



EXPLORING THE RELATIONSHIP BETWEEN LABORATORY AND REAL-WORLD LOUDNESS PERCEPTION

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INTRODUCTION

Hearing aids amplify sounds to make them audible, comfortable, and clear for listeners with hearing loss. Loudness is a critical aspect of hearing aid provision. When prescribing gain, fitting formulas typically take loudness into consideration with the goal of ensuring that loudness perception is similar to normal hearing.

To measure loudness, various tools have been developed for both laboratory and real-world settings. In controlled environments, methods such as the Adaptive Categorical Loudness Scaling (ACALOS)¹ provide standardized assessments of loudness perception. Meanwhile, tools like the Profile of Aided Loudness (PAL)² offer insights into loudness experiences in everyday situations.

The purpose of this study was to examine the relationship between loudness measurements obtained in laboratory settings and those experienced in real-world listening environments. To achieve this, we utilized two newly developed loudness measurement tools: Revoloud (Hörzentrum Oldenburg gGmbH)³ and the Cambridge Aided Loudness Profile (CALP)⁴. By comparing results from both tools, we aim to enhance our understanding of how individuals with normal hearing and hearing-aid users perceive and experience sounds across different contexts, ultimately informing more effective hearing aid fittings and improving user satisfaction.

METHODS

PARTICIPANTS:

- 16 normal-hearing listeners (NH), Age: 23 to 31 years (M=27.5, SD=2.6); Female: n=5
- 36 experienced hearing aid users (Aided), Age: 44 to 88 years (M=71, SD=9.7); Female: n=11

HEARING AIDS:

- Starkey receiver in canal (RIC) rechargeable devices, programmed to e-STAT 2.0 fitting formula
- Acoustic coupling based on degree of hearing loss.

REVOLOUD:

Provided a loudness rating for each of the 60 non-speech everyday sounds, presented from a loudspeaker at 0°. These sounds comprise three levels (soft, average, loud) and four frequency bandwidths (low, mid, high, broadband).

CAMBRIDGE AIDED LOUDNESS PROFILE (CALP):

Is an improved version of PAL. This questionnaire assesses the loudness and appropriateness of soft, average, and loud everyday sounds. Example: *Soft*: "You chewing soft food;" *Average*: "Sound of cutlery on a plate, when eating;" *Loud*: "A door slamming, standing a few feet away."

PROCEDURES:

- The normal hearing (NH) listeners completed the Revoloud and CALP on the same day. Hearing aid users (Aided) completed them after acclimatization of 1-2 weeks.

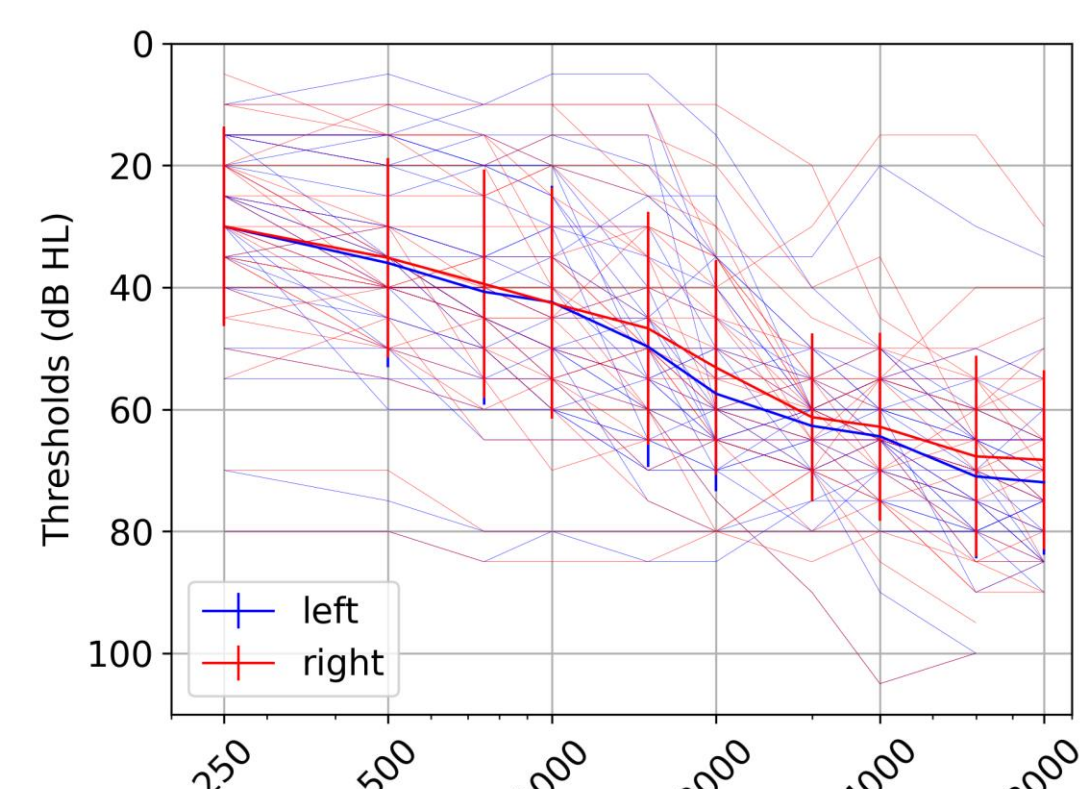


Figure 1. Audiograms for hearing aid users

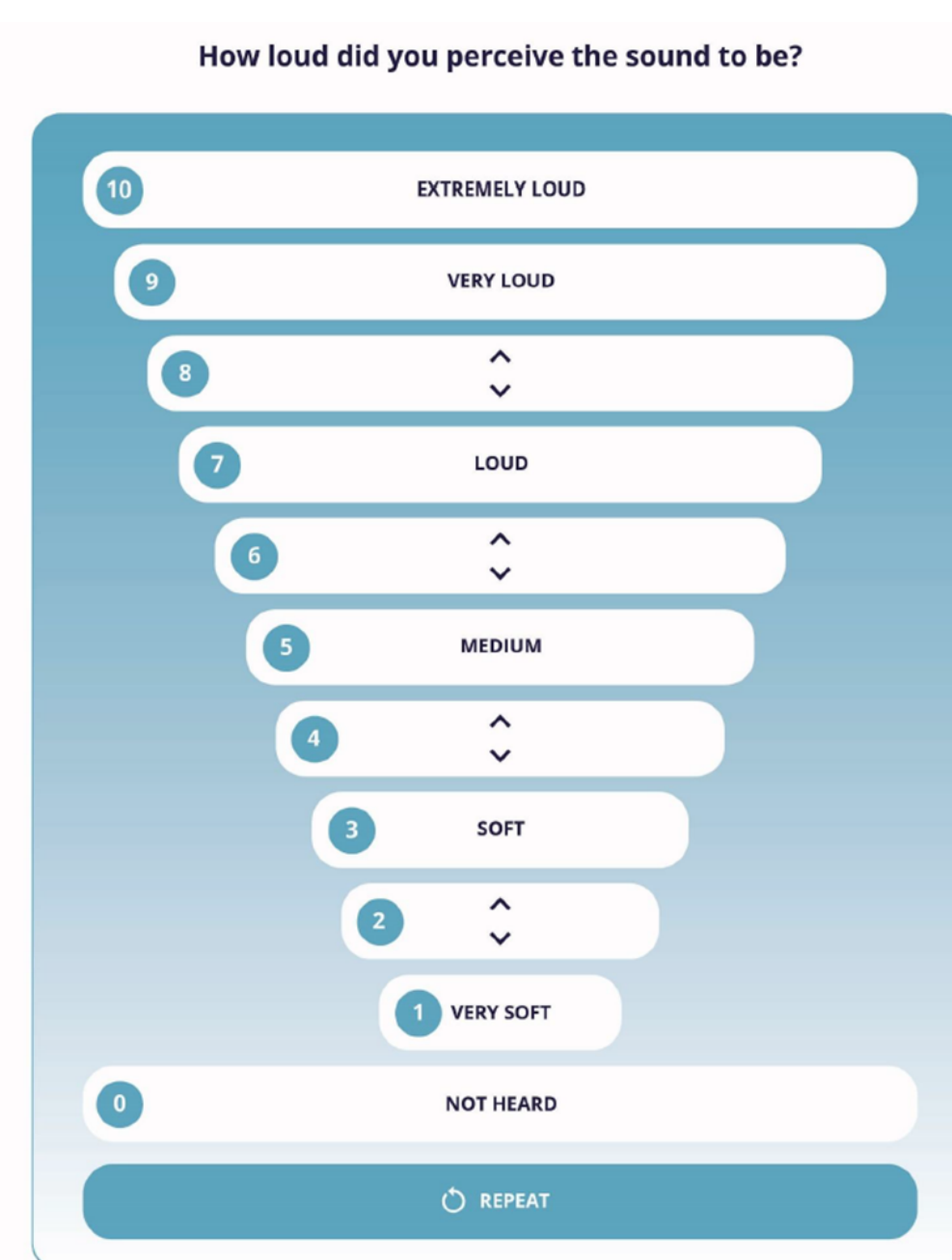


Figure 2. Loudness scale in Revoloud

RESULTS

REVOLOUD

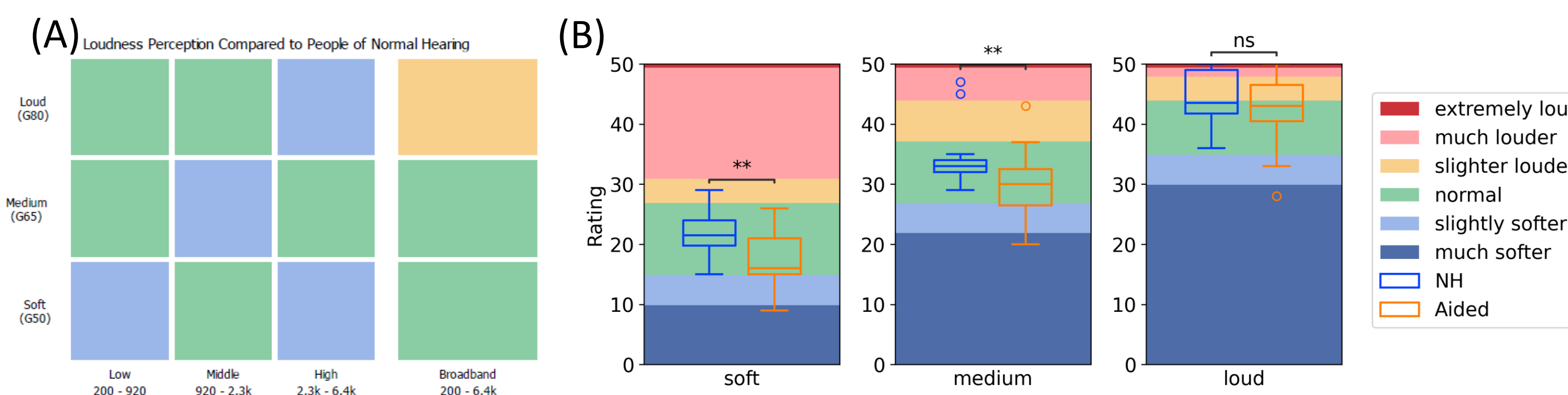


Figure 3. (A) Example of Revoloud results, which include 12 loudness ratings (3 loudness levels x 4 frequency ranges), color-coded to indicate alignment with ratings from normal-hearing listeners. (B) The broadband Revoloud results in this study.

- Broadband loudness perception for both soft and medium sounds differed significantly between the NH and aided groups (independent t-test: $p = 0.002$ for soft sounds; $p = 0.005$ for medium sounds).

CALP

- 11 items were used, yielding three ratings (soft, average, loud) each for Loudness and Appropriateness.
- NH and aided HI participants rated appropriateness similarly despite differences in loudness for loud sounds (independent t-test $p < 0.001$)

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

Figure 4. The loudness and appropriateness scale in CALP.

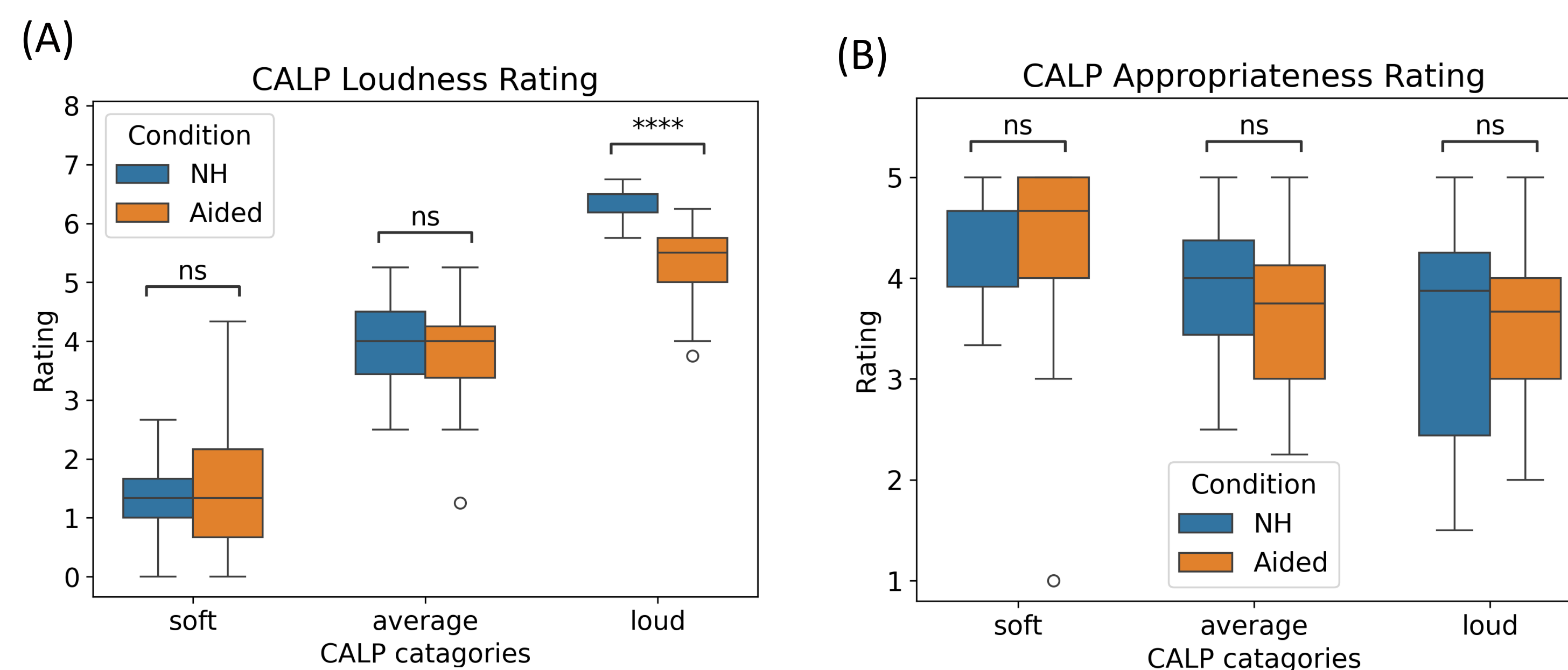


Figure 5. The CALP loudness (A) and appropriateness (B) rating results.

CORRELATION ANALYSIS

- Spearman's rank correlation analyses were conducted using the Revoloud and CALP ratings. Only broadband loudness ratings were used from Revoloud.
- CALP rating and Revoloud rating were strongly correlated when all sound levels were considered for both NH ($\rho = 0.87$) and aided HI ($\rho = 0.80$) participants.

RESULTS (CONT.)

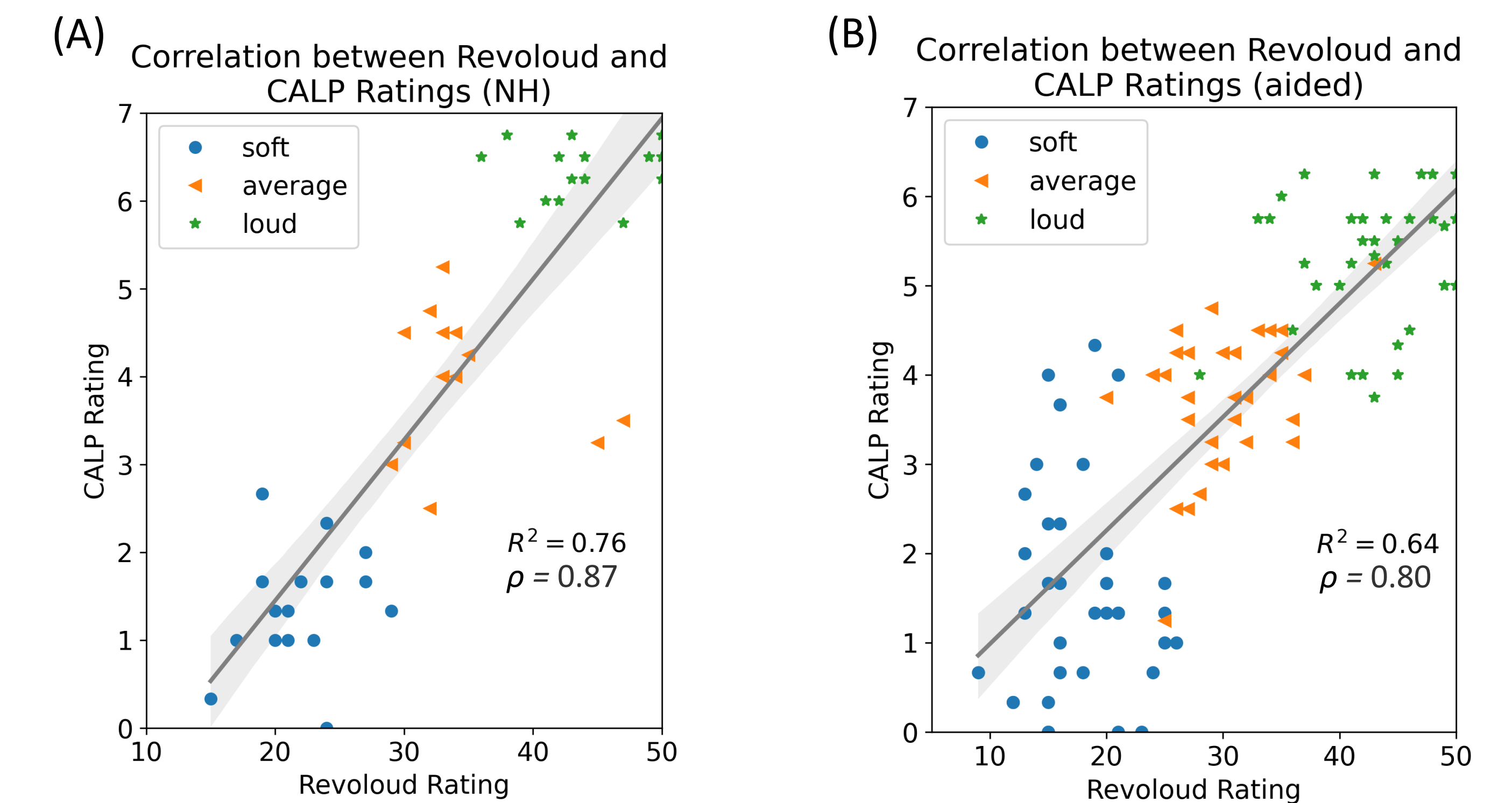


Figure 6. Correlation of Revoloud and CALP loudness ratings for NH (A) and aided (B) participants.

- Aided HI participants showed a larger variance in both CALP and Revoloud rating than NH participants.

CONCLUSIONS

- With Revoloud, the aided broadband loudness for soft and medium (average) sounds was significantly lower than that of the NH group, although most ratings still fell within the normal range (green). Both groups had similar loudness perception for loud sounds (Figure 3B).
- In CALP, the loudness ratings were significantly different only for loud sounds. Appropriateness ratings were similar in both groups. This suggests that hearing aids may alter the absolute loudness perception for loud sounds, but they do not negatively impact the perceived appropriateness of those sounds.
- The aided loudness appropriateness ratings in CALP aligned with a previous study using the PAL with the CAMEQ2-HF formula⁵.
- Loudness ratings are subjective and influenced by factors like memory, cognition, multisensory interactions, and listener state⁶. Large inter-individual variations were observed, especially for aided HI participants, yet despite sound differences between Revoloud and CALP and potential recall bias in CALP, the two measures still showed strong correlation across all sound levels, underscoring the importance of assessing loudness during fitting.

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