Finding the Optimum Gain:
NAL-NL2 and Trainable Hearing Aids

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... with a little help from Dr. Harvey Dillon (NAL, Australia)
Hearing aid fitting is a multi-step process

- NAL-NL2
- Auditory Training
- First Fit
- Fine-Tuning & Trainable Aids
Finding the Optimum Gain: NAL-NL2 and Trainable Hearing Aids
NAL-NL2

- Rationale: Maximizing Intelligibility and accounting for individual factors
- Developers: Harvey Dillon, Gitte Keidser, Theresa Ching, etc.
- Successor of, and improvement upon: NAL-NL1
- Release April 2010
- Stand-alone version from NAL, CXX6.4, Unity
Motivation behind NAL-NL2

- NAL-NL1 was often perceived as too loud
- The underlying principles and assumptions have been evaluated
  - Is the rationale appropriate?
  - What other psychoacoustics should be taken into account?
  - Do new hearing aid users prefer less gain than experienced hearing aid users?
  - Do other individual factors play a role? (age, gender...)
Research behind the formula

- **Basic research**
  - Led by Theresa Ching
  - How much information can people with hearing loss extract from amplified speech?
    - improved model for speech intelligibility

- **Empirical research**
  - Led by Gitte Keidser
  - What patients prefer by sound quality & overall loudness
    - individual factors affecting preferred amplification

- Combine knowledge from both research efforts for new formula
NAL-NL2: What’s different

Rationale of maximizing speech intelligibility remains

1. Changed the intelligibility modelling so that new target gain provides more speech intelligibility
   - more gain for soft sounds (more compression!)
   - less gain for low frequencies

2. Considers additional individual factors:
   - Age: More gain for children than adults
   - Experience: More gain for more experienced users
   - Gender: More gain for male users
   - Language: More low frequency gain & less high frequency gain for tonal languages
Factoring in individual differences: HI Experience vs Loudness

New HI users prefer less gain than experienced users as hearing loss increases.

- Prescriptive formulas can only generalize trends based on widely varied individual data.
ISMADHA Audiogram Flat-2
NAL-NL2: Age

Higher overall gain prescribed for children than for adults
NAL-NL2: HI experience

Up to 10 dB less target gain for new users to account for acclimatization
NAL-NL2: Gender

More gain for male users than female users

Graph showing ISMADHA F2 65 dB for different frequencies with more gain for male users than female users.
NAL-NL2: language

Tonal languages rely more on vowels and not as much on consonants. More low frequency gain and less very high frequency gain.
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NAL-NL2 vs ConnexxFit: open fittings

More than 20 dB difference above 4 kHz!
Who is right?
First Fit: manufacturers‘ defaults

Frequency Responses for commercially available Hearing Aids after FirstFit for Audiogramm ISDMADHA 2
(KEMAR, ISTS Noise, L_I=65 dB)
First Fit: manufacturers‘ defaults

Frequency Responses for commercially available Hearing Aids after FirstFit for Audiogramm ISDMADHA 2
(KEMAR, ISTS Noise, L_i=65 dB)
First Fit

- Hypothesis:
  - Some manufacturers optimize spontaneous acceptance rather than speech intelligibility

- Verification / Falsification:
  - Conduct & analyse clinical studies with different „First Fits“
    - Real Ear Measurements
    - Speech Intelligibility tests
    - Preference (Spontaneous acceptance)
First Fit: Clinical Study (University Oldenburg)

Test protocol:

- 15 subjects
- mild to moderate hearing loss
- Mean age = 67 yrs
- 5 female, 10 male
- all new users

- Open fitting (RIC)
- Two manufacturers
- First Fit
- REIG measurements
- speech intelligibility
- preference
Measurement with 65 dB ISTS, setting after First Fit

Large differences! 15 dB at 1.5 kHz, 17 dB at 4 kHz
Instrument B much louder
First Fit: Speech intelligibility in quiet

Boxplot, showing average speech intelligibility scores for soft speech in quiet

**Instrument B yields higher speech intelligibility scores for soft inputs**
First Fit: Speech intelligibility in noise

Speech intelligibility in Noise at $L_s=65\text{dB}$ in $S_0N_{180}$ condition
(German speech material Oldenburger Satztest)

Boxplot, showing average speech intelligibility scores for speech in noise

➔ Instrument B yields higher speech intelligibility scores in S0N180 condition
First Fit: Preference

- Instrument A is preferred by 73% of all subjects right after First Fit (and also after home trial)
First Fit: Conclusions from Clinical study

- Hearing aid B applies more high-frequency gain than Hearing Aid A
- Hearing aid B results in better speech understanding
- Hearing aid A is clearly preferred!
- Manufacturer A seems to successfully optimize spontaneous acceptance
First Fit: „Optimum“ high-frequency gain

![Graph showing the relationship between REIG at 4kHz and perception in quiet, noise, and preference for different devices.](image-url)
First Fit: Summary

- Manufacturer’s First Fit often prescribes much less (high-frequency) gain than scientific formulas like NAL-NL2

**Who is right: NAL-NL2 or ConnexxFit?**

- Both! When to use which formula:
  - For optimal speech intelligibility → NAL-NL2
  - For optimal spontaneous acceptance → ConnexxFit

- Due to auditory deprivation, subjects often prefer less gain AND may not be able to use audibility for understanding (“Desensitization”)

- With gradual fine-tuning, learning hearing aids, automatic gain increase and auditory training, hearing aid wearers will finally accept the required amount of gain to achieve optimum speech understanding
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NAL-NL2

Auditory Training

First Fit

Fine-Tuning & Trainable Aids
Trainable Hearing Aids: Situation Specific Listening Goals

A

Frequency Response Compression

Intelligibility

Speech

B

Frequency Response Compression

Sound Quality

Music

C

Frequency Response Compression

Comfort

Noise
Situation & level specific preferences
Study at NAL (Convery et al. 2008)

- 28 participants
- Fitted to NAL-NL1 target (less 3 dB overall gain)
- Equipped with small sound recorder and diary
- Recorded 2 min of daily listening environments, classified and rated the overall loudness of the situation

Convery E., Chalupper, J., Keidser, G. “The importance of acoustic parameters in designing an efficient algorithm for training hearing aids”, presented at ASA 2008, Canberra
Preferred loudness depends on listening situation

→ Situation specific optimization required to get it right in all situations

Situation & level specific preferences
Study at NAL (Convery et al. 2008)
Situation & level specific preferences
Study at NAL (Convery et al. 2008)

On average, 70% of all subjects assigned more than 1 category per situation

Class dependent learning not able to achieve comfortable loudness in all situations

Compression learning more effective than class dependent learning?
Situation & level specific preferences
Study at NAL (Convery et al. 2008)

- Offline simulation of four different learning algorithms
- Prescriptive formula achieves comfortable loudness in ~50% of recorded situations
- Clear improvement with all learning algorithms

→ Situation-specific Compression learning is the most effective learning algorithm
New Approach: Situation-specific compression learning

- Learning
- VC & Treble Changes
  - Speech
  - Music
  - Noise
- Setting For Speech
- Setting For Music
- Setting For Noise
- A
- B
- C
- Automatic Switching
- Universal Program

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Finding the Optimum Gain: NAL-NL2 and Trainable Hearing Aids
Auditory Training
Desensitization & Deprivation

- If hearing loss > 60 dB HL @ 4kHz, audibility has very little or no benefit regarding speech intelligibility
- Potential cause for desensitization: dead regions & deprivation
- Auditory training can address deprivation („Re-train the brain“)
Auditory training
PC-based training (eARena)

- movies
  - Hearing and hearing loss
  - Benefits of modern hearing aids
  - Multimedia user guide

- auditory training
  - 20-day training curriculum
  - 5 days short version (trial phase)
  - extension >20 days possible
  - 30 minutes / day

- for end consumers at home
- or with assistance of the hearing care professional

- available on hybrid DVD-Rom
  - DVD player / TV
  - Computer

- currently available in English, French, German, Italian, Spanish
Auditory training
PC-based training (eARena)

- based on experiences from science and practice (Wright, Speth, LACE, Gatehouse, Tyler, Lehrl, Gebhardt, D. Moore)
- dynamic
  Difficulty level is user adaptive
  70% of all trials are correct
- easy to use
  No installation needed
  No special computer knowledge necessary
- relevant
  only everyday sounds are used
Auditory training
PC-based training (eARena)

Exercise types
- Loudness scaling
- Perception of everyday sounds
- Basic auditory skills
- Word recognition
- Timbre discrimination
- Speech in noise
- Cognitive skills
- Homework
- Tip of the day

Dynamic & individual
- Difficulty level is user adaptive
Auditory training
Study Results

Personal training

PC-based training

Control

Start interview
OLSA (S0N90)
Freiburger (quiet)
KAI
SSQ*
GHABP*
Quality of Life*

Start interview
OLSA (S0N90)
Freiburger (quiet)
KAI
SSQ*
GHABP*
Quality of Life*

Exit interview
OLSA (S0N90)
Freiburger (quiet)
KAI
SSQ*
GHABP*
Quality of Life*

* Hand out to patients

Session 1:
Pre-measures

Session 2:
Post-measures

Session 3:
Longterm effects

start

4 weeks

3 months

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SSQ (Gatehouse and Noble 2004)
Speech, Spatial and Qualities of Hearing Scale

Improvement for control group!
- new hearing aids
- participation in study

Auditory training significantly improves hearing aid benefit with regards to subjective speech intelligibility
No improvement without training!

→ Auditory training important in habituation phase

PC-based training somewhat more beneficial for first time users
Finding the Optimum Gain: NAL-NL2 and Trainable Hearing Aids

- Retrain auditory brain to overcome desensitization
- Accept optimum gain
- Optimum speech intelligibility
- Individual factors: age, experience, gender, language
- Optimum spontaneous acceptance
- Individual factors: critical gain curve
- Individual, situation-specific preferences
- Gradual gain increase (manual or automatic)
- Fine-Tuning & Trainable Aids

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