Designed for Music Listening

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Introduction

Starkey Hearing Technologies' Synergy platform introduces a suite of features designed to enhance the enjoyment of music for patients. Maybe the most significant feature is a new dedicated music memory. This memory is built specifically for music listening, motived by fundamentals of the auditory system and fine-tuned with input from professional musicians and conductors.

Motivation for music

"Music produces a kind of pleasure which human nature cannot do without." -Confucius

Music is all around us. It is in our homes, in our cars, in places of business and in places of worship. Music is in shopping malls and restaurants, at sporting events, picnics, in movies and on television. We celebrate and relax with music. Many people wake to music, some fall asleep to music, and we experience music deliberately and incidentally in many different environments. We process and perceive music effortlessly, often in the background, without even being aware of it.

For people with hearing loss, however, listening to music can prove frustrating, and modern hearing aids often provide little assistance. Hearing aids have been developed with the primary goal of improving speech intelligibility and have made great strides in this direction. Music dynamics are broader and more slowly varying than those of speech. Spectral variation is wider and more significant to the perception of music than that of speech, so that spectral distortion is more impactful to music listening. Speech of interest is most often single-source; as a result speech processing often seeks to identify the speech part and suppress everything else. Music is inherently multi-source and rarely embedded in noise; the ambience of a performance space, including reverberation, are essential elements of the experience of music. For these reasons, it is generally not appropriate to suppress any part of the signal when listening to music.

Because music signals have different acoustic features from speech signals, different dynamics and different spectral characteristics, the speech-oriented processing in today's hearing aids may adversely impact music listening. Compared to speech, music listening involves different listening goals and strategies. It presents different challenges for listeners with hearing loss. Hearing aid speech processing often conflicts with those goals and strategies, degrading music to such an extent that patients gradually stop listening to music altogether.

Music is well-known to have great social and emotional significance for young people. However, Cohen, Bailey, and Nilsson (2002) found that people well into old age continue to consider music important or very important in their lives.

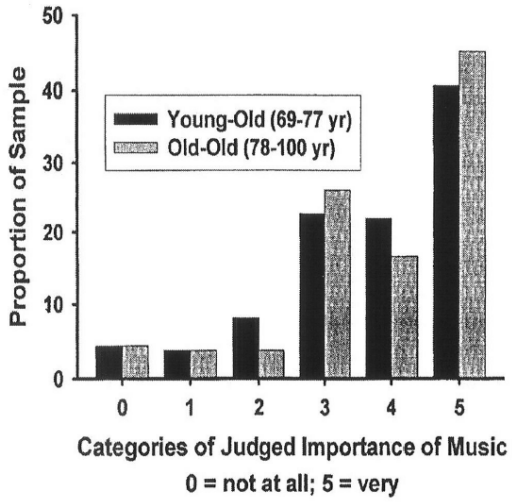

Figure 1: People well into old age continue to consider music important or very important in their lives (Cohen et. al., 2002).

The love of music isn't lost with hearing loss, but the ability to enjoy music may be negatively impacted. In a survey of listeners with hearing loss conducted by Leek and colleagues (2008), about half of survey respondents listened to music at least daily, and almost 30 percent of respondents reported that their hearing losses affected their enjoyment of music. Listeners reported that music was too loud or too soft, that they have difficulty recognizing melodies and understanding lyrics. Leek suggests that 25–30 percent of hearing aid patients may have difficulties with listening to music and may require extra attention from audiologists to minimize those problems.

Hearing aid wearers are not satisfied with the sound of music in their hearing aids. One need look no further than the Internet to find hearing aid wearers describing music as "muted, distant, fuzzy, dull, muddy, thin, steely, compressed" and "lacking a sense of the performance space." Complaints also include: "Why does music sound so bad through my hearing aids? It's like a cheap transistor radio." Moreover, audiologists are not satisfied with their ability to fit hearing aids for music listening, reporting that "sometimes the best we can do is put Scotch tape on the mics," (referring to a practice once recommended to mitigate hearing aid microphone saturation when listening to loud music). The hour is ripe to provide a comprehensive solution for music listeners with hearing loss and the audiologists that serve them.

Designed for music listening

Most implementations of a music memory in hearing aids are configured as an offset to the normal speech-listening memory, including previous Starkey Hearing Technologies hearing aids. This is convenient as it allows the manufacturer to make small and easily applied adjustments to the prescriptive targets and signal processing designed for speech. But why should the behavior in music be an offset from the behavior with speech? They are very different acoustic signals that are often met with different listening goals. For speech, the goal is to maximize speech intelligibility without sacrificing comfort. For music, the goal is to maximize the enjoyment of the music. Given these different goals, the best approach is to treat music independently.

The new Music memory from Starkey Hearing Technologies was designed for music listening from the very beginning. It consists of three main components:

- A new fitting rationale specifically designed for music.
- A new dynamic range compressor designed to complement the music fitting rationale.
- New controls in Inspire to facilitate fitting the new music memory.

New fitting rationale

Rather than a modification to an existing fitting rationale like NAL-NL2 or DSL 5.0, Starkey Hearing Technologies' new music fitting rationale is based solely on what is important for listening enjoyment of music. Proprietary research has shown that this is driven by two primary factors:

Providing transparent sound quality while restoring loudness for loud music. This necessitates providing a flat insertion gain and linear non-compressive amplification at these higher input levels. At the same time, some gain must be provided to compensate for the hearing loss. At these levels, it is as if the patient really wants nothing more than a large volume control. Starkey Hearing Technologies' research team did extensive investigation into preference for loudness of supra-threshold music across a variety of hearing losses. This work led to fitting targets for loud music that are different in frequency shaping from those for soft music.

Providing audibility for soft music. This requires shaping the frequency response of the gain for soft inputs. For typical hearing losses, this often means providing amplification to the extreme high and low frequencies, while providing less amplification for the mid frequencies.

Developing a novel fitting rationale required investigation into the importance function of various intensities of soft music. This was empirically balanced with the goal of minimizing the amount of compression over a range of intensities.

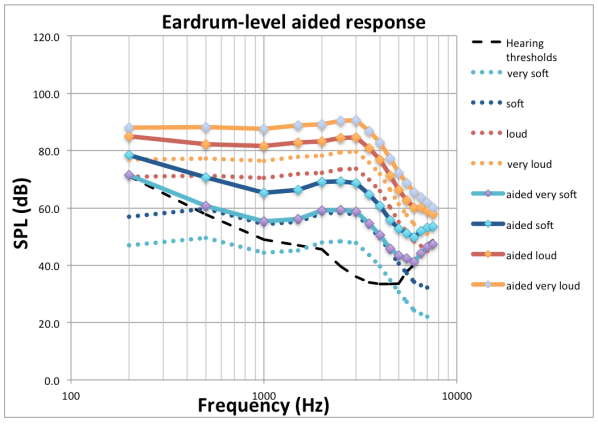

Figure 2. Frequency response characteristics for a range of input levels. The dotted curves represent a range of inputs to the unaided ear. The solid lines represent the aided eardrum-level response for the same range of inputs. The dashed black line represents the exemplar hearing threshold.

Looking at Figure 2, we can see an example of the effect for one fitting. The black dashed line represents the hearing threshold in SPL. The series of dotted lines represent a range of music input level intensity. The solid lines represent those same input levels after amplification. We can see that the soft music has been raised to audibility, primarily by amplifying the extreme low and high frequencies. At the other end of the intensity spectrum, the loudest musical inputs have a relatively flat response, indicating a flat insertion gain. Coupled with linear (non-compressive) amplification, this allows for transparent amplification of high-intensity portions of music.

One thing to note: the resulting gain characteristics are quite compressive in some frequency regions, while being linear in other regions. This is in contrast to some accepted wisdom that says music fittings need to be linear (or nearly so) to be preferred by hearing impaired individuals. Throughout the research and development of the dedicated music memory, it became clear that we as an industry had very little understanding of the needs of the hearing impaired regarding music listening. We need to be especially careful to examine "standard practice" before accepting it at face value.

New compression

A new compression architecture was developed to complement the aims of the new music fitting rationale. A new region of linear amplification (segment 3 in Figure 3) was added to provide the high-level linearity required by the fitting rationale.

The dynamic characteristics of the amplifier were also significantly altered. This was motivated by two goals:

Making compression behavior more consistent for music. Dynamic range compression for speech has become quite sophisticated, attempting to provide maximum speech intelligibility, without producing loudness discomfort. At the same time,

little attention has been paid to the overall perception of the sound. As previously stated, the goal for music is quite different. With music, the aim is to maximize enjoyment of music by providing a perceptually consistent experience during which gain changes are stabilized over time.

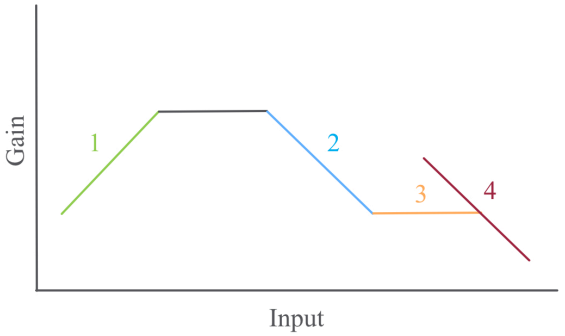

Figure 3: A cartoon of the music compressor's Input/ Gain characteristic. Segment 1 depicts expansion to minimize low-level noise; segment 2 depicts compression to transition between more gain for soft music and less gain for loud music; segment 3 depicts linear amplification for loud music; segment 4 depicts output compression limiting to prevent distortion of highest intensities.

Making dynamic amplification as compatible with music as possible. We know that the dynamics of music are larger and slower than speech, so that any artificiality in the quality of amplification will be magnified as compared to speech. With these considerations in mind, the dynamics of Starkey Hearing Technologies' music fitting rationale have been designed to present natural perception of loudness while accommodating preferred sound quality. Given the immense range of musical styles, this is a challenging prospect that was addressed first through the characterization of dynamics across a range of musical genres and styles. This characterization contributed to the development of average music spectra that are a foundational contributor in the calculation of the music fitting rationale. This work also identified representative music samples that were used during subsequent validation of music listening preference.

High-quality replication of music requires that the musical input is not distorted by the hearing aid front end, for this reason hearing aids on the Synergy platform allow for inputs as high as 110dB SPL.

New Controls in Inspire

The third major piece of the dedicated music memory is the controls in Inspire. It is instructive to contrast what we have historically known about fitting a memory for speech versus fitting a memory for music.

In addition, as we have seen, there are a number of misconceptions about how a hearing aid should be configured for music. We should avoid those

Knowledge Base		
	Speech	Music
Input spectra	Well established spectral characteristics	Variable and based on preference
Input levels	Generally accepted as 65dB SPL for conversational speech at 1 meter	Dramatically varies with listener preference
Prescriptive Targets	Established prescriptive rationales	Previously undefined
Appropriate Gain	As suggested by the prescriptive rationale	Unknown. Treated as a speech-offset
Outcome measures	Standardized speech intelligibility and subjective outcome measures	No objective outcome has been defined

pitfalls and not treat music like speech. In fine-tuning the hearing aid for music sound quality, the key to software design is facilitating dialog with the patient. After all, if our goal is to maximize the enjoyment of music, our first criterion is the patient's experience.

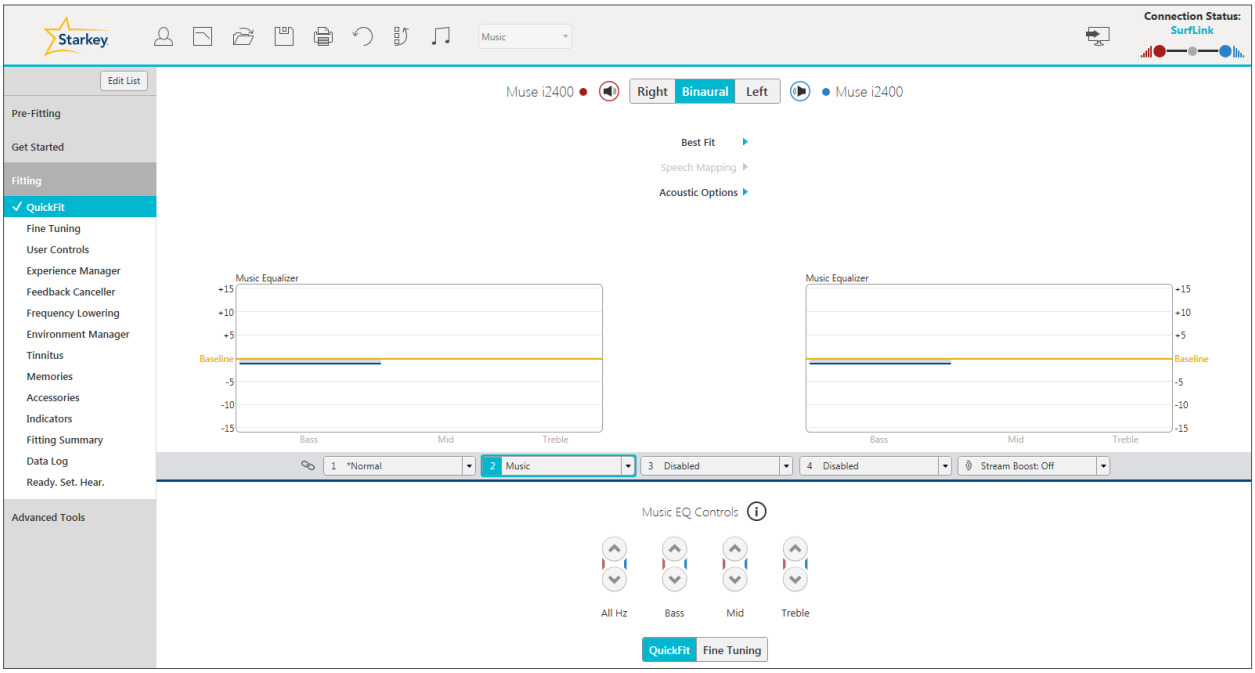

Figure 4

The Inspire QuickFit screen for music is designed to facilitate a conversation about music quality. It has controls that are easily understood by both clinician and patient. Frequencies are clearly grouped into Bass, Mid, and Treble controls and a broadband overall loudness control is provided.

New graphs have been designed to support these conversations. The Baseline or "zero" line represents the music target for that particular patient (and is different for every fitting). Any adjustments away from the default music fitting will be shown as a blue bar moving away from the zero line with additive gain being shown as positive values and reduced gain as negative values. The intent in this design was to anchor visuals to a perceptually meaningful reference, which is the deviation from the original music fitting. We have found that classical music is easily evaluated by the majority of patients, regardless of their musical tastes, so we have provided samples in the Inspire software.

Conclusion

Starkey Hearing Technologies' new dedicated music memory is a wholly new imagining of fitting for music. It is a departure from previous attempts at music fittings by starting from the ground up. It incorporates a new fitting rationale for music, with complementary new compression, and new controls in Inspire to facilitate a discussion around music fitting. The result is a complete package dedicated to bringing the enjoyment of music back to the patient.

Reference

Cohen, A., Bailey, B., & Nilsson, T. (2002). The importance of music to seniors. Psychomusicology, 18, 89-102.

Leek, M. R., Molis, M. R., Kubli, L. R., & Tufts, J. B. (2008). Enjoyment of music by elderly hearing-impaired listeners. J Am Acad Audiol, 19:519–526.

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