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The effect of hearing acuity on using semantic expectancy in degraded speech

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Abstract

Speech is degraded by extrinsic factors (e.g., background noise), intrinsic factors (e.g., hearing loss), or a combination of both. Listeners can compensate for degradation with semantic expectancy, which is the ability to apply general conceptual and linguistic knowledge to incoming language input (e.g. speech or text) in order to facilitate language understanding (Pichora-Fuller et al., 1995). Previous literature suggests that semantic expectations aid perception and that this is particularly helpful in in the presence of acoustic competitors that degrade the target acoustic signal (Fallon et al., 2002; Lash et al., 2013). However, the mechanisms by which semantic expectancy contributes to individuals' perception in the presence of acoustic competitors remains unclear. **The present study examines how acoustic degradation, from background noise and hearing loss, influences listeners' use of expectancy and how this processing affects speech perception.**

Methods

Participants

Normal-Hearing (NH) group: 24 adults (15 female, 18-31 years old) with no prior history of hearing loss, speech, and language services. All participants were native English speakers.

Hearing loss (HL) group: 7 adults with hearing loss based on provided audiogram (6 female, 21-42 years old). See demographic table for more information.

All procedures were approved by the Institutional Review Board at Northwestern University.

Stimuli

Carrier Sentences: 60 sentence carriers were developed according to the criteria established by Bloom & Fischler (1980) to create three expectancy conditions (see below). 40 sentence carriers had high semantic expectancy and ended with monosyllabic, concrete final words that either made the sentence semantically (1) *congruent* or (2) *conflicting*. 20 sentence carriers did not contain semantic information to create a *neutral* expectancy condition (3). Sentences were recorded by a female talker.

Expectancy Conditions:

1	**Congruent Expectancy**	The boy hits the ball with the **bat.**
2	**Conflicting Expectancy**	The boy hits the ball with the **cat.**
3	**Neutral**	The boy looks at the **bat/cat.**

Listening conditions: Sentences were presented in the presence of steady-state speech-shaped noise (SSN). This noise was generated in MATLAB and was filtered to match the long-term average spectrum of the sentences. SSN was presented at 62 dB SPL while the intensity of the target sentences varied to create the following listening conditions:

1) **-12 dB SNR** (signal-to-noise ratio)
2) **-7 dB SNR**
3) **Quiet** (no SSN present)

Procedure

Participants sat in front of a 21.5" Dell touchscreen monitor with one Genelec speaker ±45º left and right of the monitor. While listening to sentences, participants were presented with four images and completed a four-alternative forced choice task where they were asked to identify the image corresponding with the last word of the sentence (see **Figure 1**). Participants listened to all expectancy conditions across all listening conditions. Task performance was quantified by *accuracy* and *reaction time*.

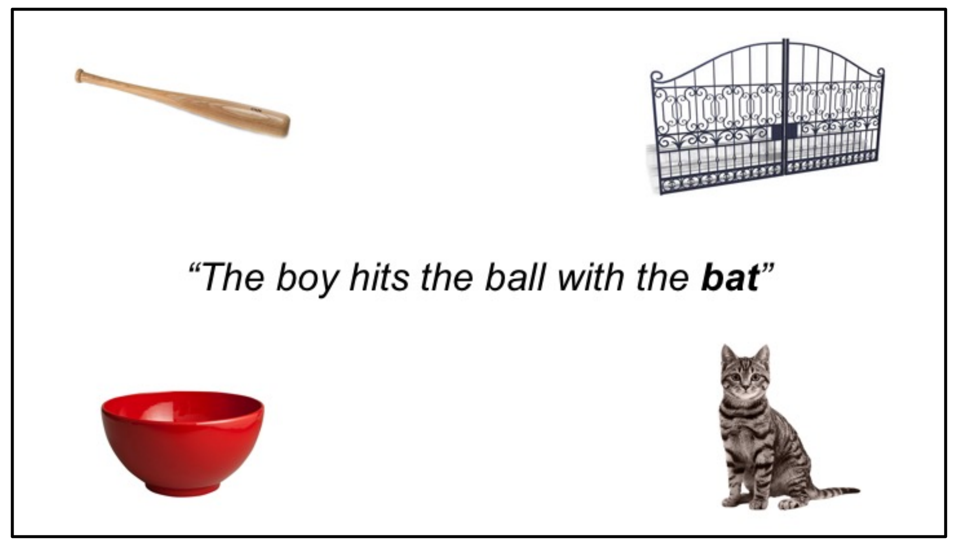

Figure 1: Image arrangement for the four-alternative forced choice task. Starting at the top left and proceeding clockwise: the congruent expectancy target/expectancy competitor (bat), random image (a gate), the conflicting expectancy target/rhyme competitor (cat), and a competitor with the same initial sound as the correct target (bowl).

NH Group: Speech Recognition Performance

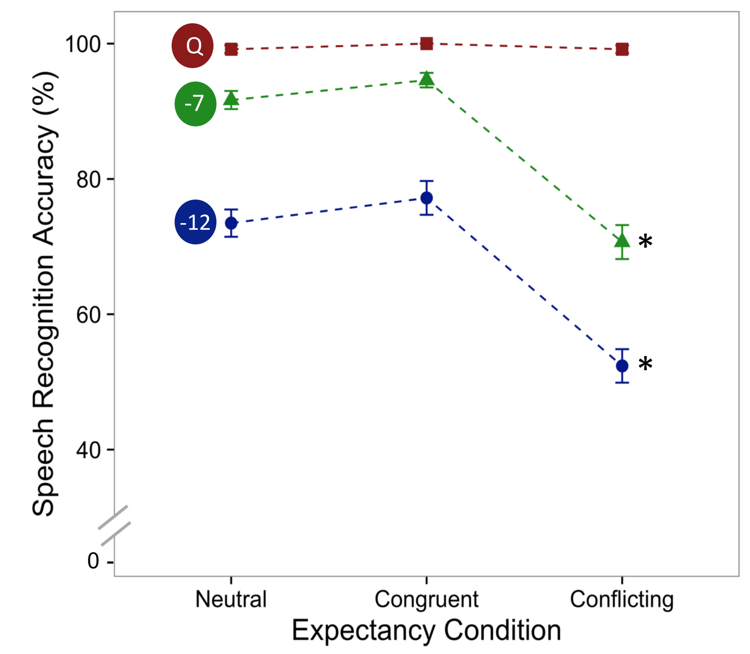

Figure 2: Mean (± SE) task accuracy, averaged across participants. A logistic mixed effects model indicated that accuracy in the congruent condition was significantly better than neutral ($\beta = 0.21$, $SE = 0.08$, $p < 0.05$). Accuracy in the conflicting condition was significantly worse than that in the congruent condition ($\beta = -1.01$, $SE = 0.08$, $p < 0.0001$).

NH Group: Speech Recognition Errors

The boy hits the ball with the…

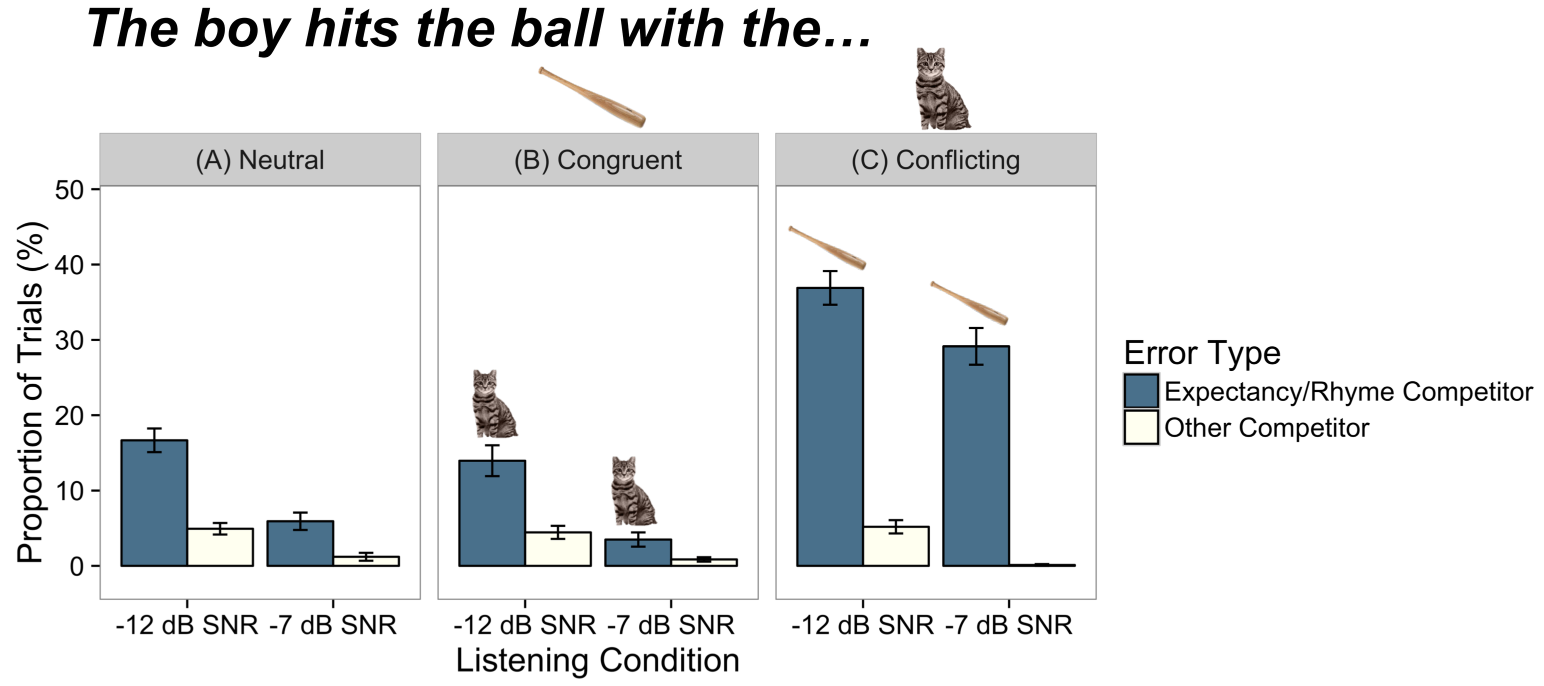

Figure 3: The mean (± SE) proportion of expectancy (blue bar in conflicting), rhyme (blue bar in neutral and congruent), and other (initial phoneme and random) error types out of total number of trials by expectancy and listening condition, averaged across subjects. Analyses show that more errors were due to selecting expectancy competitors in the conflicting expectancy condition.

NH Group Reaction Time

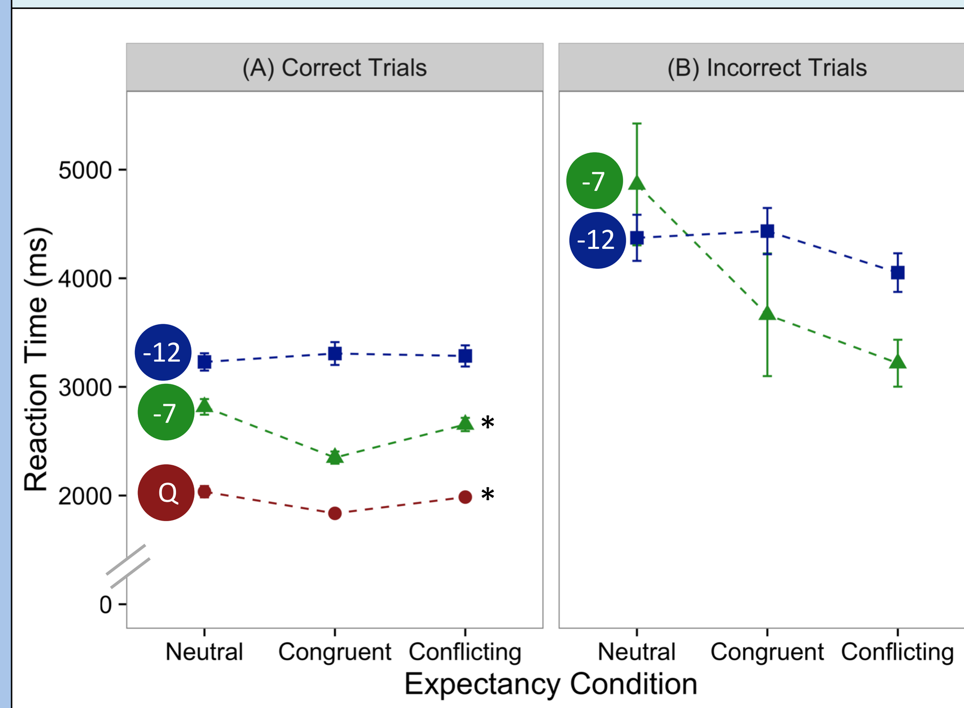

Figure 4: Mean (± SE) reaction time (RT), averaged across participants, for correct trials (A) and incorrect trials (B). RT was defined as the duration of time between the offset of the sentence and the participant's selection. A linear mixed effects model showed RT for correct trials in the congruent condition was significantly faster than RT in the neutral condition($\beta = -107.53$, $SE = 27.07$, $p < 0.001$).

HL Group Demographics

Subject	Chronological Age (years)	Age of HL Diagnosis	Degree of SNHL	Age of Device Onset (years)	Device Type
CI1	31.61	18 months	Profound bilateral	9 (left); 22 (right)	Cochlear Implant (both ears)
CI2	37.63	5 yrs old	Profound bilateral	37	Cochlear Implant (right ear only)
CI3	21.74	9 months	Profound bilateral	2	Cochlear Implant (both ears)
HA1	33.96	2 yrs old	Profound bilateral	31	BTE (both ears)
HA2	28.66	8 yrs old	Moderate bilateral	8 (FM system, situational); 11 (Hearing Aid)	BTE (both ears)
UA1	42.32	3 yrs old	Moderate bilateral	N/A	N/A
UA2	22.48	21 yrs old	Mild monaural	N/A	N/A

HL Group: Speech Recognition Performance

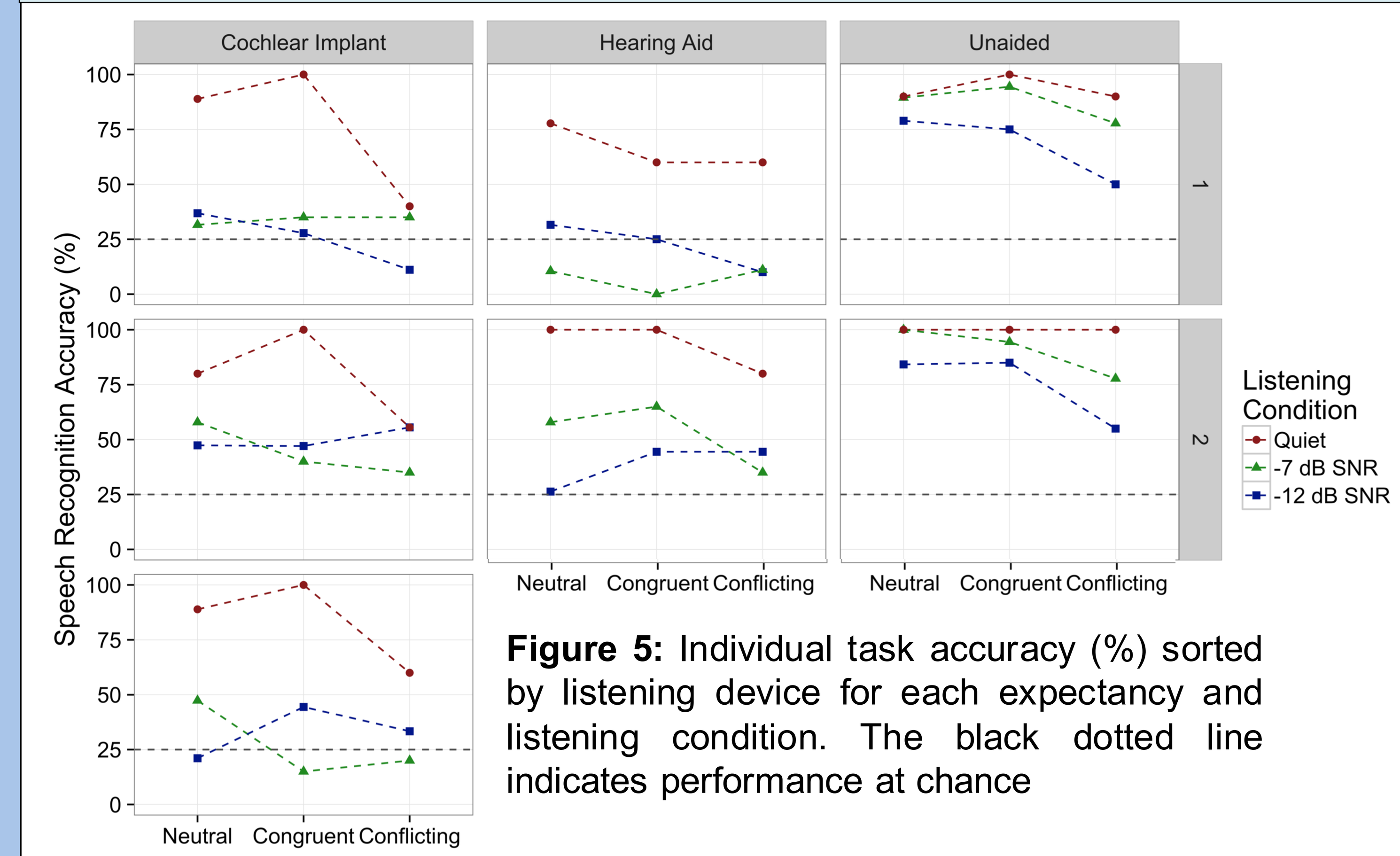

Figure 5: Individual task accuracy (%) sorted by listening device for each expectancy and listening condition. The black dotted line indicates performance at chance

HL Group: Reaction Time

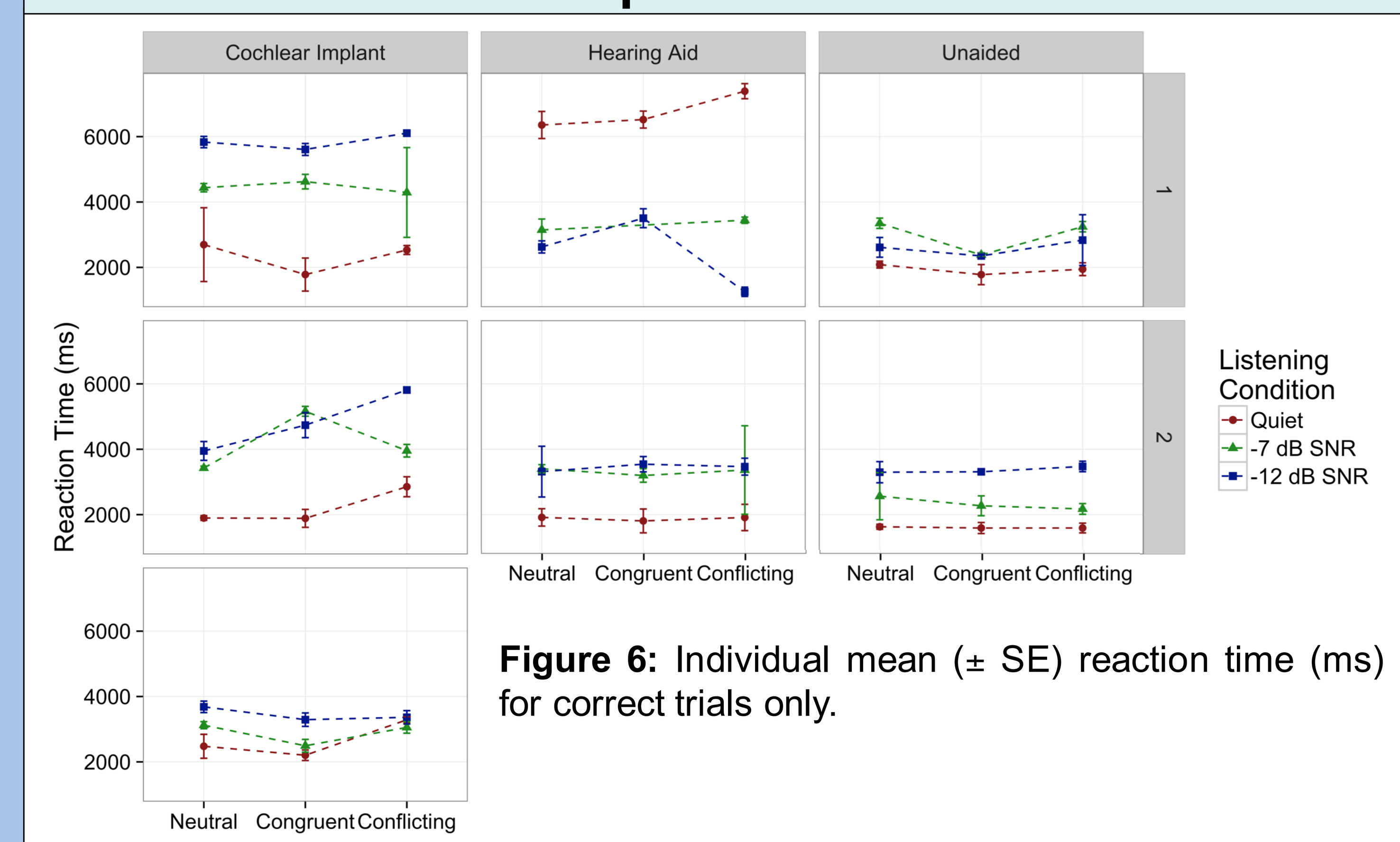

Figure 6: Individual mean (± SE) reaction time (ms) for correct trials only.

Conclusions & Summary

Results suggest that listeners use the most salient, reliable cue available. For NH listeners, semantic expectancy helps when the acoustic information is unreliable (e.g. in -7 dB SNR); however, when it is too noisy (e.g. -12 dB SNR), expectancy has little benefit. In contrast, individuals with HL demonstrated a reliance on expectancy in the quiet condition. Conflicting expectancy misled listeners suggesting they might over rely on expectancy when comprehending speech.

References

Bloom, P. a, & Fischler, I. (1980). Completion norms for 329 sentence contexts. *Memory & Cognition*, *8*(6), 631–642.

Fallon, M., Trehub, S. E., & Schneider, B. a. (2002). Children's use of semantic cues in degraded listening environments. *The Journal of the Acoustical Society of America*, *111*(5 Pt 1), 2242–2249.

Lash, A., Rogers, C. S., Zoller, A., & Wingfield, A. (2013). Expectation and entropy in spoken word recognition: effects of age and hearing acuity. *Experimental Aging Research*, *39*(3), 235–53.

Pichora-Fuller, M. K., Schneider, B. A., & Daneman, M. (1995). How young and old adults listen to and remember speech in noise. *The Journal of the Acoustical Society of America*, *97*(1), 593-608.

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