggests that current bilateral fitting of acoustical hearing aids [in 2006] do not preserve the underlying cues…"[4] required to maximally attend to speech.

Shinn-Cunningham and Best[5] reported the ability to know where to "selectively attend" one's listening effort depends on the ability to analyze the "acoustic scene." Further, people who cannot accurately construct the auditory scene (ie, people with hearing loss) may not be able to "filter out competing sound sources." They report people with hearing loss are generally less able to use prominent auditory cues (specifically location, pitch, and timbre) "which enable normal hearing listeners to select a desired sound source" across multiple sounds. Shinn-Cunningham and Best note peripheral hearing loss initiates many problems which challenge the abilities of people with hearing loss to communicate in social settings (speech in noise) and to employ "selective attention." Indeed, laughter, conversation, and other competing auditory signals can render the person with hearing loss intimidated and overwhelmed.

Pittman[8] reported in 2011 that modern DNR circuits do not negatively impact speech perception, but DNR significantly improved word learning rates for older children.

In 2010, Stelmachowitz and colleagues[7] evaluated 16 children ages 5 to 10 years with mild to moderately severe hearing loss. All participants were fitted with DSL v5.0 and were tested with noise reduction engaged and disengaged. They reported the variable of noise reduction "on-or-off" was not statistically significant and, indeed, the noise reduction circuit did not have a "differential effect" with regard to the children's ability to correctly identify speech in noise.

Likewise, Pittman[8] reported in 2011 that modern DNR circuits do not negatively impact speech perception, but DNR significantly improved word learning rates for older children.

Beck and Flexer[9] noted "listening is where hearing meets brain"; the sub-goals of an excellent hearing aid fitting include keeping the sounds as natural as possible so as to provide the brain with the abundant and natural acoustic information it seeks. Specifically, when the brain hears sounds which are stripped of their natural acoustic cues—when sounds are highly compressed and when interaural timing differences (ITDs) and interaural loudness differences (ILDs) are not present—the brain has to work harder to listen. Of course, listening in a background of noise is difficult as the brain attempts to focus on the one voice of interest while ignoring environmental noise (fans, traffic, motor noises, etc). However, the task of listening is even more problematic when the background sound includes multiple voices (ie, speech in speech) as the brain actively attempts to focus on the one voice of maximal interest while ignoring or dismissing other voices with meaningful speech and linguistic value, all of which typically overlap in phonemes, pitch, inflection, timing, loudness, and more.

In a 2012 interview[10] for the American Academy of Audiology (AAA), the first author (Dr Beck) referred to Harvey Dillon, PhD, and colleagues' chapter titled "Special Hearing Aid Issues for Children" in the 2008 textbook *Pediatric Audiology–Diagnosis, Technology and Management*[11]:

> **Beck:** "You stated (more or less) that modern hearing aid technology is so good that audiologists and dispensers should use noise reduction and directional microphones for children of all ages—just like adults! That was a very important declaration for many reasons, not the least of which was that it came from you and your co-authors, not from a hearing aid manufacturer! I believe many pediatric audiologists will read those words from four years ago and will be shocked! Have I encapsulated your thoughts accurately and do you still believe the same?"
>
> **Dillon:** "Yes. You presented it succinctly and correctly and I still stand by those remarks…"[10]

Ng, Rudner & Lunner[12] in 2013 reported "competing speech" has a disruptive effect with regard to recall of speech which occurred in challenging acoustic environments, and this effect was reduced via noise reduction for people with better working-memory capacity. The authors evaluated 26 people with moderate to moderately severe SNHL. They reported listening in background speech noise is more demanding (cognitively) than listening in artificial noise, as lexical and semantic information (as contained in speech) is more interesting and harder to ignore. Additionally, they reported, for people with high working-memory capacity, DNR was useful and the DNR circuit "virtually canceled out" the disruptive effect of the competing speech with respect to recall. They stated "noise reduction can reduce the adverse effect of noise on memory for speech...for people with good working memory capacity..."[12] They also noted DNR allowed quicker word identification

and facilitated enhanced encoding of heard material into working memory.

Rudner and Lunner[13] reported noise reduction may facilitate a "release" of "cognitive resources" such that improved memory coding occurs. Specifically, DNR not only makes it easier to listen to speech in noise, but high quality noise reduction facilitates improved recollection of speech heard in noise. They stated background noise most often reduces recall performance, whereas DNR "counteracted this effect."

Desjardins and Doherty in 2014 evaluated listening effort with and without DNR for 12 adult experienced hearing aid wearers. A dual-task paradigm was used. Listening effort was determined based on performance changes in the secondary-task. The authors reported "The NR algorithm used in this study significantly reduced" listening effort in the most difficult listening situation and while the "NR algorithm used in the present study did not improve speech recognition scores in babble, it also did not degrade performance…." The authors concluded DNR significantly reduced listening effort for their participants and, importantly, DNR did not significantly alter (improve or degrade) word recognition scores. Finally, they reported listening effort measured using their dual task paradigm is more sensitive to changes attributable to DNR than is a word recognition score.[14]

In a 2013 interview for the American Academy of Audiology,[15] Andrea Pittman, PhD, stated "Many hearing aids will reduce the SNR (make it worse) as the sound goes through the circuit. But a hearing aid with an active DNR circuit can improve the SNR by as much as 6 dB and may provide the listener with a signal closer to the original and more like what normal-hearing listeners are hearing."

Lowery and Plyer[16] reported on 30 adults with mild-moderate SNHL with regard to their Acceptable Noise Levels (ANLs). They concluded ANLs were improved with DNR engaged, and the improved ANLs were apparent. Likewise, listeners preferred DNR engaged, as DNR improved their ability to accept noise. Of note, they also reported listeners with the worst baseline ANL scores benefited the most from DNR.

In 2015, Ng, Rudner, Lunner, and Ronnberg[17] noted for people of all working-memory ability, "noise reduction improved memory for speech heard in competing speech for hearing aid users."

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Discussion

Based on the peer-reviewed and other literature cited above, it seems apparent modern DNR circuits are indeed highly beneficial for most people, most of the time. However, the benefits are not to be found in improved word recognition scores—that particular benefit has simply not been shown.

The benefits of DNR indicated above included more rapid word learning rates, less listening effort, better recall of words, an improved SNR at the hearing aid output, improved ANLs, improved attention and quicker word identification and better neural coding of words.

Therefore, we suggest the typical fitting rule in 2016 should include activation of the DNR circuit as the "go-to" setting for adults and children. Further, as we continue to advance with respect to DNR processing speed and quality, advances in DNR previously not possible will quickly enter the marketplace, providing even greater benefit for the majority of adult and pediatric hearing aid wearers. These benefits should target and are likely to include: improved speech understanding in noise, decreased listening effort in noise, and additionally improved recall for conversations which occur in deleterious listening situations. ◗

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