TEMPORAL STABILITY OF AUDITORY ECOLOGY AMONG ADULT HEARING AID USERS

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BACKGROUND

- Many hearing aid technologies that provide benefit in a laboratory setting do not provide benefit in the real world [1]. One reason for this may be that laboratory settings do not adequately represent the auditory ecology of the real world.
- Auditory ecology refers to the relationship between the external world and the unique listening demands of the individual [2]. Elements that affect a person's auditory ecology are both environmental and psychosocial.
- Prior experimental and theoretical work on auditory ecological factors and hearing aids supports the idea that auditory ecology fluctuates and that hearing aid preferences and benefit may be partially controlled by these changes in auditory ecology [e.g. 3, 4, 5, 6, 7].
- A better understanding of auditory ecology as a dynamic system with many fluctuating factors and complex interactions may improve our understanding of the needs of listeners with hearing loss and the outcomes of hearing aid use. As a first step toward this understanding, **the aim of this project was to determine whether location affects auditory ecology stability and to characterize how environmental and perceptual elements comprised by auditory ecology change in a given place over time.**

METHODS

- Participants were 54 older adults (26 males and 28 females; age range: 65 to 88 years; mean age: 73.6 years) with sensorineural hearing losses consistent with typical presbycusis [8]. Mean audiometric thresholds are shown in **Figure 1**.
- Each subject wore each of four hearing aid configurations (basic hearing aid with features on and off, premium hearing aid with features on and off) for one month. Some participants also completed an optional unaided condition.
- Ecological momentary assessment (EMA) was implemented through the use of smartphones (Samsung Galaxy S3) and a custom application [9,10]. 14,770 individual surveys were completed by 54 participants. 11,155 surveys were included in the final analysis. Screenshots from the application are shown in **Figure 2**.

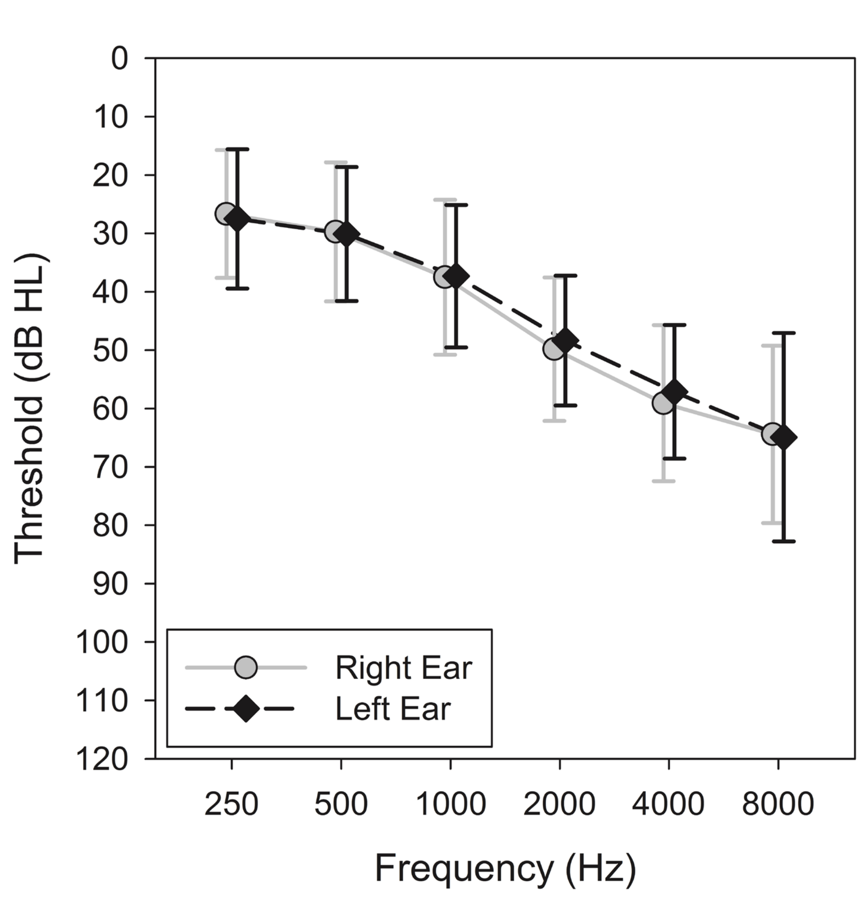


Figure 1: Mean audiometric thresholds for all participants.

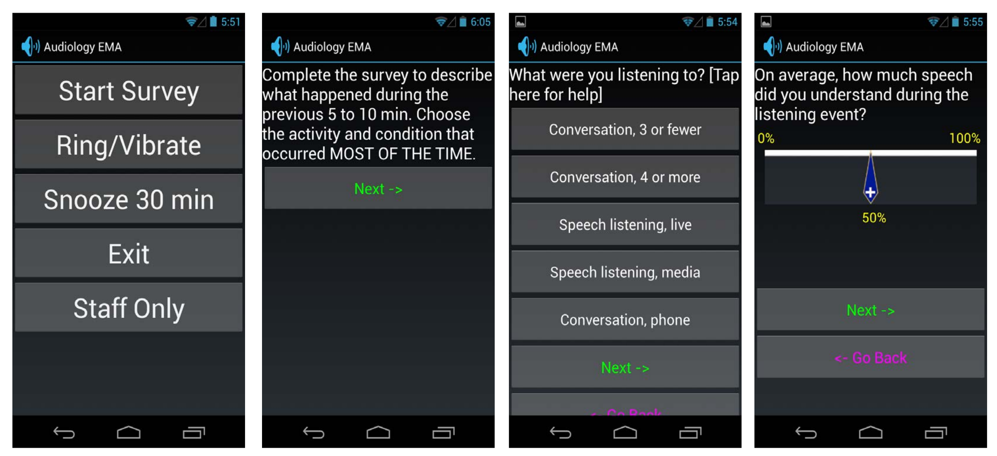


Figure 2. EMA Application

- Questions included in the survey asked participants to report on **environmental factors,** which were ordinal or categorical, as well as **perceptual factors**, which were continuous (0-100 scale). Survey questions and possible responses are shown in **Figure 3.**
- GPS tags on surveys were used to compare each survey to all other surveys taken by that same participant within 10 meters. Distances were calculated using a haversine-adjusted interpoint distance matrix.
- A **stability index** (*SI*) was calculated by dividing the number of same responses (with reference to a particular survey) by the number of total responses in that location. If $\{R_S\}$ is the set of same responses and $\{R_T\}$ is the set of total responses within 10 meters of the reference survey then:

$$SI = \frac{|\{R_S\}|}{|\{R_T\}|}$$

- A stability index of 1.0 then indicates the participant rated that factor the same each time they took a survey within 10 meters.
- **Baseline Stability Indices** were also calculated, where all surveys were considered as being taken in the same location.
- Because perceptual factors were continuous and registered using a slide bar, and because different participants used different areas or spans of the scale, a response for a perceptual factor was considered the "same" if it was within the median difference between all response differences for that subject. If $M(R_{Diff})$ is the median of the difference distribution among all responses for a subject then:

$$R_1 \le \left(R_2 \pm M(R_{Diff})\right) \to (R_1, R_2) \in \{R_s\}$$

- Because environmental factors had different numbers of responses, each mean *SI* for each environmental factor was transformed into a comparative *SI*, or *compSI*, by subtracting a decimal that represents one over the number of possible choices for that factor, μ, from the *SI* then dividing this number by one minus this μ, or:

$$compSI = \frac{SI - \mu}{1 - \mu}$$

- Mean Stability Indices were calculated by taking the mean of the individual subject means for each hearing aid condition.

RESULTS

- Stability indices for all factors in all conditions are shown in **Figure 4**.
- Significant differences were found between all hearing aid conditions ($p < 0.0001$).
- Significant differences were observed between all stability indices with the 10 meter criterion and the baseline (no location specification) criterion ($p < 0.0001$).

ENVIRONMENTAL FACTORS

Location –*Where were you?*
1. Outdoor, moving traffic.
2. Outdoor, other than traffic.
3. Home, 10 or fewer
4. Other than home, 10 or fewer
5. Crowd of people, 11 or more

Reverb –*Based on room size and carpet presence.*
1. High
2. Low

Signal Type –*What were you listening to?*
1. Speech
2. Non-speech
3. Not actively listening (excluded)

Listening Activity –*If speech, what type of speech?*
1. Conversation, 3 or fewer
2. Conversation, 4 or more
3. Speech listening, live
4. Speech listening, media
5. Conversation, phone

Noise Location –*Where was the noise most of the time?*
1. Front
2. Side
3. Back
4. All-around

Noisiness –*On average, how noisy was it during the listening event?*
1. Quiet
2. Somewhat noisy
3. Noisy
4. Very noisy

Talker Familiarity –*Were you familiar with the talker(s)?*
1. Unfamiliar
2. Somewhat unfamiliar
3. Somewhat familiar
4. Familiar

Talker Location –*Where was the talker most of the time?*
1. Front
2. Side
3. Back

Visual Cues –*Could you see the talker's face?*
1. No
2. Yes, but only sometimes
3. Almost always

PERCEPTUAL FACTORS (All 0-100)

Speech Perception –*How much speech could you understand during the listening event?* (0%-100%)

Listening Effort –*How much effort was required to listen effectively?* (Very easy – Very effortful)

Localization –*Could you tell where sounds were coming from right away?* (Not at all – Perfectly)

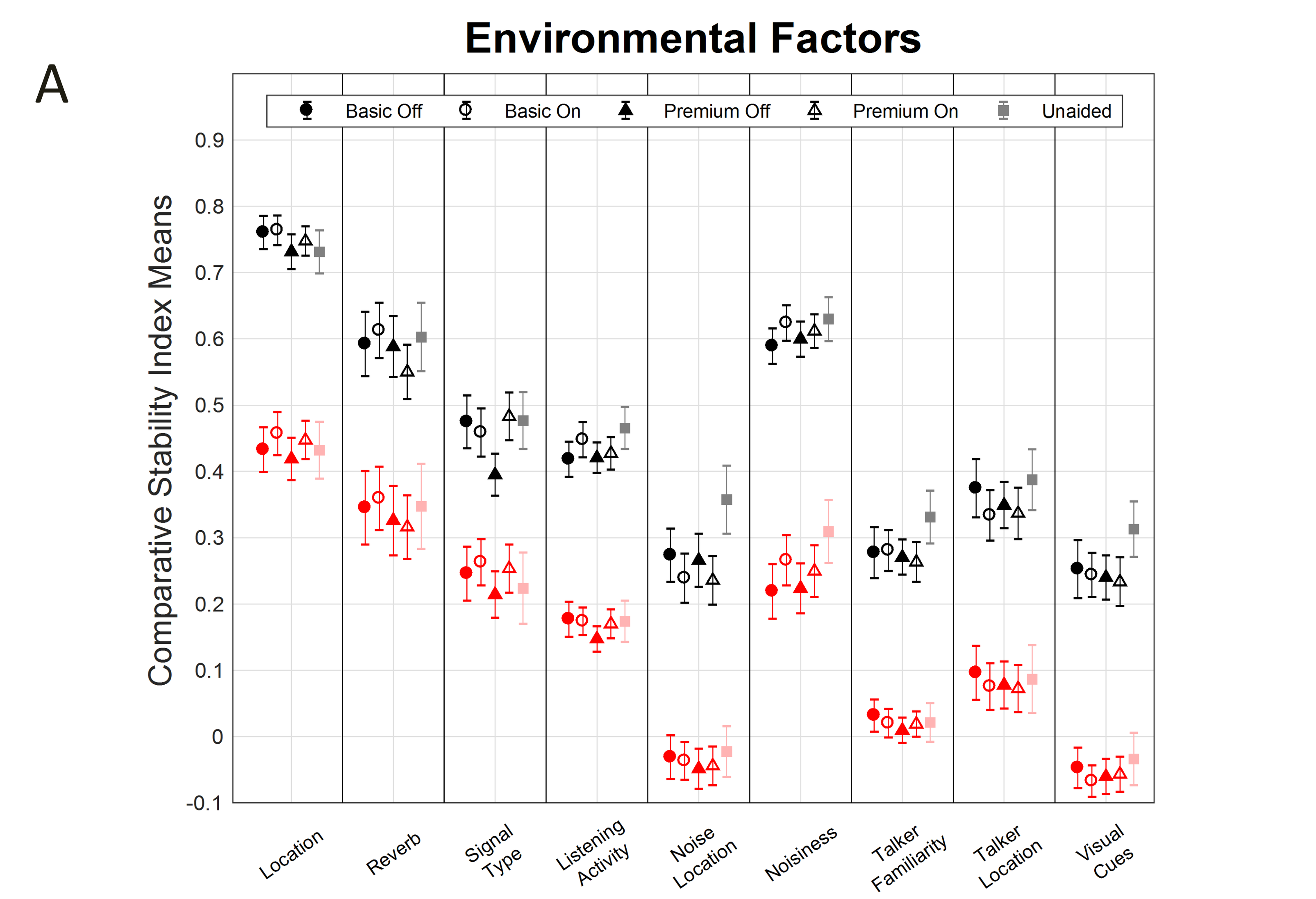
Loudness –*How would you judge the overall loudness of the sound?* (Very soft – Uncomfortably loud)

Loudness Satisfaction –*Were you satisfied with the loudness of the sound?* (Not good at all – Just right)

Hearing Aid Satisfaction –*Were you satisfied with your hearing aids?* (Not at all – Very Satisfied)

Activity Restriction –*How much of your hearing difficulties affected what you wanted to do in this situation?* (Not at all – Very much)

Figure 3. EMA Questions



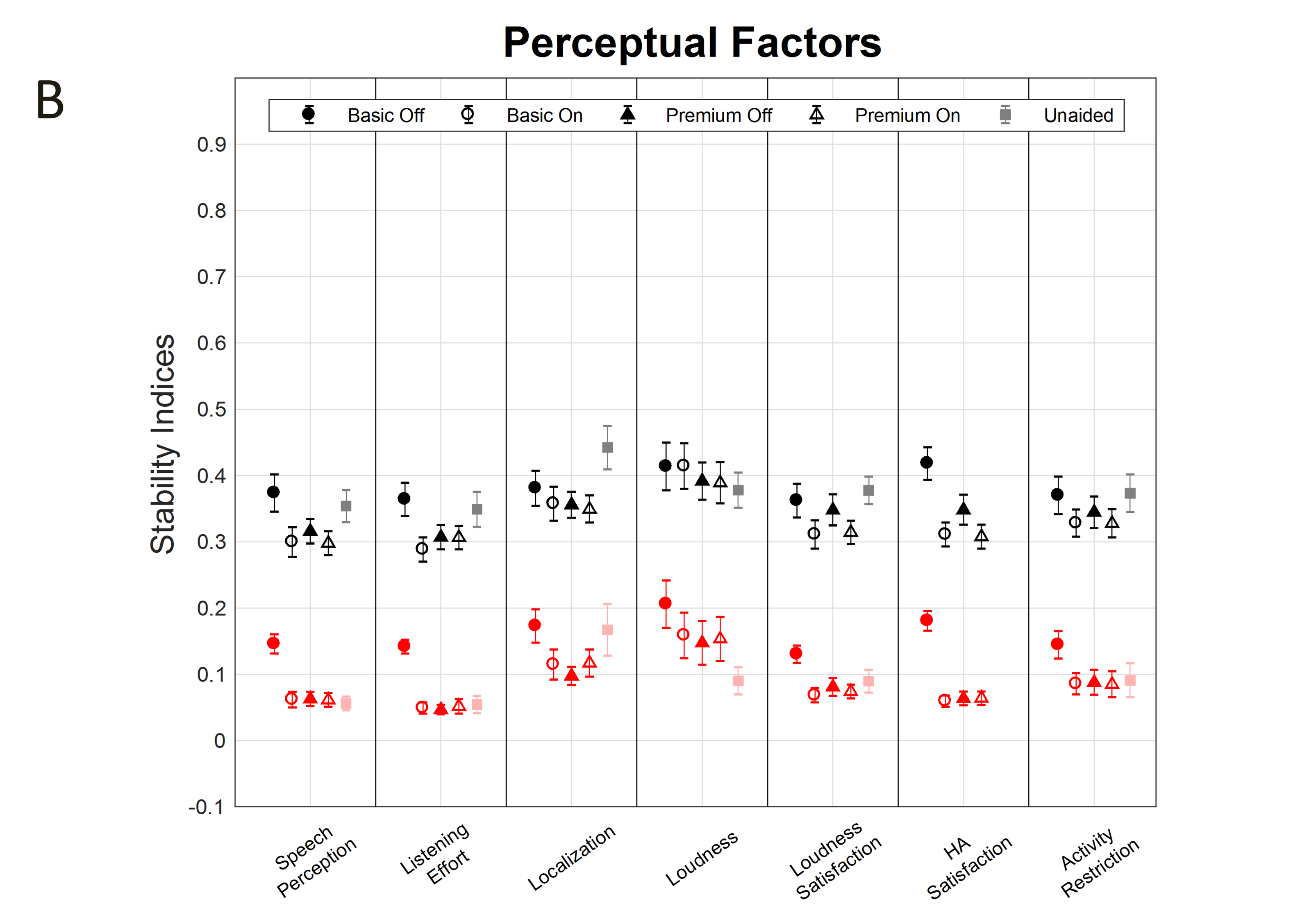


Figure 4. Stability indices with standard errors for environmental (A) and perceptual (B) factors. Indices using the **10 meter criterion are shown in black.** Baselines indices (no location) are shown in red.

DISCUSSION

- The high stability index for location may validate the use of the 10m distance criterion, as location coded for the setting the listener was in. The lower index for reverb may indicate that GPS is not accurate enough to be room specific. The high index for location also suggests that the crowd size tended to be the same at each location over time.
- Significant differences between the 10m and baseline indices indicates that location does affect ecological stability. That is, greater ecological stability is observed when measured at a specific location.
- However, even when location was controlled for, Environmental factors (Figure 4A) generally exhibited a large degree of change over time. While group size, reverb, and noise level were fairly consistent in one place over time, other factors were relatively less stable. In particular, how familiar participants were with the talkers, their access to visual cues, and the location of the talker(s) varied considerably in each location over time. Less variation was seen in perception factor stability overall (Figure 4B). This may indicate a true phenomenon or may be an artifact of how these were measured and calculated (e.g., categorical variable vs. continuous variable).
- These findings may have implications for the clinic and for hearing aid design. In particular, that signal type, noisiness, listening activity, and number of talkers were relatively stable may indicate that GPS controlled hearing aid settings could be beneficial. However, that talker familiarity, talker location, and access to visual cues, which are known to affect speech perception and listening effort[5, 6], were not stable may indicate that listening performance will vary as a function of these factors despite appropriate geographical changes to hearing aid processing. This may account for the large degree of variability observed in perceptual factors.

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