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ASHA Convention
New Orleans • November 19–21, 2009
Two Professions: Powerful Partners

Vocal Audiometry in Hearing Aid Outcome Measurements

Session Number: 0164
Day/Time: 11/20/09 -- 3:30PM-3:45PM
Room: 346

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Humes & Amos (2009)*:
VALIDATING HEARING AID FITTINGS

❑ aided & unaided speech audiometry
preferably in noise and
representative of daily listening conditions

❑ data logging on hearing aid usage

❑ self-reported "benefaction" (benefit/satisfaction)

• Humes, L.E. , Amos N.E. (2009): Are your hearing aid fittings "on target"?
The ASHA Leader (14) p. 7

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According to Humes and Amos, hearing aid verification should include three aspects. Speech audiometry in noise is one of them. This study is about speech audiometry in quiet. It is often used to validate hearing aid fitting with poorly performing clients. We will investigate what it is worth.

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distribution of daily
speech sound pressure levels
PART II
speech audiometry revisited
PART III
results (n=45)

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PART I
distribution of daily
speech sound pressure levels

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In 2004 we did a large scale survey to document the distribution of sound pressure levels in daily speech.
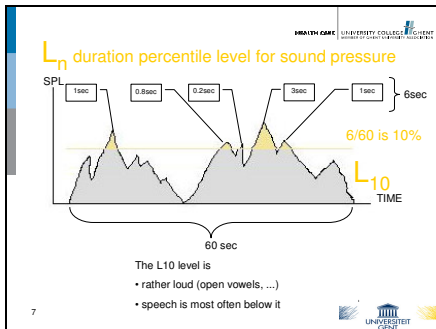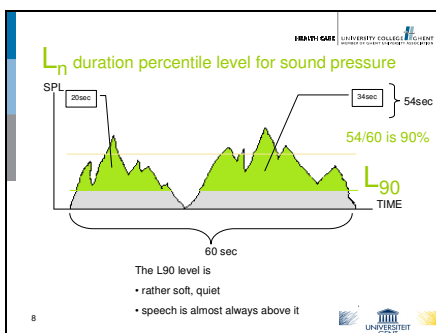

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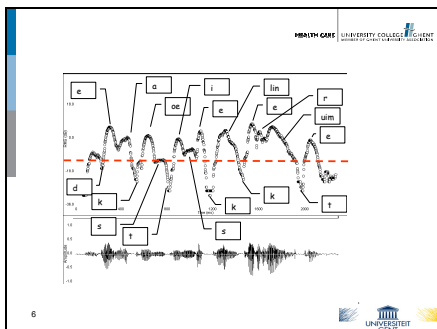
Sound pressure of running speech can go up or down 30 dB within a fraction of a second. As a rule of thumb we can say that all sonorant sounds correspond to sound pressure level peaks, while obstruent sounds correspond to sound pressure level minima. In fact this is a pity because the bulk of the information is in the obstruents.
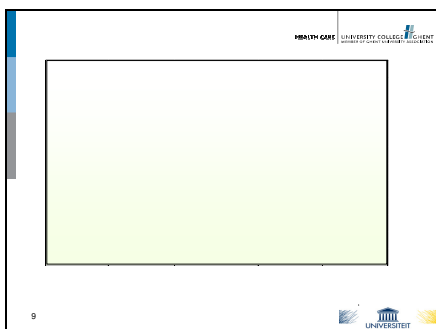
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A state of the art sound level meter can follow all details and produce several indices, for instance, the duration percentiles of sound pressure level. Here we see the tenth percentile or L10 (6 seconds of the 60 seconds measurement episode is 10 % of measurement time).

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These duration percentile levels are not all equally relevant. The lower duration percentile levels (higher decibel values) are rare, most of the time speech is softer. Moreover, since these levels represent the loudest speech fragments, they are caused by vowels, not by consonants. We all know that the bulk of information is in the consonants, not in the vowels.

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We will now try to implement this knowledge in the realm of speech audiometry, particularly speech audiometry for the purpose of hearing aid evaluation.

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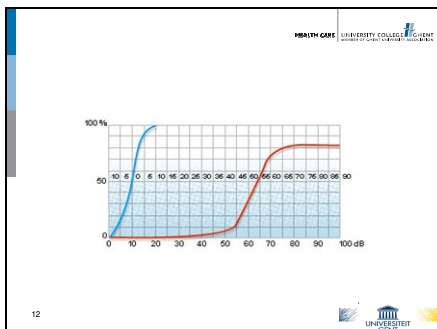

In speech audiometry, more sound pressure levels than just those of daily speech can be presented.

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The graph shows levels that in speech audiometry softer or louder can be presented, but these clearly do not relate to daily speech. They may be diagnostically relevant (for detecting the roll over phenomenon for instance), but when it comes to predict real life performance in hearing aid users they are irrelevant because speech does not sit in that range.

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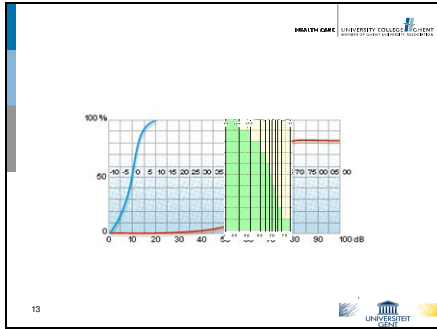
Of course, we have to accept the fact that the position of the representative zone is an approximation. For instance, the acoustics of the room can change sound pressure level for a listener at any given distance.

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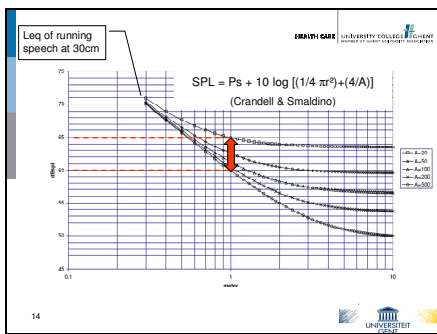
This graph shows the effect of room acoustics. Depending on the room's absorption factor, sound pressure level varies. When we compare a room with rather hard, reflecting walls with a room with extremely absorbing wall surfaces at a typical conversation distance(let's say 1m), this variation is limited to about 5 dB.

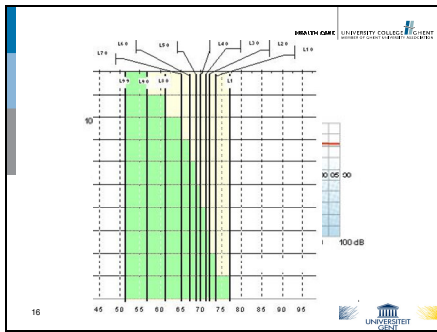SPL (Crandell & Smaldino) = Ps + 10 log [(1/4 πr^2)+(4/A)]

where Ps stands for the power of the sound source, r for the speaker-listener distance and A for absorption in the room.

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These are the most representative sections of the vocal audiogram when it comes to predict performance for daily speech

| representative sections of vocal audiogram	adjusted for 1m minimal absorption in room rounded to nearest multiple of 5 dB
L_{50}	70 dBSPL
L_{70}	65 dBSPL
L_{90}	55 dBSPL
L_{99}	50 dBSPL

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Even within the dynamic range of speech, the most relevant part is the L99-L50 zone. It is there that speech sits most of the time and it is there that the bulk of the information is to be found. This was corroborated in a preliminary investigation (Hilde Ooms, 2003): we found that the higher duration percentile levels such as L99 and L90 (i.e. the softer sound pressure levels that occur more often) correlated better with questionnaire data on aided performance than the lower Ln levels (louder sound pressure level that occur less often).

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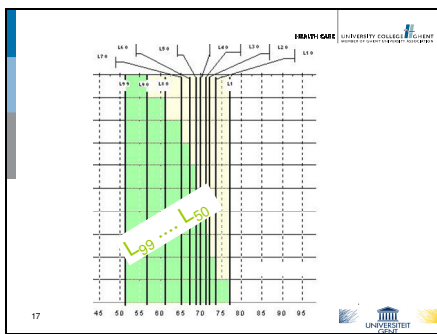
This is why we decided to concentrate on test results in the L99-L50 zone. We collected information from 45 hearing aid users. We looked at the functional gain on their speech audiogram. This concept of functional gain, i.e. the difference between the free field aided and unaided results, can be quantified in several ways.

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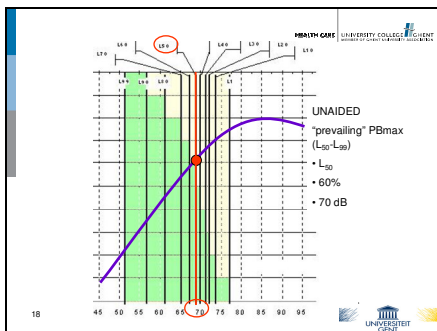
Let us look at a fictional patient. These are his unaided results. The best score (PBmax) within the most representative zone is 60% on 70 dB which corresponds to duration percentile level 50.
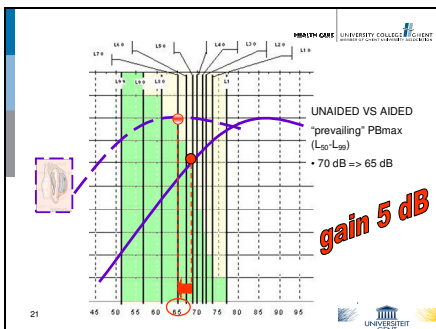
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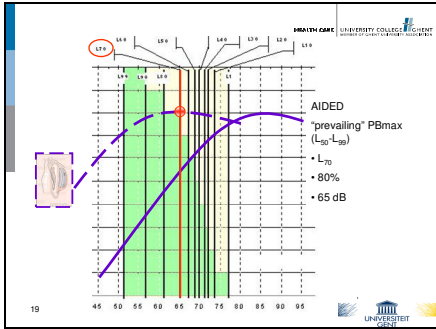
These are his aided results. The best score (PBmax) within the most representative zone now is 80% on 65 dB which corresponds to duration percentile level 70.
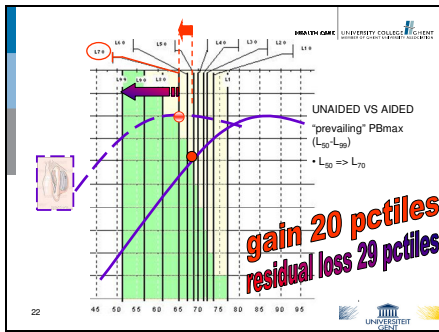
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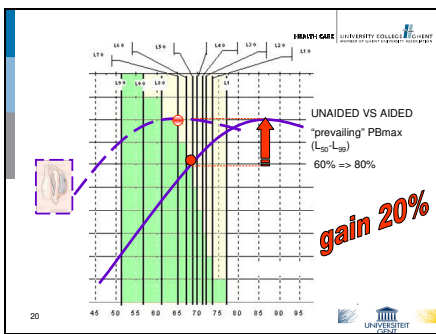
Quantified as a percentage of words understood, his functional gain is 20% (from 60 to 80%)
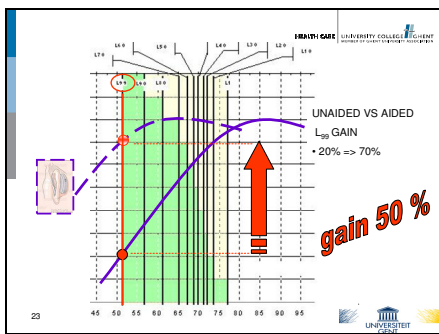
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Quantified as a jump on the decibel axis, his functional gain is 5dB (from 70 to 65dB)
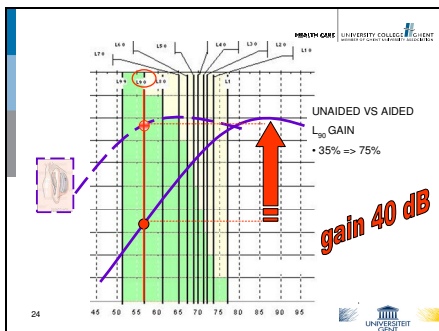
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Quantified as a jump on the duration percentile scale, his functional gain is 20 percentiles (L50 to L70)
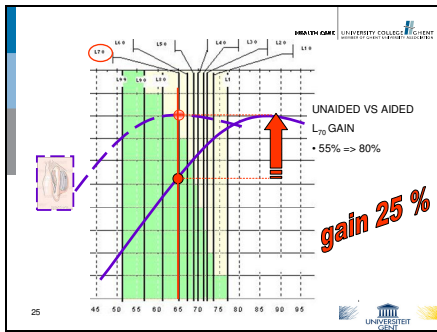
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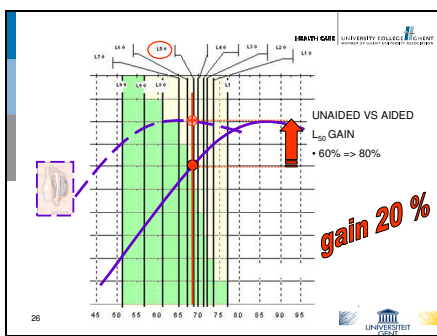We could also quantify functional gain on discrete duration percentile levels.
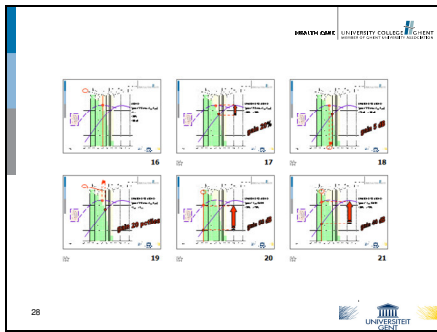
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The question now is: which of these quantification schemes, if any, is valid. One could say they are all provider-driven estimates of fitting success. We should confront them with consumer driven estimates of fitting success.

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The best way to verify validity is to ask patients themselves. The International Outcome Inventory for Hearing Aids (IOI-HA) questionnaire (we used the authorized Dutch translation) covers several domains. One of these domains is hearing aid benefit.

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- **45 hearing aid users**
  22 males, 23 females
  between 31y5m and 87y6m
  sensorineural hearing loss (see next slide)
  12 unilateral, 33 bilateral fitting
  1 to 11 years of experience with hearing aid(s))

- unaided & aided speech audiometry: **provider driven indices**
- hearing aid benefit questionnaire: **consumer driven indices**
- predictive value of provider indices: correlations, regressions

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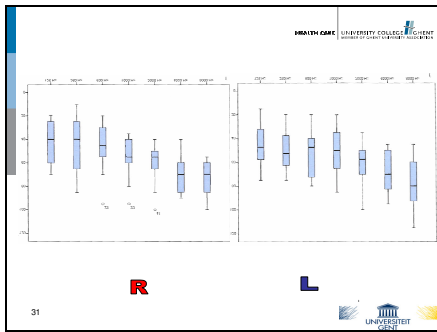
Unaided hearing thresholds in R and L ear. Mostly symmetrical sensorineural losses.

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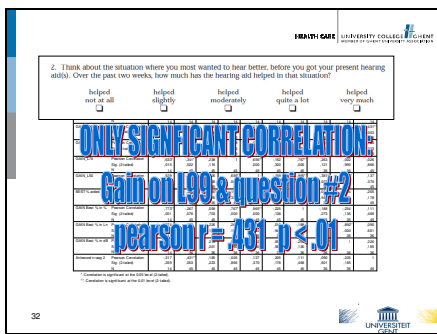The only question from the IOI questionnaire correlating significantly with any of the speech audiometry indices was question #2. Question #2 is about hearing aid benefit. You can see the logic in that: better results on the vocal audiogram results in consumer satisfaction. The striking points here are that none of te other domains in the questionnaire relate to speech audiometry, and secondly: it is the L99 region in particular relates to hearing aid benefit.

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We did stepwise multiple regressions, using all duration percentile indices as potential predictors of hearing aid benefit. Again all indices were rejected except one: speech audiometric gain for duration percentile Level99. This does not mean that the other indices are completely irrelevant. As the tolerance coefficients show, the reason for their being absent in the final model is multicollinearity. The concept of multicollinearity refers to a high intercorrelation between one independent variable and another one or a combination of others within the set. Stated otherwise, multicollinearity signals a situation where predictors, which are the so-called independent variables, are in fact not entirely independent. The tolerance coefficient shows how much variance a predictor can still explain on its own after the contribution of all of its correlates has been partialled out. These values are quite high for a lot of duration percentile level indices.

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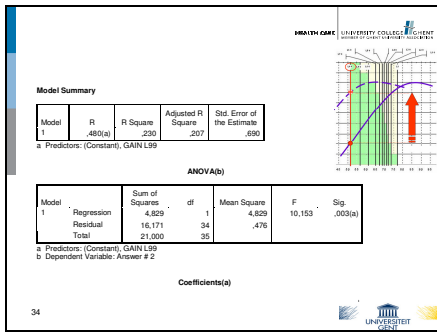
Adjusted R² values point out that about one fifth of all variance in consumer appreciation is determined by speech audiometric gain expressed in % and measured on duration percentile Level99.

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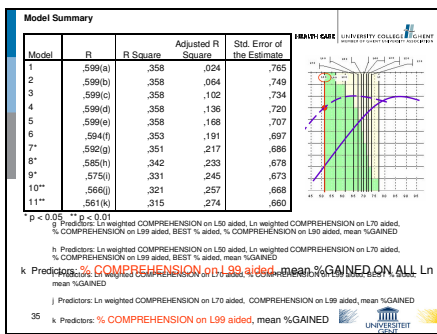
Another approach to the same question is a backward muiltiple regression analysis. Just as in stepwise multiple regression, this is a competition among variables or teams of variables and the competition still is predicting self-ratings hearing aid benefit. The difference between the two games is that stepwise regression invites predictors one by one seeking one single champion or a winning coalition, whereas backward regression starts with all possible coalitions and individual players. The result is that more possibilities pop up. The first six models are not significant. The last model is the best one, since adjusted R² values now climb to 27%. The combination of predictors is: (1) comprehension on duration percentile Level99 and (2) overall gain on all Ln levels from L50 to L99. Beta coefficients point out that both weigh about equally. Again duration percentile L99 is among the relevant predictors. When this metric is combined with

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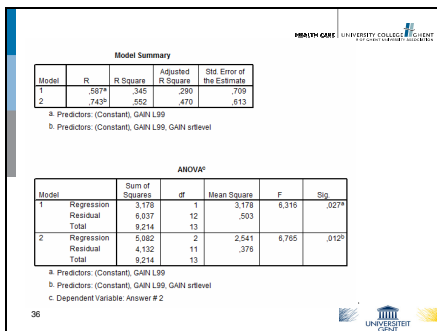
Here we have thrown in an old favorite in the competition of predictors (forward regression): prosthetic gain on SRT level, i.e. shift of the PI-curve to the left measured in decibels at the 50% comprehension level, the so-called threshold of intelligibility has been added. In contrast to all predictors up to now, this is not a % score (upward shift of the PI-curve), this is a decibel score (leftward shift of the PI-curve). There is one caveat here, we could do this only for a subset of the database, so the number of participants is less. When we introduced extrapolated SRT values to expand the dataset, all coefficients decreased. Anyhow, this team of predictors gives a boost to R² values (the adjusted R² climbs to 47% of variance explained). Note that even now there is a L99 duration percentile metric in the winning team and, according to the Beta coefficients, it outweighs the old dB-shift favorite.

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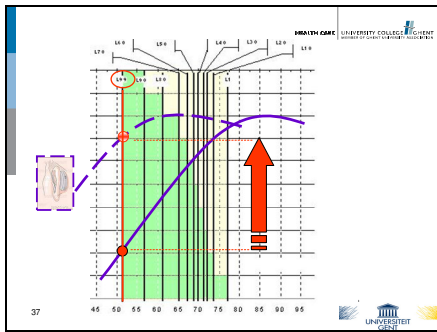
If there is one hint for hearing aid evaluation procedures that emerges from all of this, this is it: keep an eye on the results for duration percentile level L99, which is near 50 dBSPL This level correlates with consumer ratings of hearing aid benefit. It pops up in all prediction schemes weighing considerably on the equation. There is some logic in that: it is is the bottom level of speech sound pressure level. Gain on even softer presentation levels do not directly relate to speech intelligibility. The more prosthetic gain on this level, the better the guarantee for appropriate amplification of soft sounds, which carry the bulk of the information.