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with Catherine V. Palmer, Ph.D.

Normal loudness perception: Is it important, is it achievable?

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Normal loudness perception: Is it important, is it achievable?

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Significant Contributions from:

Reem Mulla and Min Zhang

PhD students at the University of Pittsburgh

Common Goal

- Return normal loudness perception (DSL)
- To a lesser extent NAL
- "Soft sounds should sound soft, moderate sounds should sound moderate, and loud sound should sound loud"
- Like the idea that at least we can make something normal

Verification of return to normal loudness perception

- Judgments in the sound booth
- Profile of Aided Loudness (PAL)
- Patient interview

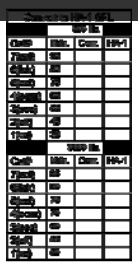
Option 1: Judgments in the sound booth

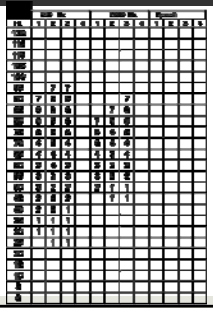
- **Contour Test of Loudness**
  - Listeners judge the loudness of sounds presented in the sound field using a seven category loudness growth scale to determine the sound level required for each one of these categorical levels for a given listener.
- Controlled
- Not real world
- Timing?
- Based on complaint?

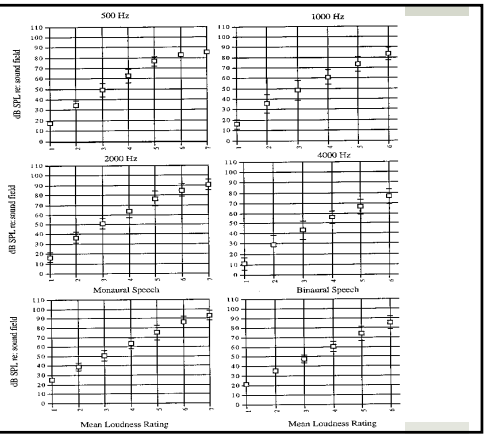
The Contour Test of Loudness Scoring Sheet

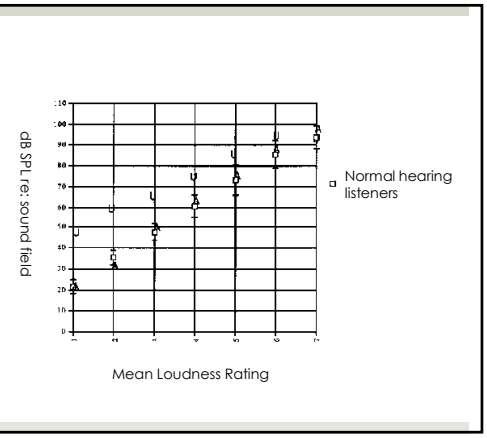
Loudness Categories

7. Uncomfortably loud
6. Loud, but o.k.
5. Comfortable, but slightly loud
4. Comfortable
3. Comfortable, but slightly soft
2. Soft
1. Very soft



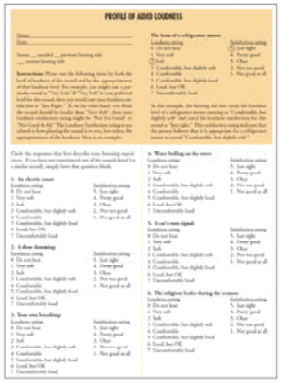






Option 2: Profile of Aided Loudness

- **Profile of Aided Loudness**
  - A subjective outcome measure of loudness. It is the only measure currently available that is designed specifically to assess aided loudness perception in daily life.
  - Includes 12 environmental scenarios, 3 for each category, soft, moderate and loud (e.g., own breathing, electric razor, door slamming).
  - Listeners are asked to rate each scenario in two different scales, one for loudness and one for satisfaction of that loudness rating.


PROFILE OF AIDED LOUDNESS

Loudness and Satisfaction Rating Scales on the PAL

Loudness Rating	Satisfaction Rating
0 – Do not hear	5 – Just right
1 – Very soft	
2 – Soft	4 – Pretty good
3 – Comfortable, but slightly soft	
4 – Comfortable	3 – Okay
5 – Comfortable, but slightly loud	
6 – Loud, but OK	2 – Not too good
7 – Uncomfortably loud	1 – Not good at all

Option 3: How do things sound?

- Patient description
- Decide the frequency range
- Decide the input level
- This is what the "assistant" is based on in the software

Relationship Between Measured and Perceived Loudness Perception

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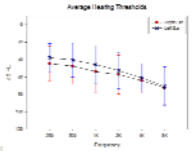
PREMISE

- Hearing aid fitting protocols verify that speech sounds are audible, outputs are safe, and normal loudness perception is returned for listeners with mild to moderately-severe sensorineural hearing loss.
- Returning normal loudness perception can be subjectively evaluated through a self-perception questionnaire (Profile of Aided Loudness, PAL) (Palmer et al, 1999) or a real-time loudness judgment test (The Contour Test of Loudness) (Cox et al, 1997).
- A self-assessment with a rating of satisfaction included may be more clinically feasible than to complete test booth procedures.
- The current investigation determined the correlation between the PAL and the Contour Test of Loudness.
- A positive relationship between the PAL and the Contour Test of Loudness would allow the choice of one, efficient measure.
- A lack of positive relationship would necessitate further research.

Method

- Participants:
  - 30 adults (mean age= 63) with bilateral mild to moderately-severe SNHL.
  - Successful bilateral full time hearing aid users of at least 2 months (mean time= 18 months).
  - Fitted by a clinic that follows best practice in hearing aid fitting.



Method

- Procedures:
  - Hearing Test
  - Aided Profile of Aided Loudness (PAL)
  - Aided Contour Test of Loudness
  - Stimuli: 500 Hz, 2000 Hz, and Connected speech
  - 5 dB step
  - RECD and REAR for soft, moderate, and loud sounds to insure audibility.

Descriptive Measures

- **Profile of Aided Loudness**
  - A subjective outcome measure of loudness. It is the only measure currently available that is designed specifically to assess aided loudness perception in daily life.
  - Includes 12 environmental scenarios, 3 for each category, soft, moderate and loud (e.g., own breathing, electric razor, door slamming).
  - Listeners are asked to rate each scenario in two different scales, one for loudness and one for satisfaction of that loudness rating.

- **Contour Test of Loudness**
  - Listeners judge the loudness of sounds presented in the sound field using a seven category loudness growth scale to determine the sound level required for each one of these categorical levels for a given listener.

RESULTS

- Group data for ratings of soft, moderate, and loud sounds on the PAL were compared to soft, moderate, and loud ratings on the Contour Test of Loudness completed in the sound booth for 500 Hz tone, 2000 Hz tone and connected discourse speech.
- For all three levels of sounds, soft (rating of 2), moderate (rating of 4), and loud (rating of 6), there was NO significant correlation between the PAL data and the Loudness Contour Test data obtained from the hearing aid users.

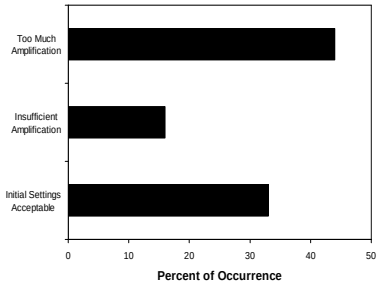
DISCUSSION

- The PAL requires hearing aid users to rate loudness of recalled sounds. Rating the loudness of sounds heard in a previous experience might result on data skews to memory experience, whereas the contour test requires HA users to rate the loudness of sounds in real time.
- For this group, the PAL and the contour test of loudness are measuring different aspects of loudness perception.
- Further research is needed to define those measurement variables.

What clinicians know…

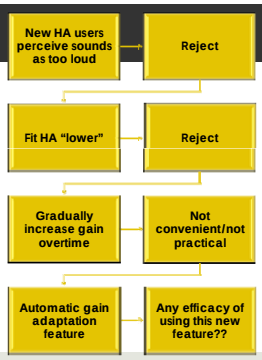
- On the day of the fitting, if you match targets, sounds are too loud (especially soft sounds?)
- So the patient enters a period of "adaptation"

Data from Schum D. Adaptation management for amplification. Seminars in Hearing 2001;22(2):173-182.
(142 individuals, first time and experienced users)



How can we manage adaptation?

Strategy	Who is the expert
Turn HA down based on patient report	Patient
Turn HA down with plans to turn it up over time	Audiologist and Patient
Turn HA down, aid tunes up to your goal over time	Audiologist
Trainable hearing aid	Patient (but audiologist's starting point matters)
Volume control/program button	Patient



Individual differences

- Put the individual in control…

Background

- Currently, "trainable" hearing aids refer to hearing aids that employ a strategy to track gain adjustments (either overall gain or compression based on gain as a function of input level) made by the hearing aid user and to modify the hearing aid gain/compression settings based on these user selections.

Figure 1. SII change obtained from the two groups for the soft speech (55dB SPL) and the soft noise (55dB SPL) inputs. SII change is determined by subtracting prescribed SII from preferred SII.

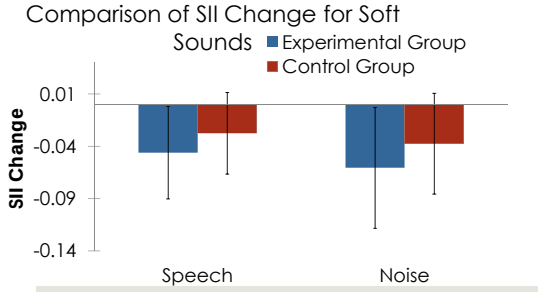
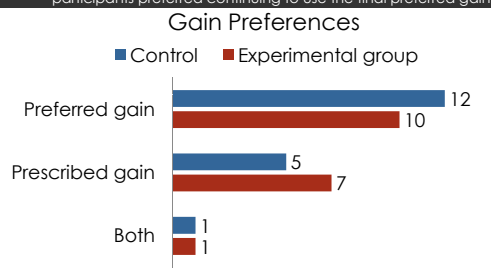
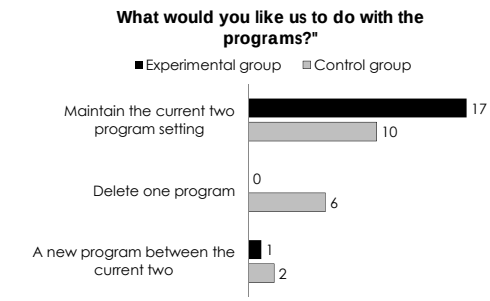
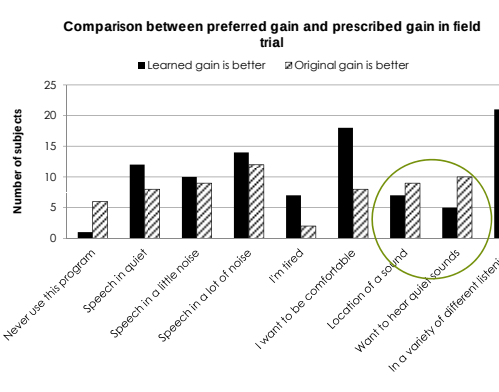


Figure 6. Gain preference by number of participants: 22 out of 36 participants preferred continuing to use the final preferred gain.







Conclusion

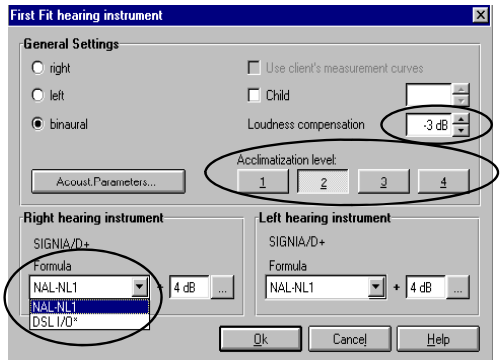
- The timing of turning on the gain learning feature has an impact on preferred gain for soft sounds obtained at the end of 8th week after fitting, but no impact on speech performance or self-report outcome measures.

Adaptation to soft, moderate, and loud sounds

- The typical new hearing aid user with moderately sloping, bilateral, sensorineural hearing loss has not been hearing soft sounds. Moderate sounds are what they want to hear and loud sounds have seemed OK.

Manufacturers are taking "adaptation" seriously

- Adaptation vs fine tuning: should one come before the other?



Data from Schum D. Adaptation management for amplification. Seminars in Hearing 2001;22(2):173-182.

Changes with Increasing Adaptation Level

Manufacturer	Model(s)	Adaptation Levels	Attack/Release Time	Compression Ratio	Gain
Electone	The Pointe	1-4	No change	Increases	Increases
Oticon	Digilife	1-3	No change	Increases	Increases each channel separ.
	Digifocus II	1-3	Increases Attack times	Increases	Overall gain increases (band 1,2,7)
Phonak	Claro	1-3	No change	Increases	Increases 10% per level
Siemens/ Rexton	Prisma	1-4	No change	Increases (related to gain changes)	Increases 10% per level NAL
	Signia	1-4	No change	Increases (related to gain changes)	Increases 10% per level NAL

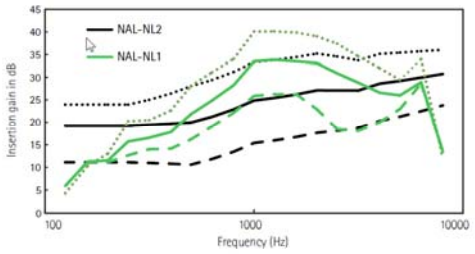
Data from Eberwein et al. Adaptation managers in hearing aid fitting software. Seminars in Hearing 2001;22(2):199-207.

Prescriptive Formulas continue to change as well (this would assume a lack of adaptation)…

Formula	Soft	From Behind	Speech in noise	Hearing loss
DSL	X	X		Greater loss
NAL			X	Less Loss

No significant findings for preference.
Need more than NAL and less than DSL.
Both have changed accordingly in NAL-NL2 and DSL v.5.

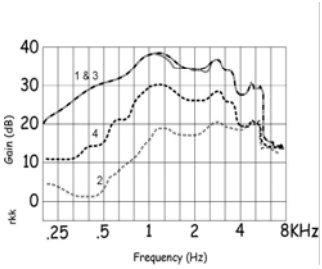
Comparison of NAL-NL1 (2001 through 2011) and NAL-NL2 (2011-2013), courtesy of Mead Killion, 2013.



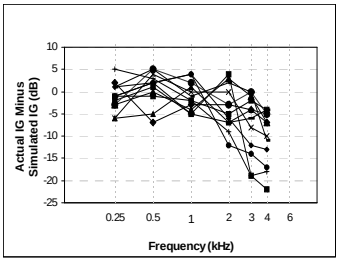
What can/should the audiologist do?

- Measure, don't guess!
  - real ear probe microphone measurements to insure audibility
  - loudness judgments of loud sounds to ensure comfort (loudness summation data need to be verified and applied to fitting strategies)
  - use adaptation managers wisely - the patient can't get used to something he/she can't hear, on the other hand, he/she won't wear something they can't tolerate

Don't assume the manufacturer has made the best choices…

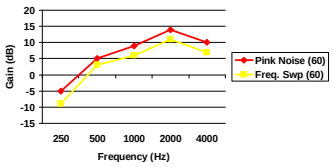


Insertion Gain, Hawkins and Cook, 2003



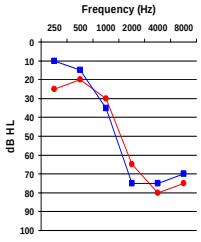
If audibility for soft and moderate inputs with comfort for loud inputs is your goal, you need:

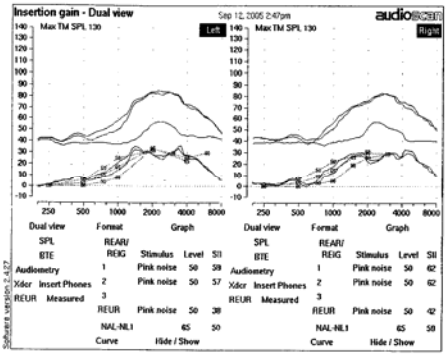
- The correct signal
- A measure of audibility
- The true dynamic range of the individual in dB SPL

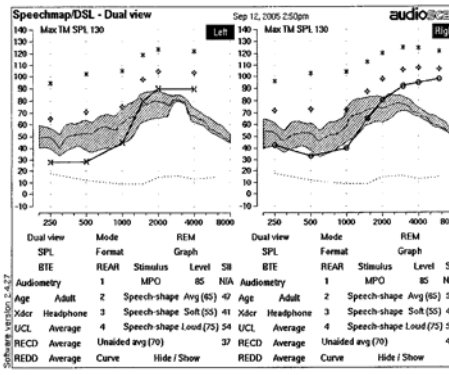


Use a simulated speech signal (e.g.,ICRA) or speech for the best estimate of the response that will be achieved with continuous discourse.

Insertion gain is not a measure of audibility…

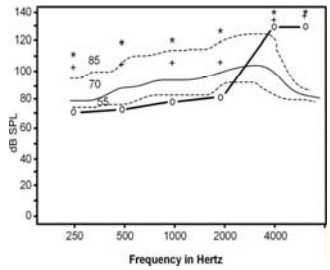




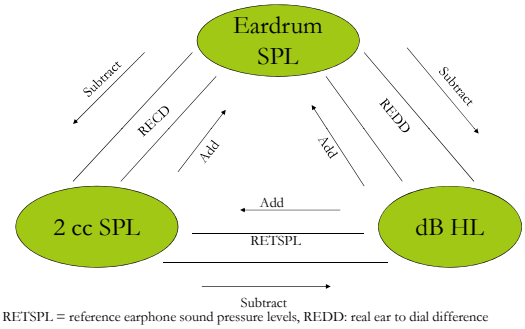


- Auditory mapping is only as good as the HL to SPL conversion…

Auditory mapping with average RECD

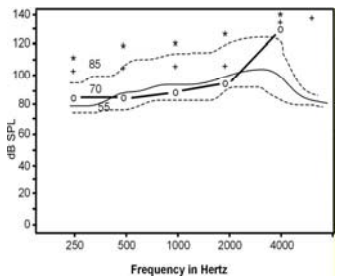


These data are used to transform HL insert earphone data to SPL



RETSPL = reference earphone sound pressure levels, REDD: real ear to dial difference
RECD: real ear to coupler difference. Thanks to Larry Revitt, Treatment, Thieme.

Auditory mapping with individual RECD

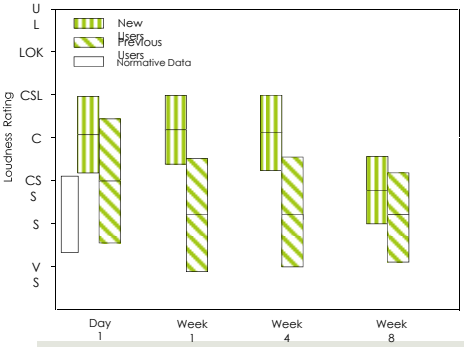


- So we measure everything correctly, use evidence-based prescriptive targets and patients still say soft sounds are too loud…

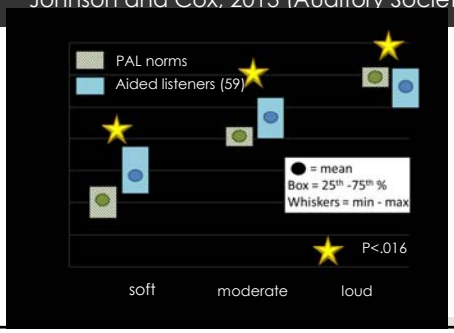
We have some evidence to look at…

Data from Mueller HG, Powers T. Consideration of Auditory Acclimatization in the Prescriptive Fitting of Hearing Aids. Seminars in Hearing 2001;22(2):103-124.

Data indicate that some adaptation is taking place for soft sounds.



Johnson and Cox, 2013 (Auditory Society)



OBSERVATIONS FROM MULLA ET AL

- Normal loudness perception (loudness rating within 2 SD of the contour test norms and within 1 SD of the PAL norms) has been returned to the majority of this group of HA users (≥ 70%) for the moderate and loud sounds (rating of 4 and 6). However, the perception of soft sounds was the least normalized.
- The perception of soft sounds was returned to normal for the majority of the HA users only for the pure tone signals (500 Hz and 2000 Hz). When the signal was a broad-band signal (the speech stimuli in the contour test and the soft items in the PAL), normal loudness perception was returned to a small part of the group (20% and 47%, respectively).
- The majority of HA users in this group (≥ 70%) were satisfied with their loudness perception of soft, moderate, and loud environmental sounds whether or not their hearing aid fitting returned their normal loudness perception. This conclusion was consistent with Johnson et al. (2013), Mueller et al. (2007) and Shi et al. (2001).

OBSERVATIONS

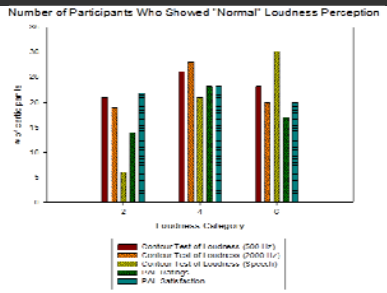
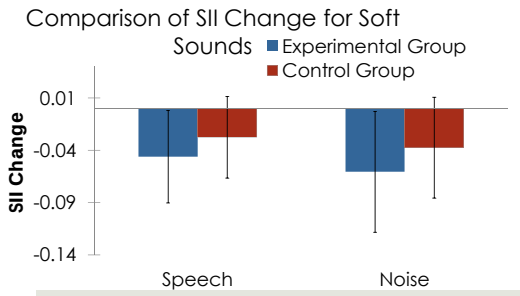


Figure 1. SII change obtained from the two groups for the soft speech (55dB SPL) and the soft noise (55dB SPL) inputs. SII change is determined by subtracting prescribed SII from preferred SII.



Shi et al, 2007

Found the same thing.

Soft sounds are never perceived as soft.

Patients may report being satisfied.

Loudness Near Threshold, Is it Softness Imperception or Rapid Growth?

a psychoacoustical concept by Florentine

Why Recruitment was Questioned?

- Buus, 1999 and Buus and Florentine, 2001 collected data on loudness summation in listeners with cochlear hearing loss
- Found that
  - loudness at elevated threshold was greater than normal
  - loudness grew normally near elevated thresholds (~15 dB SL)

Softness Imperception (SI)
(Florentine and Buus, 2002)

- Loss of ability to perceive soft sounds due to cochlear hearing loss.
- Reduced dynamic range in cochlear hearing loss in terms of SPL as well as LOUDNESS

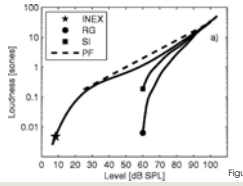


Figure obtained from Marozeau and Florentine (2

How was the assumption tested?

- Reaction time paradigm
  - Reaction time as an indirect measure of loudness
  - the faster the response, the louder it was perceived

Refuting Study

- Moore (2004)
  - Used loudness matching to measure loudness
  - 4 listeners were tested
  - Results did not agree with the concept of softness imperception

Applying SI in Fitting Hearing Aids

- But if the model is correct…
- Amplified soft sounds to hearing impaired listeners with cochlear origin who have SI will always be perceived louder than soft because they simply lack the ability to perceive softness.

Reality Check

- Things sounded too loud, now they sound correct
- Things still sound too loud, I'm going to adapt to accepting this and being successful with my hearing aids.
- I am going to be less successful, but more comfortable by reducing my ability to hear soft sounds.

Adaptation presumes…

- There has been a change
  - Introduction of amplification
- Intrinsic or extrinsic value in adapting
  - Increased comfort if adaptation occurs
  - Tolerate the amplification that will help you better if you adapt
- Physiology or psychology basis/ability to adapt
  - Is it possible?

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