

**Performance Perceptual Test (PPT)  
and the  
Acceptable Noise Level (ANL):  
What do they measure?**

**Gabrielle Saunders Ph.D.**

**National Center for Rehabilitative  
Auditory Research,  
Portland OR**

# Overview

- Describe Performance Perceptual Test (PPT) and the Acceptable Noise Level (ANL)
- Summarize current literature
- Report data from our current study
- Draw some conclusions

# Hearing Aid Outcome

Both include a subjective element

- **Acceptable Noise Level (ANL)**  
by Nabelek and colleagues of University of Tennessee
- **Performance-Perceptual Test (PPT)**  
by Saunders and colleagues of the NCRAR  
(that's me)

# Acceptable Noise Level (ANL)

- **Maximum background noise individual will tolerate when listening to speech at MCL**
- **Unit of measurement: S/N (*although not referred to as such*)**

# Rationale for the ANL

- Weak correlations between speech-in-noise scores subjective evaluations of communication skills and HA outcome
- Background noise primary problem for HA users
- Therefore.... successful HA use might be more associated with willingness to listen in noise than is actual speech understanding in noise

**Developed the ANL to ‘quantify an individual’s allowable signal-to-noise ratio (S/N)’**

*(Nabelek et al 1991, 2004)*

# Instructions

*“the level of background noise that is the MOST you would be willing to put up with without becoming tense or tired while following a story”*

*Nabelek et al, 2004*

# ANL

- Participant listens to ongoing speech (Arizona Travelogue) presented at 0° azimuth
- Level is adjusted to MCL (2dB steps)
- Background multitalker babble added to signal (also from 0° azimuth)
- Level of babble is adjusted to reach level that is “the most participant will put up with ....etc.”

# ANL = MCL – BNL

$$\begin{array}{ccccccc} 50 \text{ dB HL} & \text{minus} & 20 \text{ dB HL} & = & 30 \text{ dB} \\ \text{MCL} & & \text{BNL} & & \text{ANL} \end{array}$$

→ High ANL = Participant has a low tolerance for noise

$$\begin{array}{ccccccc} 50 \text{ dB HL} & \text{minus} & 45 \text{ dB HL} & = & 5 \text{ dB} \\ \text{MCL} & & \text{BNL} & & \text{ANL} \end{array}$$

→ Low ANL = Participant has a high tolerance for noise

# Rationale for the PPT

- Questionnaire responses often do not reflect measured performance
- Different tools are used to measure each so it is difficult to compare the two

**We came up with a test that enables a direct comparison of subjective perception and measured ability to understand speech-in-noise.**

# Performance-Perceptual Test (PPT)

Measure two different speech reception thresholds in noise (SRTNs):

Performance SRTN = Actual ability to understand speech in noise (HINT)

Perceptual SRTN = Perceived ability to understand speech in noise

**USING THE SAME TEST PROCEDURES**

# Performance

Repeat back HINT sentences presented in noise

Noise level is fixed

Speech level is altered depending upon response:

Decreased when sentence is repeated correctly (S/N more adverse)

Increased when repeated wrongly (S/N less adverse)

**S/N for 50% correct**

# Perceptual

Report whether they can “understand everything that was said” for HINT sentences presented in noise

Noise level is fixed

Speech level is altered depending upon response:

Decreased when subject reports “understanding everything that was said” (S/N more adverse)

Increased when subject reports “not understanding everything that was said” (S/N less adverse)

**A third variable can be computed: The difference between the Performance SRTN and the Perceptual SRTN**

**It is a direct measure of the degree to which individuals (in)correctly assess their ability to hear**

**= Performance Perceptual Discrepancy (PPDIS)**

**e.g.**

**5 dB S/N**      **minus**      **5 dB S/N**      **= 0 dB**  
Performance SRTN      Perceptual SRTN      PPDIS

**→ Subject accurately estimates hearing ability**

# Negative PPDIS

$$\begin{array}{ccccc} \mathbf{5 \text{ dB S/N}} & & \text{minus} & & \mathbf{10 \text{ dB S/N}} & & = & & \mathbf{-5 \text{ dB}} \\ \text{Performance SRTN} & & & & \text{Perceptual SRTN} & & & & \text{PPDIS} \end{array}$$

→ Subject underestimates hearing ability

# Positive PPDIS

$$\begin{array}{ccccc} \mathbf{5 \text{ dB S/N}} & & \text{minus} & & \mathbf{0 \text{ dB S/N}} & & = & & \mathbf{+5 \text{ dB}} \\ \text{Performance SRTN} & & & & \text{Perceptual SRTN} & & & & \text{PPDIS} \end{array}$$

→ Subject overestimates hearing ability

# Performance Perceptual test (PPT)

Obtain three measures:

- Performance SRTN: S/N 50% correct performance
- Perceptual SRTN: S/N for understanding everything that is said
- PPDIS: dB difference between the above

# ANL versus PPDIS

## Similarities

- incorporate a 'subjective' element
- use adaptive algorithm
- Same motivation: to better explain/predict hearing aid outcome

# ANL versus PPDIS

## Differences

- ANL relies on listener to judge whether they are actually 'following the story' .
- The PPDIS incorporates a 'validation' of actual performance
- Assessing different perceptions:

**ANL assesses 'tolerance'**

**PPDIS is a (mis)-judgment of own ability to hear speech in noise**

# Review of literature

IHCON, August 14<sup>th</sup> 2008



# Relationships to demographic and audiometric variables

## ANL

### Independent of:

Gender  
Hearing level (PTA)  
Speech-in-noise  
Aiding

## PPDIS

### Independent of:

Age  
Gender  
Hearing level (PTA)  
Aiding  
Presentation level

### Negative correlation:

Age

Older individuals were MORE tolerant of noise

Presentation level

Increased speech level resulted in decreased tolerance for background noise

### Positive correlation

Speech-in-noise score

Poorer performers tended to underestimate hearing ability

Nabelek et al 1991, 2006,  
Freyaldenhoven et al, 2007, 2008  
Rogers et al 2003

Saunders et al 2004,  
Saunedrs & Forsline, 2006  
Saunders & Cienkowski, 2002

# Relationships to reported activity limitation and participation restriction

## ANL

- ANLs are independent of APHAB scores

More handicap was associated with underestimation of hearing ability

More disability and less satisfaction were associated with underestimation of hearing ability

Freyaldenhoven et al, 2008

## PPDIS

- PPDIS explained 10-15% of variance in HHIE/A scores
- PPDIS explained significant variance in reported difficulty understanding speech (18%) and hearing aid satisfaction (32%)

Saunders & Cienkowski, 2002  
Saunders et al, 2004,  
Saunders & Forsline, 2006

# Relationships to hearing aid outcome

## ANL

FT users were MORE tolerant of noise than PT

- Full-time HA users had significantly lower ANLs than part-time users
- ANLs correctly classified 87% of successful users and 84% of unsuccessful users

## Probability of HA success:

ANL < 7  $p \geq 85\%$

ANL > 13  $p \leq 15\%$

More tolerant of noise = greater probability of success with HAs

Nabelek et al, 1991, 2006

## PPDIS

- Combination of PPDIS and Performance SRTN correctly classified 77% contented HA users and 73% discontented users

Underestimation and poor performance resulted in discontented users

Saunders & Cienkowski, 2002

# Test-retest Reliability

PPDIS data from a number of studies

$r = 0.810$  to  $0.880$

ANL data from a number of studies

$r = 0.791$  to  $0.965$

Nabelek et al, 1991, 2006

Saunders & Forsline 2004,  
Saunders & Cienkowski, 2002

IHCON, August 14<sup>th</sup> 2008



# Summary of literature review

- Both are independent of demographic variables
- Both are independent of hearing level
- Both are predictive of hearing aid outcome
- Both are associated with reported activity limitations/participation restrictions

# Current Study

Participants completed both the Performance Perceptual Test (PPT) and the Acceptable Noise Level (ANL)

**Purpose: To determine whether the PPDIS (misjudgment of hearing) can be used as a counseling tool to improve hearing aid outcome**

## 73 participants

- Age: mean=65.8 yr, SD = 7.9 Range: 42-75 yr
- Thresholds
- All experienced binaural HA users
- Reported dissatisfaction prior to visit

# Protocol:

2 groups of participants:

**Group 1: Counseling based on PPDIS**

**Group 2: General counseling**

2 visits, 10 weeks apart

Counseling provided at end of visit 1

***Data presented here are those collected during Visit 1 prior to counseling***

# Test measures (subset)

- **PPT unaided and aided**
- **ANL unaided and aided**
- **Hearing Handicap Inventory for the Elderly/Adults (HHIE/A, Ventry & Weinstein, 1982), Newman et al, 1990)**  
**25 items, 2 scales, 2 versions (E for 65+, A for <65), 3-point response scale (Yes, Sometimes, No)**
- **Abbreviate Profile of Hearing Aid Benefit (APHAB, Cox & Alexander 1995)**  
**24 items, 4 scales (EC, RV, BN, AV), 7-point response scale (Always to Never)**

# Results

IHCON, August 14<sup>th</sup> 2008



# Are the ANL and PPDIS related?

IHCON, August 14<sup>th</sup> 2008



# Are the ANL and PPDIS related?

## Raw correlations (Pearson r-values)

- Unaided PPDIS and unaided ANL:  $r=-0.092$ , n.s.
- Aided PPDIS and aided ANL:  $r=-0.291$ ,  $p=0.012$

# Are the PPDIS and ANL related?

Another approach using PPDIS as a categorical not continuous variable

Group subjects into Underestimators, Accurate and Overestimators and then examine ANL scores for each group

Underestimators: **Can hear better than they think they can**

Accurate: **Accurately assess their hearing**

Overestimators: **Think they can hear better than they can**

# Are the PPDIS and ANL related?

Definitions from Saunders et al (2004) :

**Underestimator: PPDIS value in lower third (<33<sup>rd</sup> %ile)**

**Accurate: PPDIS value in middle third (33<sup>rd</sup> to 66<sup>th</sup> %ile)**

**Overestimator: PPDIS value in upper third (>66<sup>th</sup> %ile)**

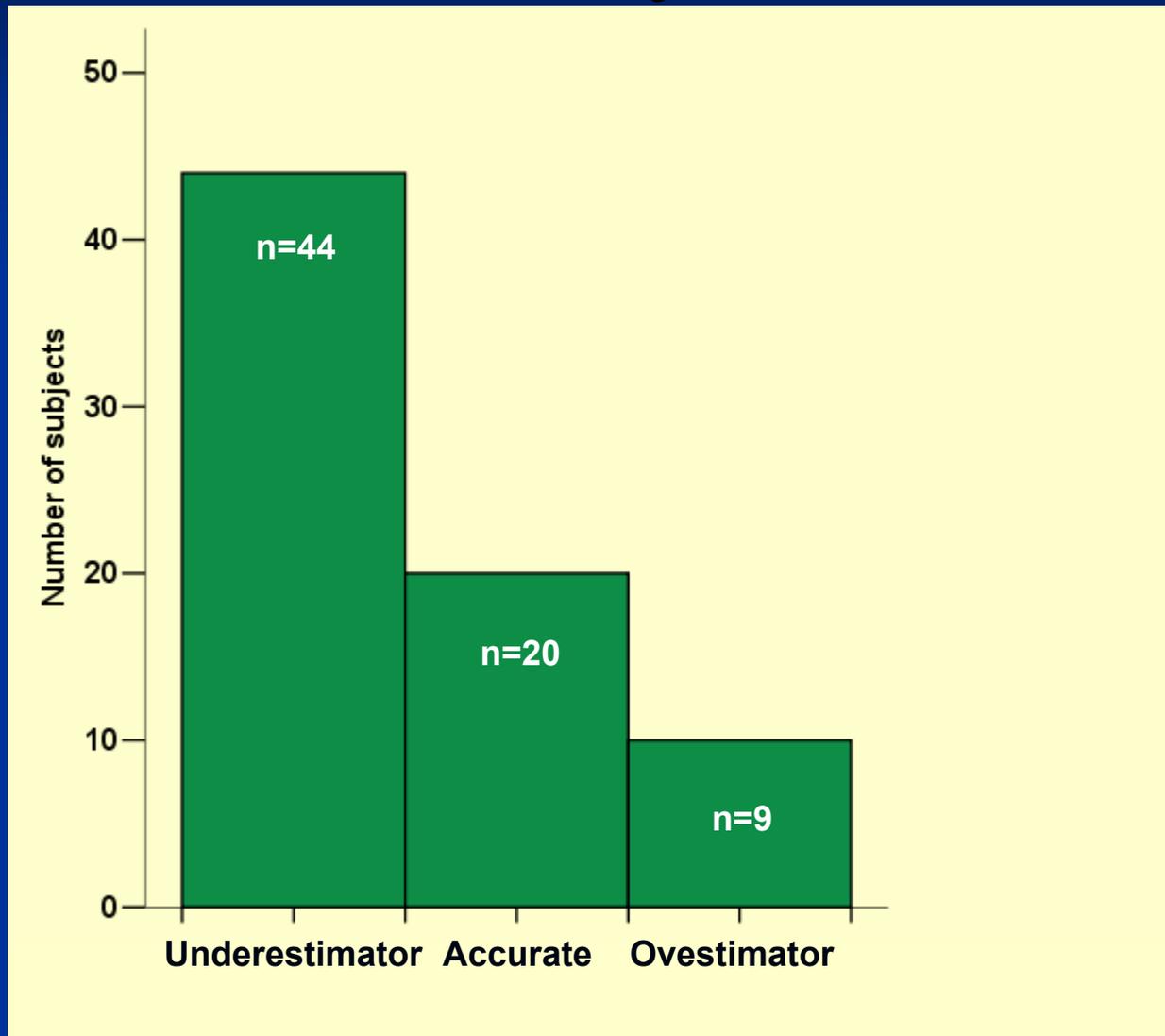
**Actual values:**

**Underestimator: PPDIS  $\leq$  -3 dB**

**Accurate: PPDIS  $>$ -3 dB and  $<$ 0.2 dB**

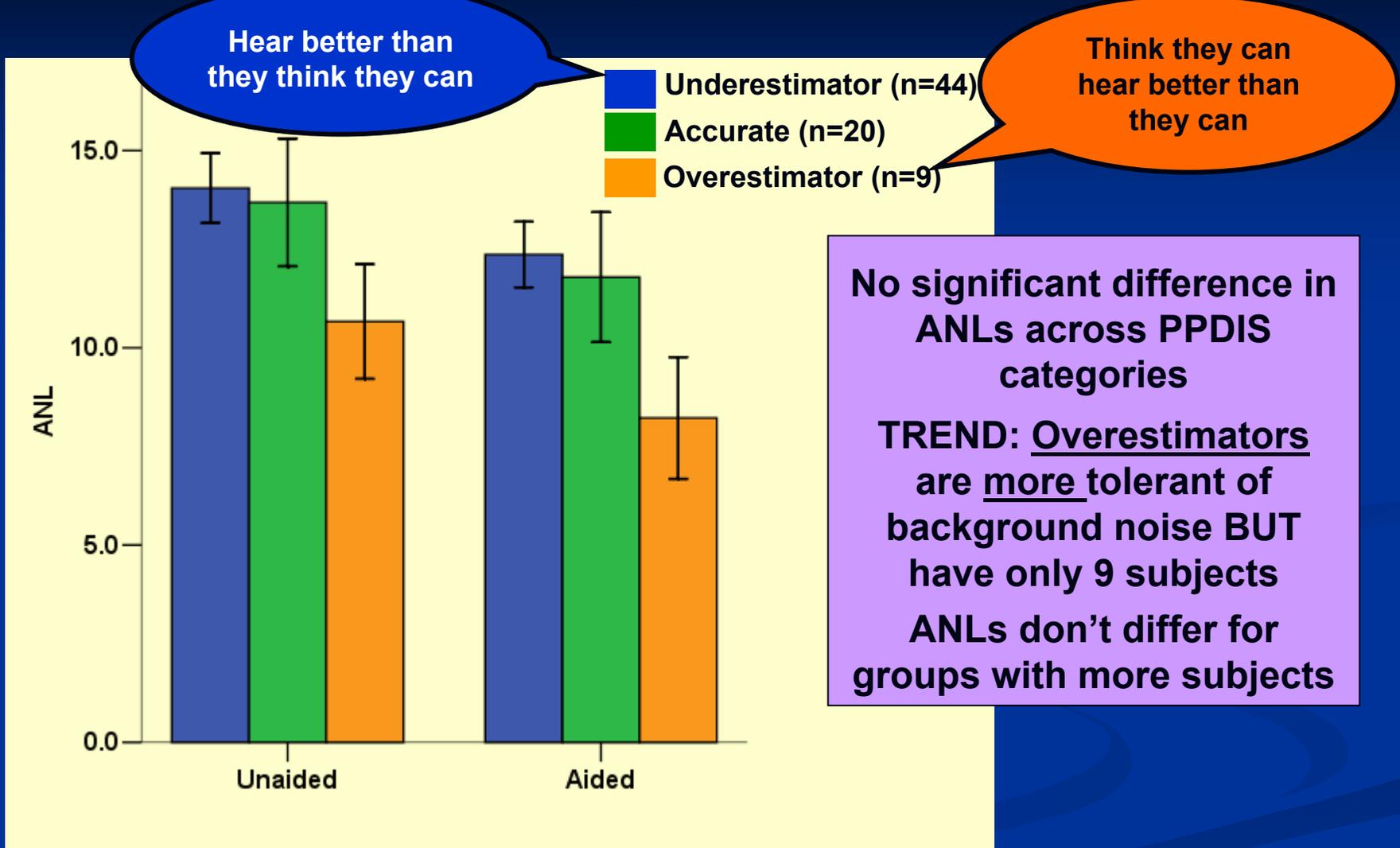
**Overestimator: PPDIS  $\geq$  0.2 dB**

# Number of individuals who underestimated, accurately estimated and overestimated their unaided hearing ability



IFCON, August 14<sup>th</sup> 2008

# ANLs of the three PPDIS groups



# If this relationship holds, what might be going on?

- **Overestimators select a more adverse S/N than that at which they can perform**
  - i.e. For a fixed speech level they are introducing a high level of background noise
- **Presumably this is comparable to their having a high Background Noise Level (BNL) in formula:**

$$ANL = MCL - BNL$$

*Question: During the ANL measurement are they understanding the whole story OR is the ANL confounded by the fact they overestimate their hearing ability?*

# Are the PPDIS and ANL related?

Current data suggest PPDIS and ANL are not strongly related but with more even numbers in each group a stronger relationship might emerge

ANL = tolerance for noise, what are willing to put up with, ability to understand is not considered

PPDIS = (mis)-perception of ability to hear

# How do the PPDIS and ANL relate to reported activity limitation and participation restriction?

**APHAB  
scores**

**HHIE/A  
scores**

# Examined relationships between questionnaire scores and:

## PPDIS categories:

**Underestimator, Accurate, Overestimator**

## ANL categories:

**Unsuccessful, Uncertain, Successful**

**ANL < 7:  $\geq$  85% probability successful user**

**ANL  $\geq$  7 and  $\leq$  13: Unpredictable**

**ANL > 13: 85% probability unsuccessful user**

**(Nabelek et al, 2006)**

# PPDIS, APHAB and HHIE/A?

Based on past studies we expect:

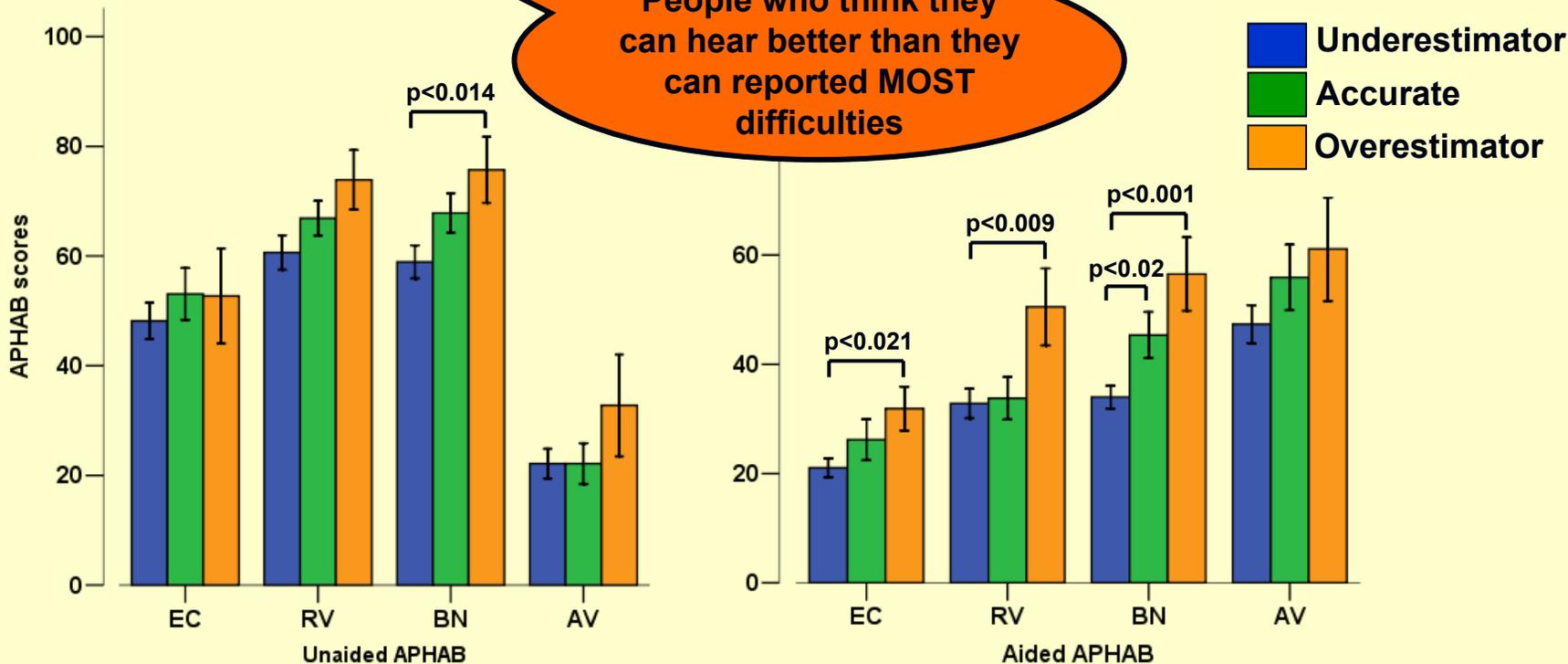
Underestimators will report more disability and handicap than overestimators

i.e. Underestimators will have higher APHAB and HHIE scores than overestimators

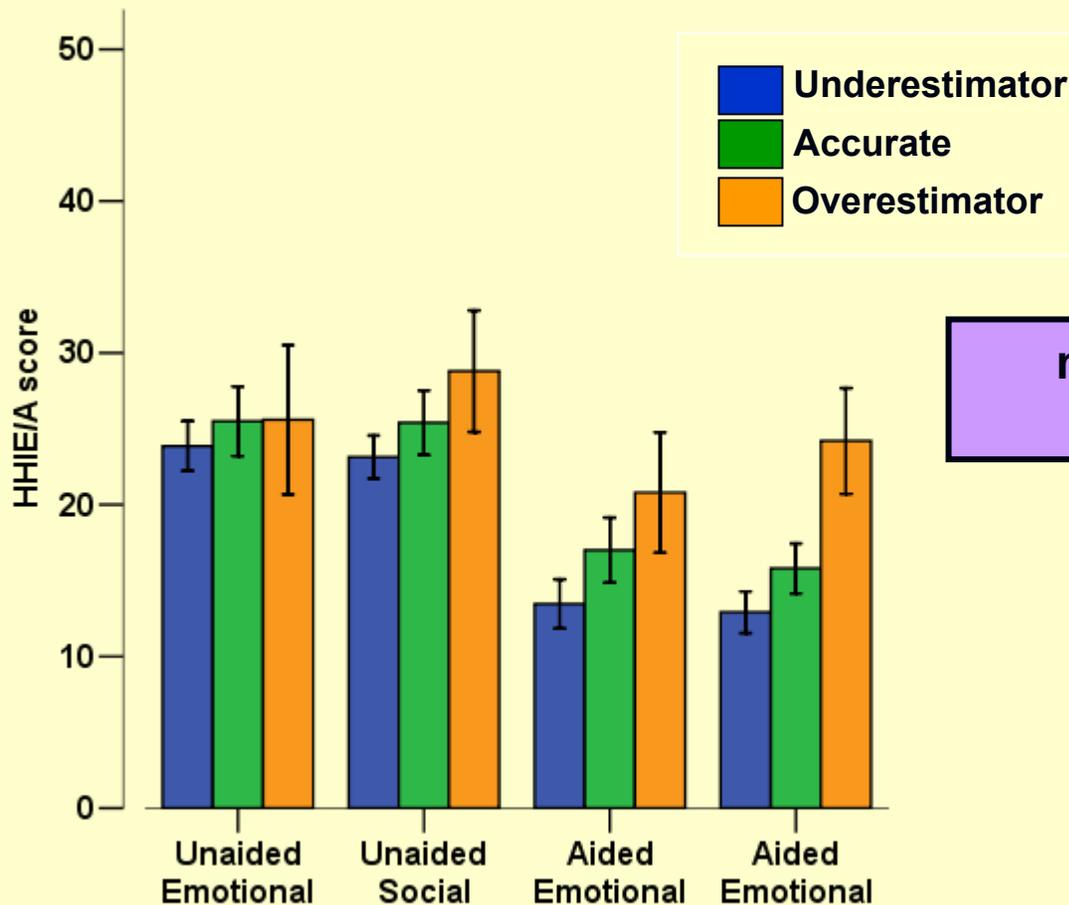
# APHAB and the three PPDIS groups

Significant effect of PPDIS category  $F=7.9$   $p=0.001$   
Overestimators reported most difficulties

People who think they can hear better than they can reported MOST difficulties



# PPDIS and HHIE/A scores



n.s. effect of PPDIS category

# PPDIS, APHAB and HHIE/A

## Why the difference from past findings?

- Population here was not randomly selected, all dissatisfied hearing aid users
- No good explanation

# ANL, APHAB and HHIE/A

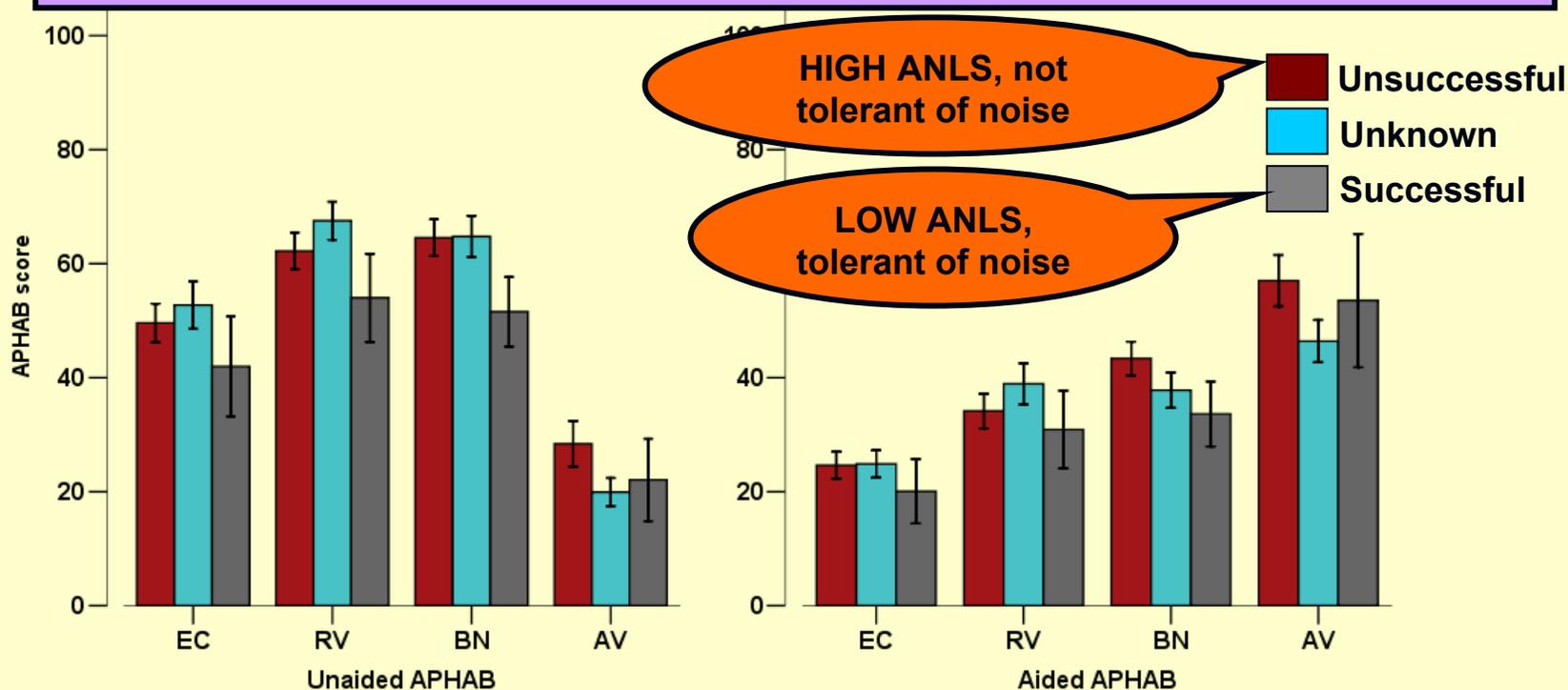
**Based on past studies we expect:**

**ANL groups will be independent of self-reported disability (APHAB)**

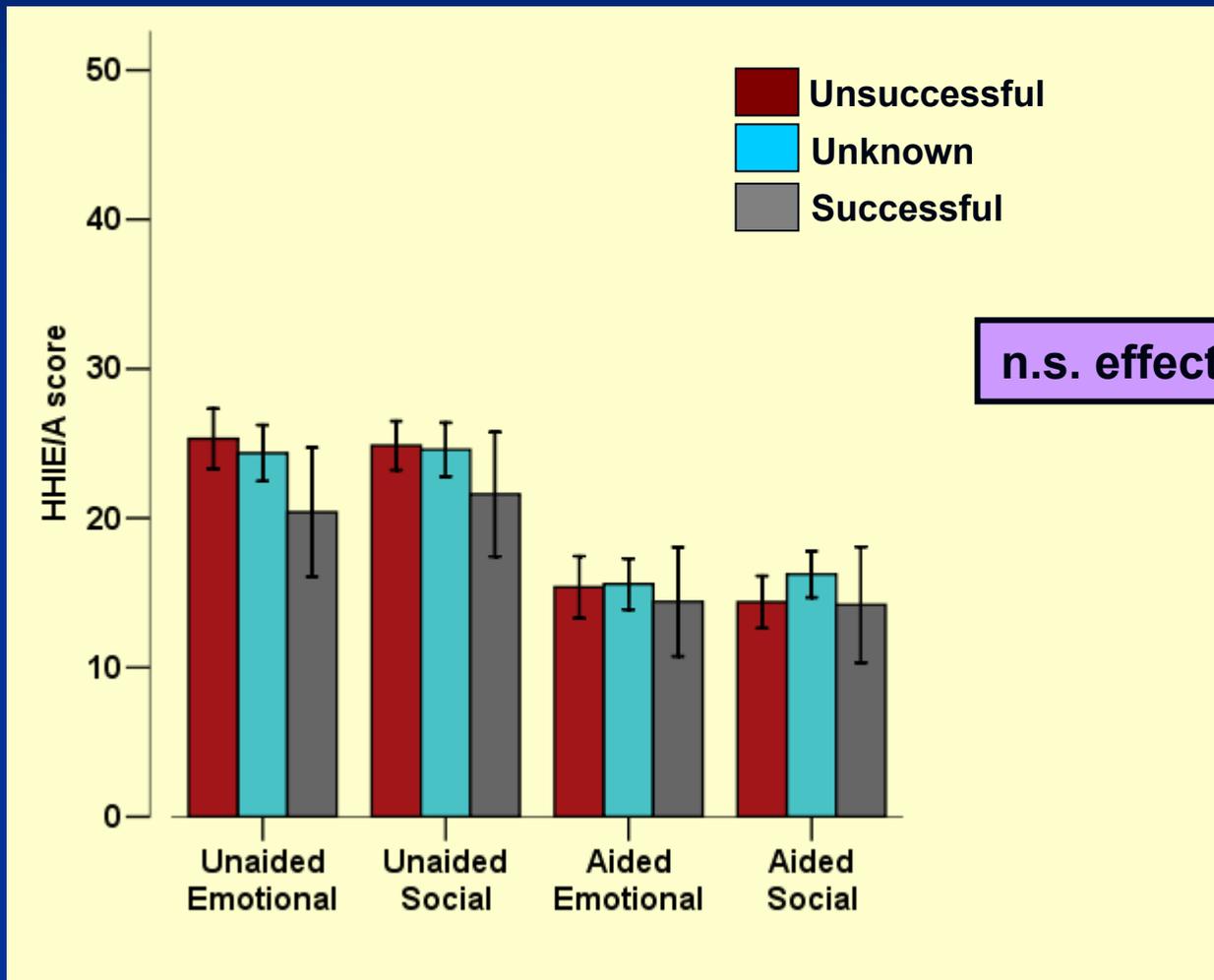
**No handicap data published**

# APHAB and the three ANL groups

No difference across ANL categories  $F=0.7$   $p=0.512$



# ANL and HHIE/A score



n.s. effect of ANL category

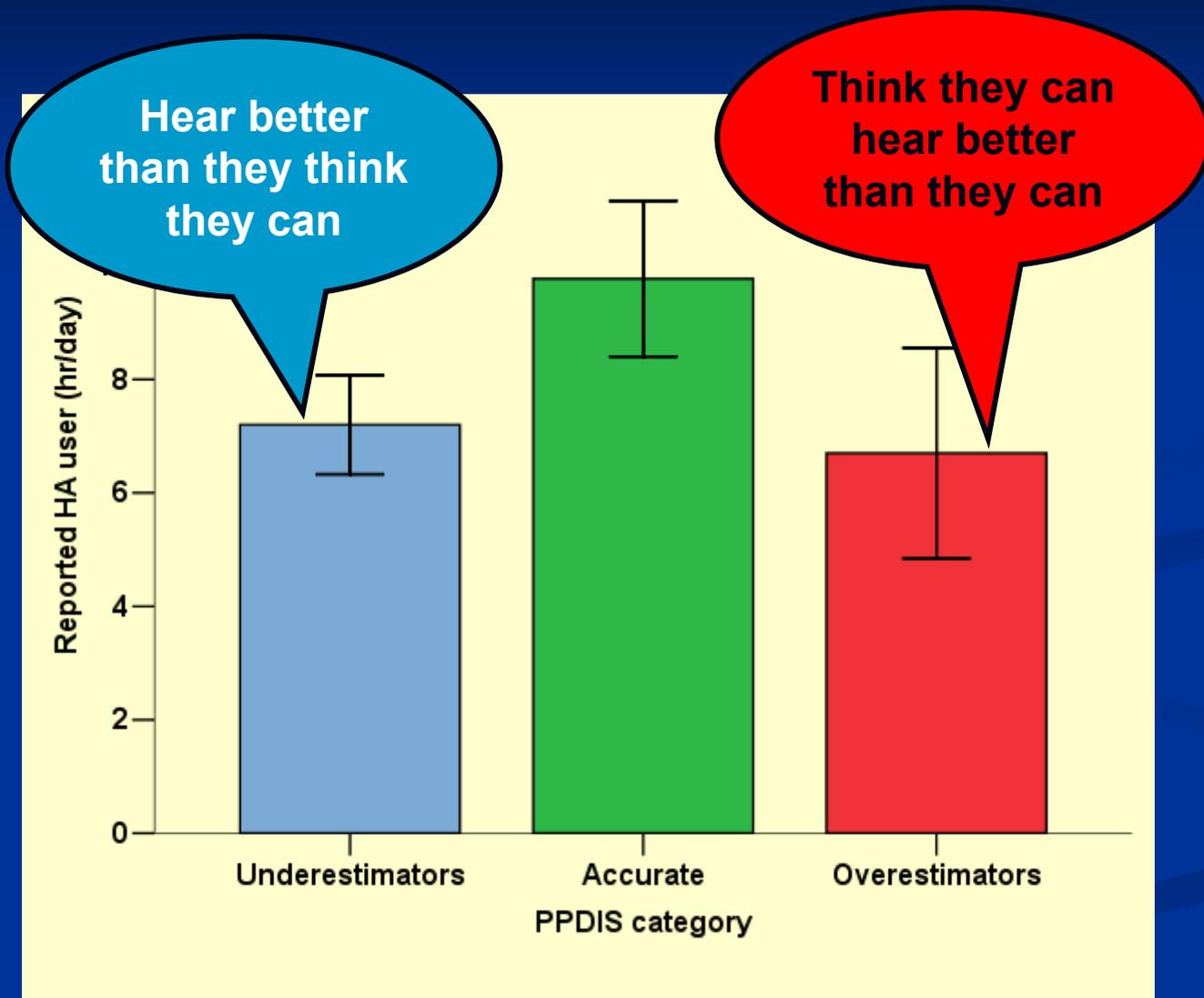
# How do the PPDIS and ANL relate to hearing aid use?

# PPDIS and hearing aid use

Based on past studies we expect:

If HA satisfaction is associated with daily hearing aid use then would expect less daily use from underestimators

# Daily Hearing Aid Use for PPDIS groups



# PPDIS and hearing aid use

## What is going on?

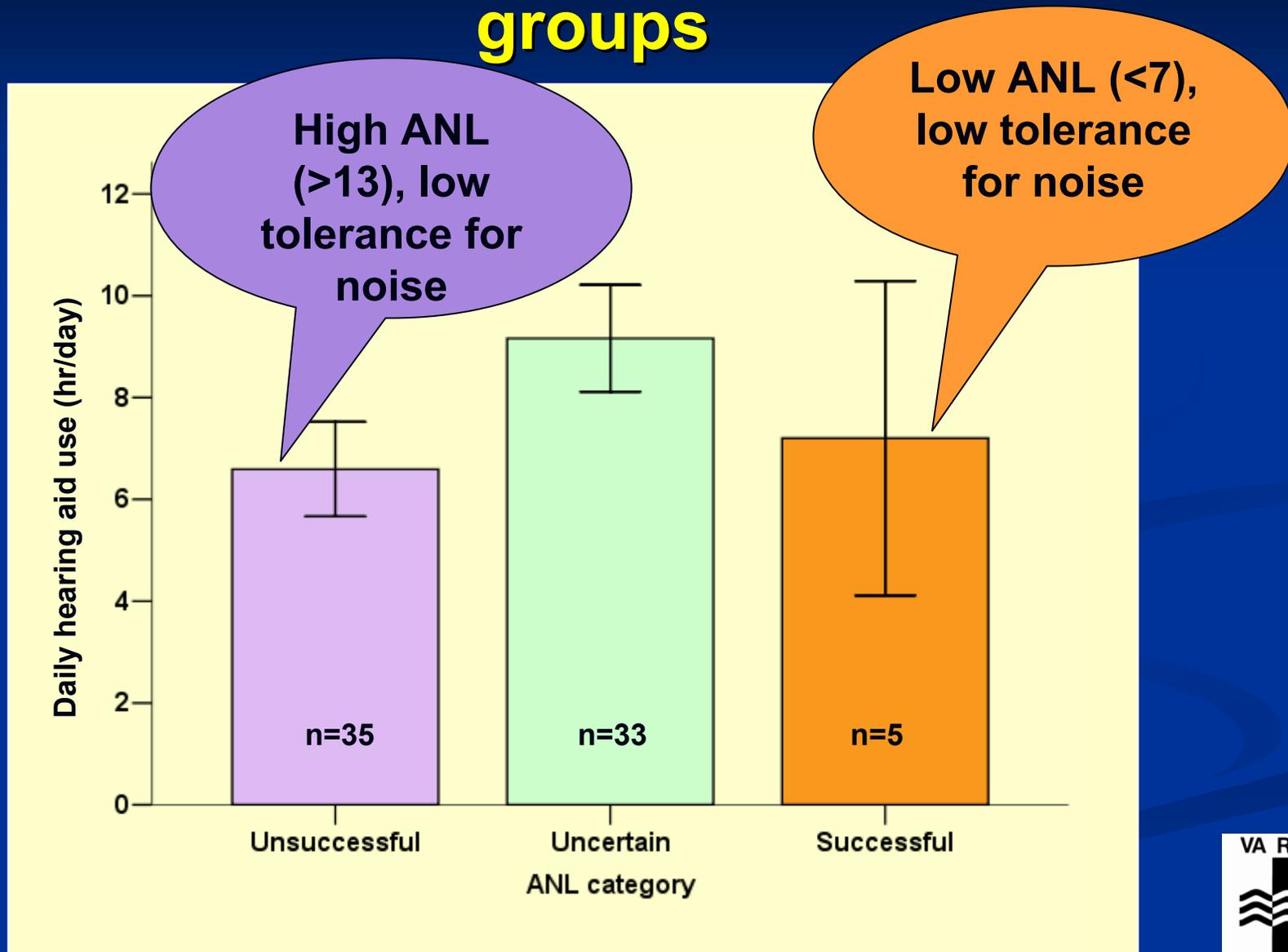
- **Underestimators:** Past data show are less satisfied with hearing aids, therefore daily use is low
- **Overestimators:** Don't think they need hearing aids so daily use is low

# ANL and daily hearing aid use

Based on past studies we expect:

If success is associated with daily hearing aid use, 'Successful' hearing aid users (as defined by ANL value) will use hearing aids more than unsuccessful users

# Hours of HA use per day versus ANL groups



## What is going on?

**‘Successful’ and ‘Unsuccessful’ users were based on definitions:**

**Successful HA users wore their hearing aids when ever they needed them**

**Unsuccessful HA users did not wear as needed**

**In Nabelek et al (2006) study this was NOT associated with daily use:**

**Successful users wore HAs 2-18 hr/day**

**Unsuccessful users wore them 0-12 hr/day**

# What are the key findings?

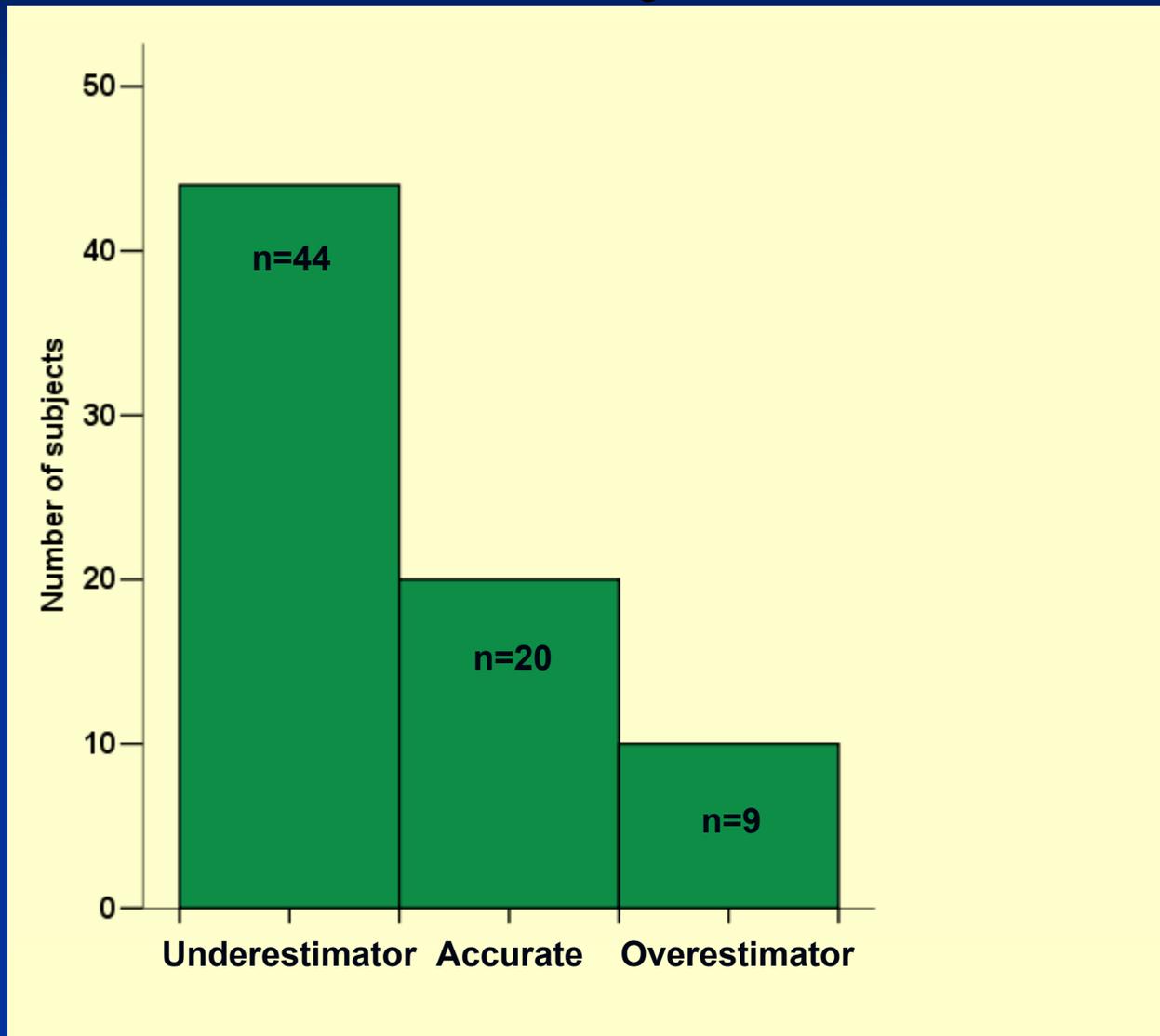
# What are the key findings?

## Key finding 1:

**Dissatisfied users underestimate their hearing ability**

*Evidence?*

# Number of individuals who underestimated, accurately estimated and overestimated their unaided hearing ability



11/03/14, August 11, 2008

Values originated from normative data in which groups were based on dividing the population into thirds:

33% Underestimators, 33% Accurate, 33% Overestimators

**Finding:**

59% Underestimators, 27% Accurate, 12% Overestimators

*How did this population differ from the population from which the norms were derived?*

**This population were all dissatisfied hearing aid users**

# What are the key findings?

## Key finding 2:

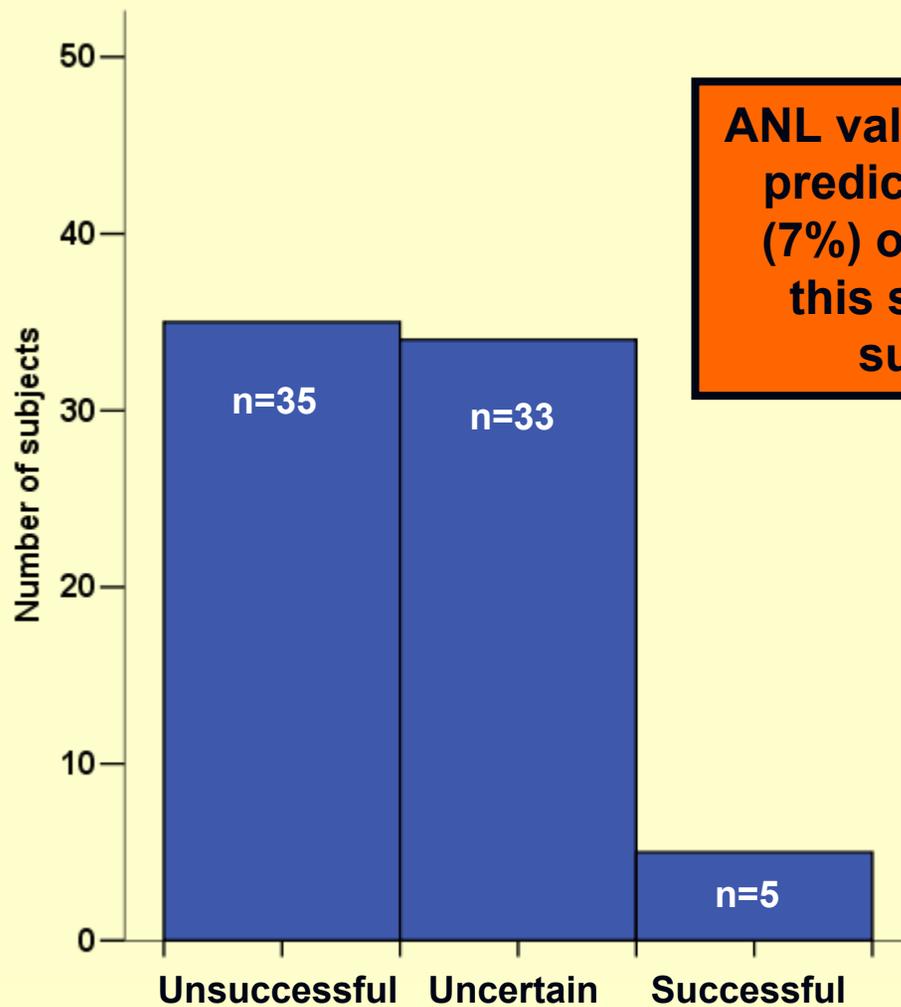
Data somewhat support Nabelek et al's (2006) values for predicting successful and unsuccessful users

*Evidence?*

**ANL < 7: Greater than 85% probability successful user**

**ANL >13: Less than 15% probability successful user**

# Number of individuals predicted to be unsuccessful, uncertain and successful hearing aid users using Nabelek et al's 2006 ANL



**ANL values of Nabelek predicts that only 5 (7%) of the users in this study will be successful**

# What are the key findings?

## Key finding 3:

**ANL and PPDIS seem to assess different constructs**

## *Evidence?*

**Lack of association between the measures**

# Conclusions

- Study suggests ANL and PPDIS are associated with hearing aid outcome

**BUT**

unequal subject numbers in the PPDIS and ANL groups decreased statistical power. Need more data before drawing final conclusions

## CAUTIONS:

1. Emphasizes how different populations can alter the findings. Hopefully clinical interpretation of individual data hold up
2. The floating definitions of successful hearing aid outcome impact results and interpretation

# Acknowledgements

These studies were funded by  
VA RR&D grants  
C2709I & C3951R

Thank you to Anna Forsline,  
Marc Caldwell and ShienPei  
Silverman – all invaluable  
members of the research group