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DSL v5 in Connexx 7

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First fit is an essential stage of the hearing aid fitting process and is a cornerstone of the ultimate fitting success. As such, various methodologies have made their appearance in time to fulfill this function. Each of them has its own philosophy and its approach, and often the fit-to-target is considered a quality assurance of the fitting. This article will detail the approach proposed by the Desired Sensation Level or DSL method as well as its implementation in the Connexx 7 software.

History

The main goal of the earliest versions of DSL was to provide specified target sensation levels for amplified speech as a function of frequency and hearing level. These desired sensation levels had to give comfortable speech sensation, good speech recognition performance, and protection against uncomfortably loud sounds with appropriate output limiting targets. The first implementation as a first fit formula in manufacturer software was done in the early 90's, with DSL v3.0 particularly designed for young children's adaptation.

In the mid 90's, another version of this algorithm called "DSL input/output" formula (DSL[i/o]) was proposed to provide prescriptive targets for fitting hearing aids with wide dynamic range compression. This DSL[i/o] method was implemented in most hearing aid manufacturers' softwares for a wide range of hearing losses. The DSL[i/o] algorithm incorporates loudness data and a curvilinear fit to target high speech recognition performance for young children with sensorineural hearing loss.

Due to the evolution of hearing instrument technology, new approaches to pediatric amplification, and objective measurements, a new version of DSL combining DSL i/o and DSL method was developed. This new version, called DSL v5, was included in Connexx 7 for use with Siemens hearing aids.

Connexx 7 Implementation

DSL v5 is one of the available fitting formulas on the Connexx 7 first fit page for all Siemens devices.

Figure 1. DSL v5 can be found on the *First Fit* page in Connexx 7

To achieve a first fit with DSL v5, air conduction audiometric values are necessary for 500 Hz, 2000 Hz, and at least a third frequency. If not inserted, all other audiometric values will be interpolated or extrapolated from provided values to calculate a target. Needless to say, the more audiometric values are available, the more precise the resulting first fit will be.
If an *InSituGram* has been conducted, the DSL v5 algorithm in Connexx 7 will use these values to calculate targets that will take into consideration the acoustic coupling in the ear canal. A first fit with DSL v5 in Connexx 7 takes into account three threshold levels: air conduction (AC), uncomfortable level (UCL), and bone conduction (BC).

DSL v5 Options

The implementation of DSL v5 under Connexx 7 offers many parameters of customization:

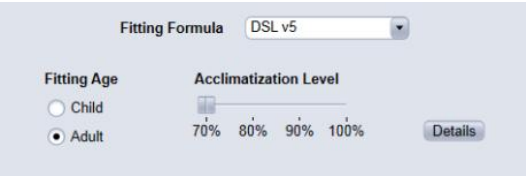

Figure 2. Options for customizing DSL v5 in Connexx 7

Acclimatization Level

The acclimatization level allows the DSL algorithm to generate slightly reduced gain for first time users. The acclimatization level, adjustable between 100% and 70 % by 10% steps, can be set according to the amplification experience of the patient, while preserving the DSL approach and philosophy. According to the chosen percentage, these settings propose not only reduced target gains but also the corresponding compression settings.

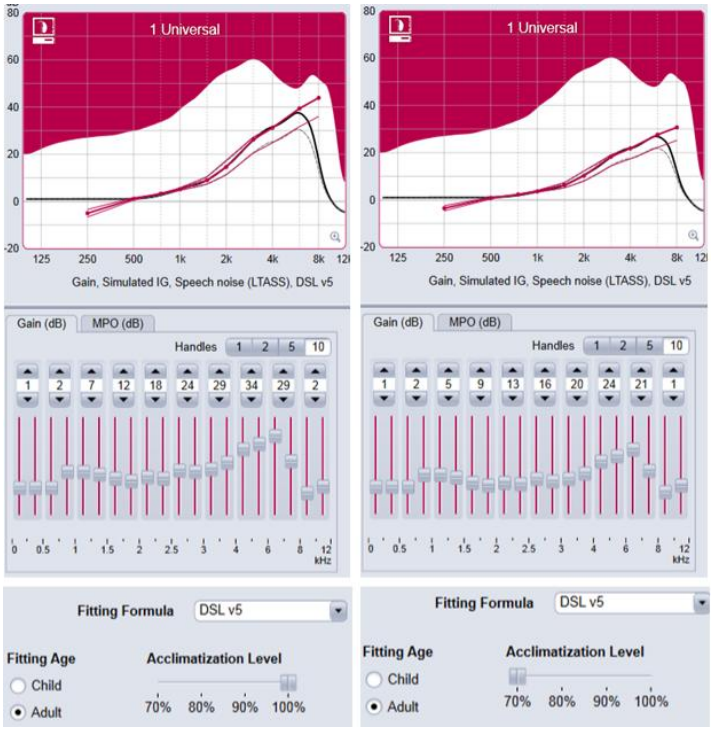

Figure 3. Acclimatization levels 100% and 70%

Under the *Personalization* and *Acclimatization Manager* tab, the overall gain can be set to automatically increase up to a certain acclimatization level, during a chosen period of time.

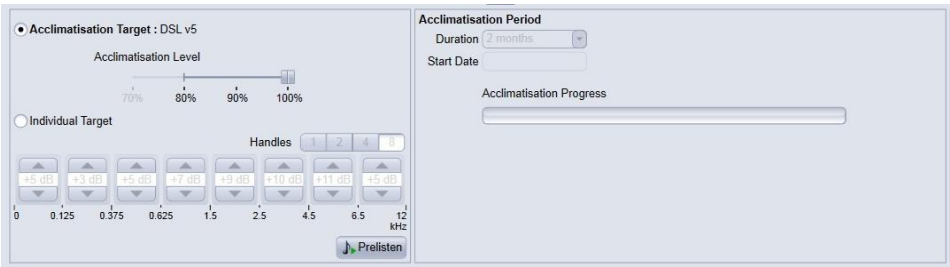

Figure 4. Acclimatization options for DSL v5 in Connexx 7

Fitting Age

Switching from an *Adult* to a *Child* profile will deactivate the acclimatization level option, and will propose specific target gains for pediatric fittings. When *Child* has been selected, the client age from the current Connexx session is used to determine the appropriate age-specific REUG and RECD curves. These statistical curves can be overridden in the RECD/REUG tab if actual measured curves are available.

Details

The *Details* icon will open the DSL v5 configuration settings page. These options allow the hearing care professional to enter the audiometry testing conditions. If *InSituGram* has been conducted, these details are not applicable. But for conventional audiometry, these options determine the precise calibration of the system.

Figure 5. DSL v5 configuration settings

Measurement Type

Here, the hearing care professional can specify the kind of measurement and the type of transducer used for the audiometry. Each of these parameters will lead to a conversion of the audiogram values to calculate the target.

- Headphones (TDH): *choose this option for thresholds obtained with a headphone.*
- LoudSpeaker with 0, 45, and 90 degrees azimuth: *choose one of these options for behavioral thresholds obtained with a loudspeaker.*
- Insert phone with tip or individual earmold: *choose one of these options for behavioral thresholds obtained with insert phones.*
- ABR (Auditory Brainstem Responses) with tip or individual earmold in normalized HL (nHL) or estimated HL (eHL): *Choose one of these options for electrophysiological thresholds (ABR, ASSR...).*

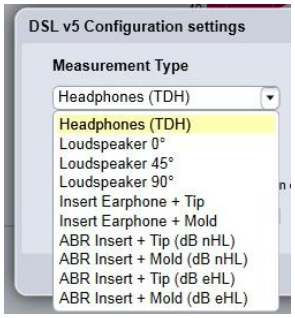

Figure 6. Types of audiometry and transducer used

RECD Type:

Here the hearing care professional can specify the kind of coupler used to measure the RECD, when available.

• Coupler type: HA1 coupler connection for ITE device, or HA2 coupler connection for BTE instruments

• Tip or Mold: the selection here takes into account the ear canal resonance when closed with a tip or a mold.

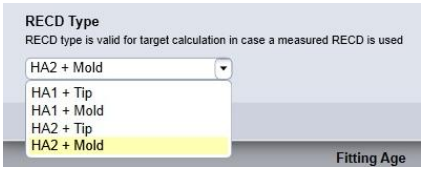

Figure 7. RECD type options

DSL v5 ABR correction:

In case of an objective audiometry like ABR, it is possible to enter specific normalization values in this field. For different frequencies, preset corrections are visible and the effective correction can be modified in the *Apply* section (see Figure 5). These corrections are taken into account if one of the two ABR inserts (dB nHL) choices is selected in *Measurement Type*.

DSL v5 First Fit results

The DSL v5 formula considers the audiometric thresholds and the parameters described above (Acclimatization level, Age, etc.) to calculate the gain targets. These targets represent the desired gain the device should deliver to compensate for the patient's hearing loss for each audiometric frequency, and for three input levels (50, 65, and 80 dB SPL). Targets provided by DSL v5 are defined for the real ear. They are, therefore, independent from the selected acoustical parameters and from the hearing aids selected. For the same hearing loss, different hearing aid form factors and acoustical parameters will lead to identical target gains in REAG or REIG.

If the REUG is different from the standard KEMAR REUG used by default (i.e. when individually measured with an in-situ measuring system like Unity 3), then for the same hearing loss, the REIG is modified accordingly to ensure that the REAG remains the same. Connexx will then adjust the device parameters, this time taking into account the type of device and the acoustical parameters, to obtain the right sound pressure prescribed by DSL for each of the three input levels at the eardrum. This means, in a fitting with a particular hearing loss, if the acoustical parameters are modified, then different settings must be applied to get back to the prescribed sound pressure at the eardrum. For the same hearing loss, targets that are displayed in 2cc coupler will thus appear different for different acoustical parameters (even though they are identically displayed in REIG or REAG). Potential differences in conversion factors (REUG, RECD, MLE, etc.) should also be considered when directly comparing targets for different DSL v5 implementations, such as those implemented in other manufacturer software. Furthermore, the original DSL v5 formula uses level dependent speech signals as the base for gain calculations, which impacts the exact target gain values.

Parameters set by the first fit algorithm

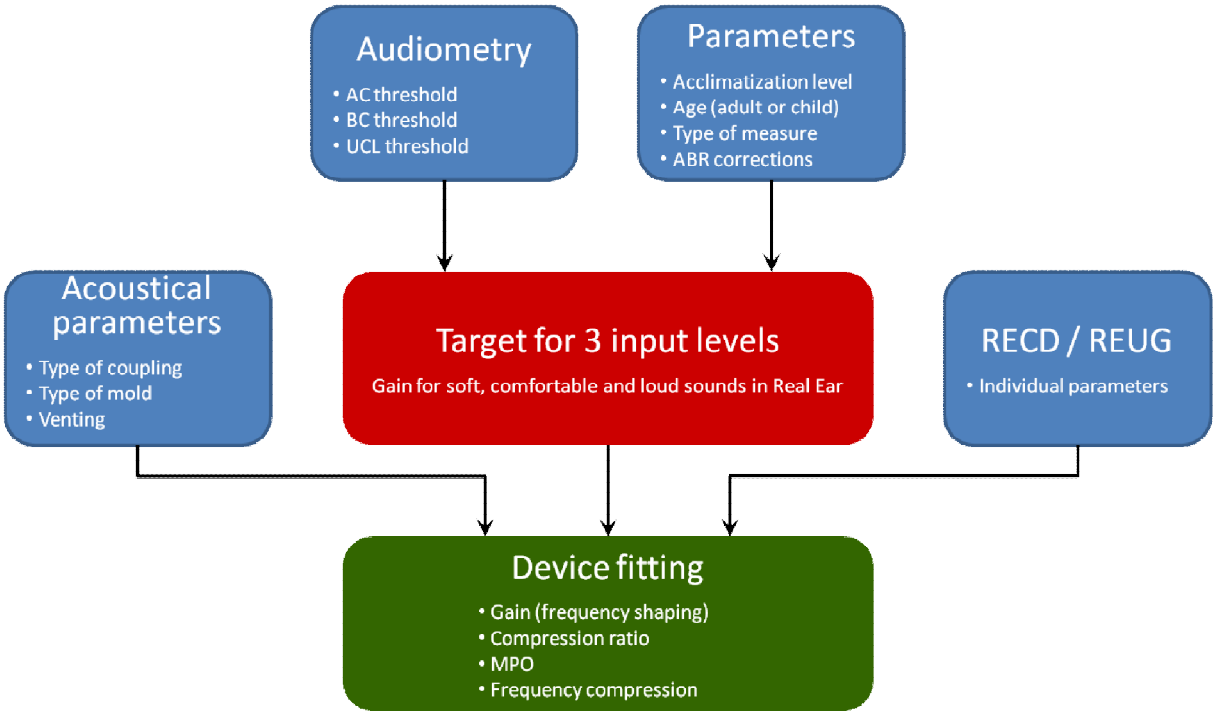

Figure 8. The First fit process for DSL v5. The audiological parameters input provided by the patient and the hearing care professional are shown in blue. The target as calculated by DSL v5 is in shown in red. The result is the device fitting shown in green. With audiometic thresholds and some customization parameters of DSL v5, Connexx 7 calculates the target gains for three input levels with DSL. Next, taking the acoustical parameters and RECD/REUG values into account, Connexx adapts gain, compression (including MPO and potentially frequency compression) to match in real ear, the target provide previously by DSL v5.

Curve gain

The frequency shaping of the gain curve is set to match the soft level target (LI 50).

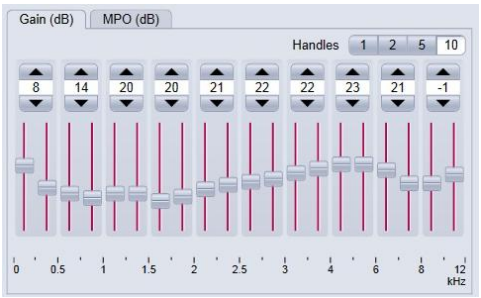

Figure 9. Example of frequency shaping with DSL v5. Gain is adjusted to match the soft level target.

Compression

Compression parameters are adjusted by Connexx to match the target curve provided by DSL v5. With binax and micon, two compression kneepoints and compression ratios are available to better match these targets. DSL v5 is originally designed for a WDRC method with fixed time constants. Generally, fast time constants are used to ensure maximum audibility of speech cues. This is why syllabic compression is the default compression method selected. However, dual compression can also be manually selected.

Compression Kneepoints

The LTASS (Long Term Average Speech Spectrum) is the reference signal for the DSL formula. In general, it is desirable to place the dynamic range of the speech signal within the range of compression, often referred to as wide dynamic range compression (WDRC). To accomplish this, compression kneepoints need to decrease with increasing frequency according to the speech spectrum (Schultz-Amling, 2015). As shown in Figure 10 left panel, LTASS has roughly 15 dB more energy in the low frequencies than in the highs. Compression kneepoints therefore need to be set accordingly to ensure that the entire speech signal is compressed consistently across all the frequencies.

Moreover, CK values are adapted to separate soft, medium, and loud speech signals from one another. Therefore, soft speech is set below CK1, average speech is set between CK1 and CK2, and loud speech is set above CK2. CK1 and CK2 are always set according to this method with DSL v5. So regardless of the hearing loss or selected hearing aids, CK1 and CK2 are always set at the same values.

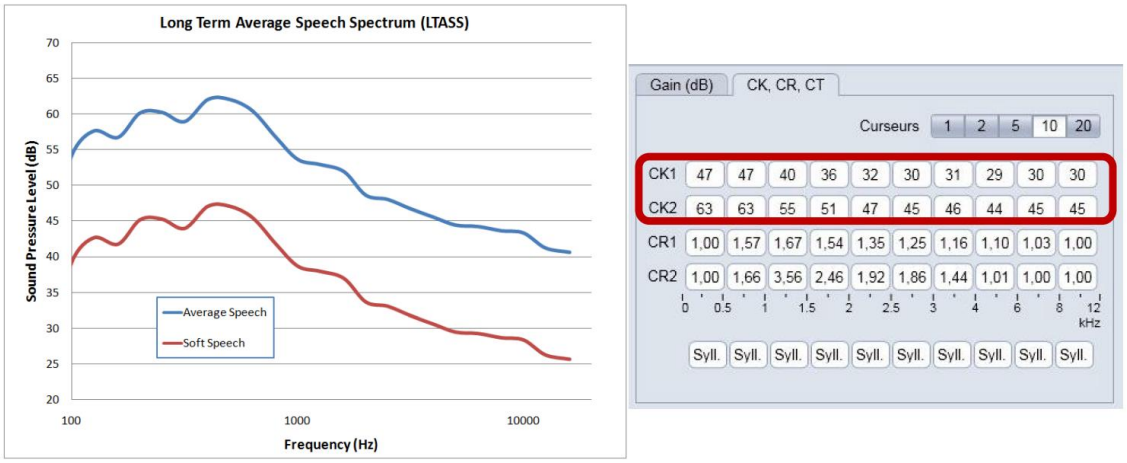

Figure 10. Left panel: the long term average speech spectrum (LTASS blue curve), as well as for soft speech (red curve). There is a level difference of 15 dB between low and high frequencies. Right panel: compression thresholds (CK) set by traditional formulas such as DSL follow this difference to synchronize compression activation for speech. That is, the first kneepoint corresponds to soft level speech, the second kneepoint to average level speech.

Compression ratio

The CR1 and CR2 values are set by the first fit algorithm to match the medium and loud input level targets, respectively. The purpose of compression is to provide different gains for different input levels, and while these are adjusted automatically by Connexx, compression kneepoints and ratios can also be manually adjusted.

MPO (Maximum Power Output)

In addition to providing targets for gain, DSL v5 also provides an output limiting target to protect patients from very loud sounds. This target is used by Connexx to set the maximum power output of the device (MPO).

Frequency compression

A first fit with DSL v5 in Connexx 7 may activate frequency compression. This is activated only if the hearing loss indicates a need for this feature. Namely, frequency compression is activated for patients with suspected cochlear dead regions, or whenever even high levels of amplification may not be enough to restore audibility. For more information on frequency compression in Connexx 7, refer to the overview by Serman, Hannemann, & Kornagel (2013).

Bone conduction thresholds strategy

The strategy applied in DSL v5 takes into account conductive hearing loss by increasing gain and making compression more linear.

DSL v5 in a nutshell

DSL v5 aims to provide audible and comfortable speech cues in all listening situations. It provides less overall gain than in the previous DSL versions to avoid saturation of the hearing aid for average to loud speech, and ensures that the peaks of speech are within the patient's audible range. DSL v5 also supports binaural fittings with a -3 dB gain correction to compensate for the binaural summation effect.

DSL v5 offers two rationales: pediatric and adult. DSL v5 Child targets are formulated for congenital hearing loss, regardless of the child's age, while DSL v5 Adult targets are formulated for those who have acquired hearing loss. The Adult targets are approximately 7 dB lower than the targets for children.

References

Schultz-Amling, R. (2015). binax fit: How It's simulated in Connexx, How to Verify It, And How to Match-o-Target the Easy Way. Sivantos Publication.

Serman, M., Hannemann, R, & Kornagel, R. (2013). micon Frequency Compression. Sivantos Publication.

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