

# Within-Consonant Perceptual Differences in the Hearing Impaired Ear

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Objective: Understand how hearing impaired (HI) ears perceive the acoustic cues in speech.

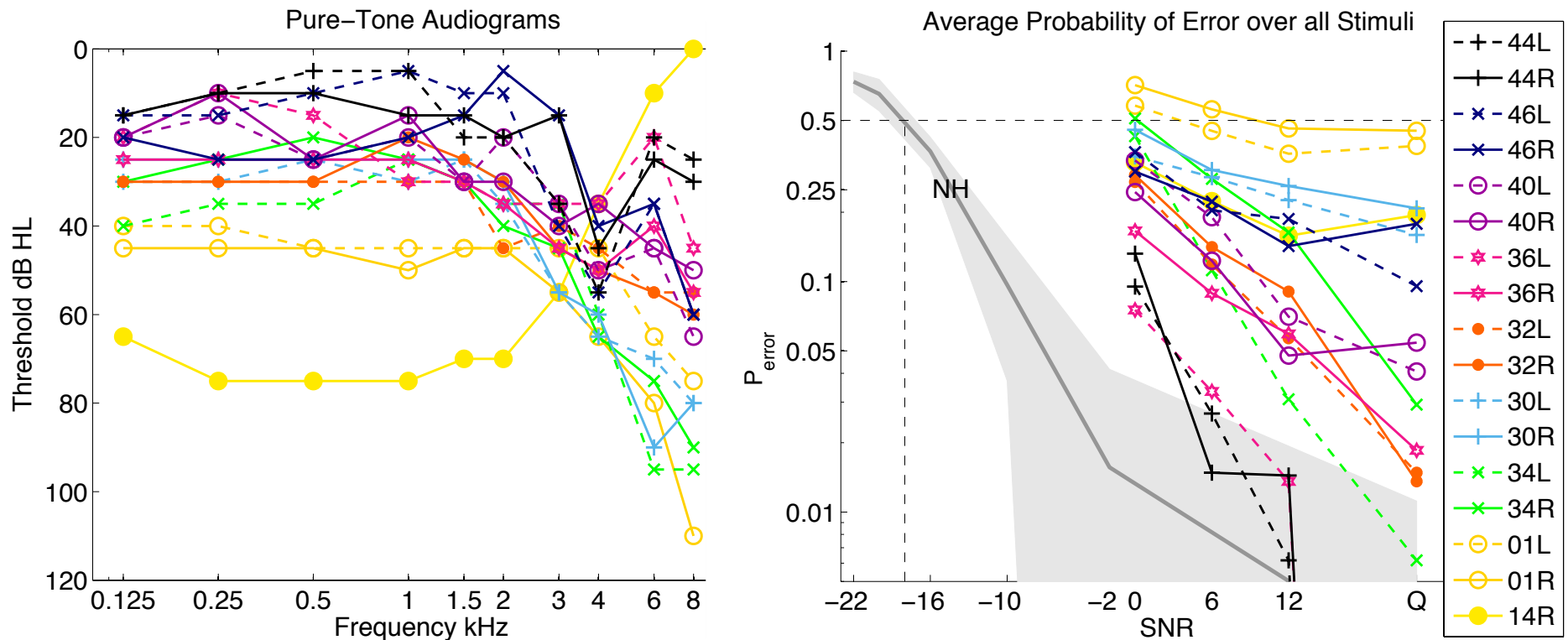
Methods: 14 Consonant Vowel stimuli (“zero-error,” unambiguous)  
/b, d, f, g, k, m, n, p, s, ʃ, t, v, z, z/+/ɑ/ (in plots: Z= z, S=ʃ)  
2 talkers for each consonant (1 male, 1 female)  
Speech Weighted Noise at 4 SNRs (0, 6, 12 dB, Q)  
*Token* - 1 talker & 1 consonant

Results: 1) HI errors can be contained to a small subset of tokens

2) Tokens of the same consonant can be perceptually different for HI listeners (noise-robustness/confusions)

3) Consistencies are observed across NH and HI ears in terms of noise robustness and confusion groups

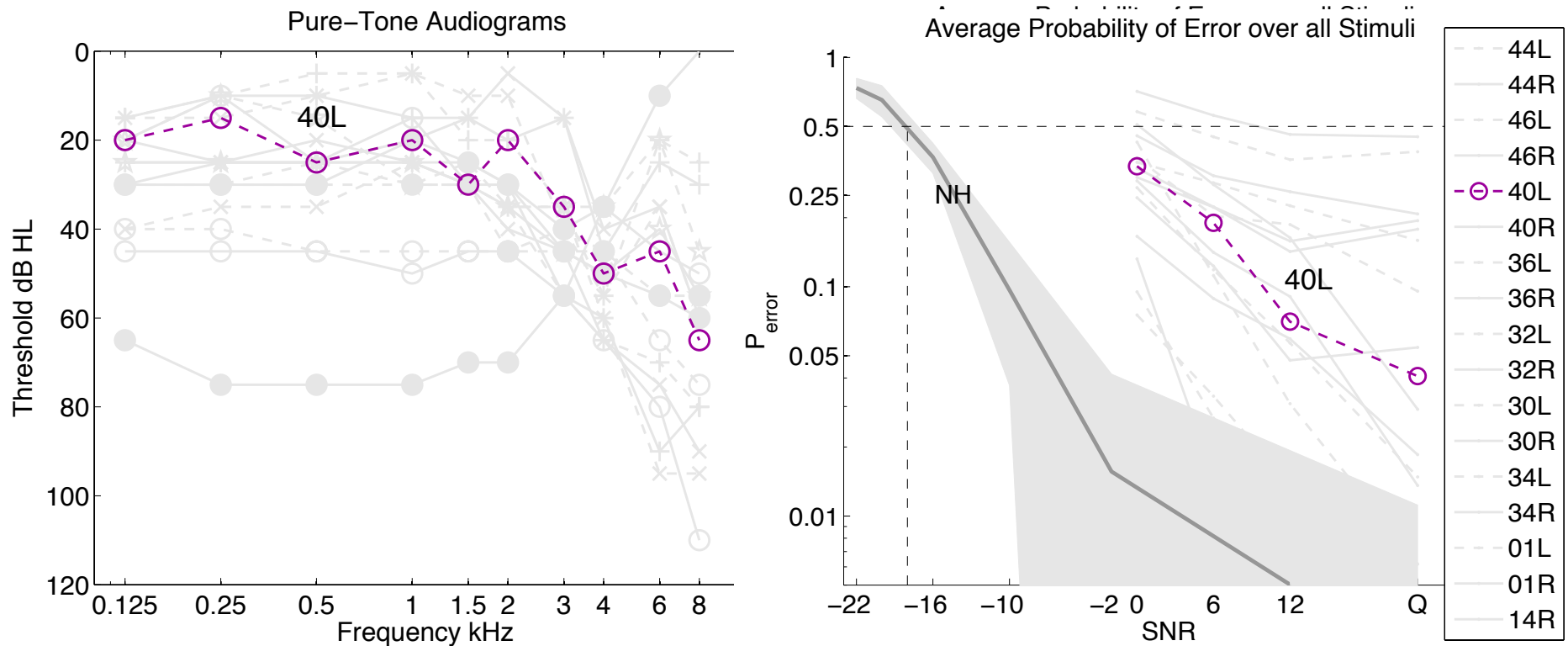
# Audiogram and Average Error - 17 HI ears



14 Miller-Nicely Consonant Vowel stimuli,  
2 talkers per consonant (1 male, 1 female)

/b, d, f, g, k, m, n, p, s, ʃ, t, v, ʒ, z/+/a/, Speech Weighted Noise (SWN)

# Audiogram and Average Error - 17 HI ears

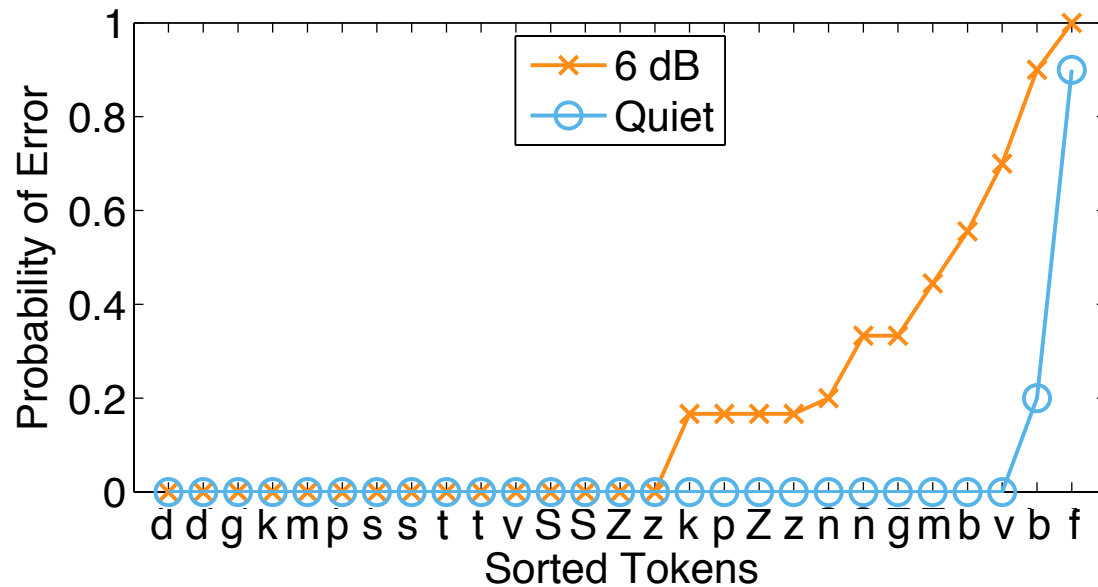
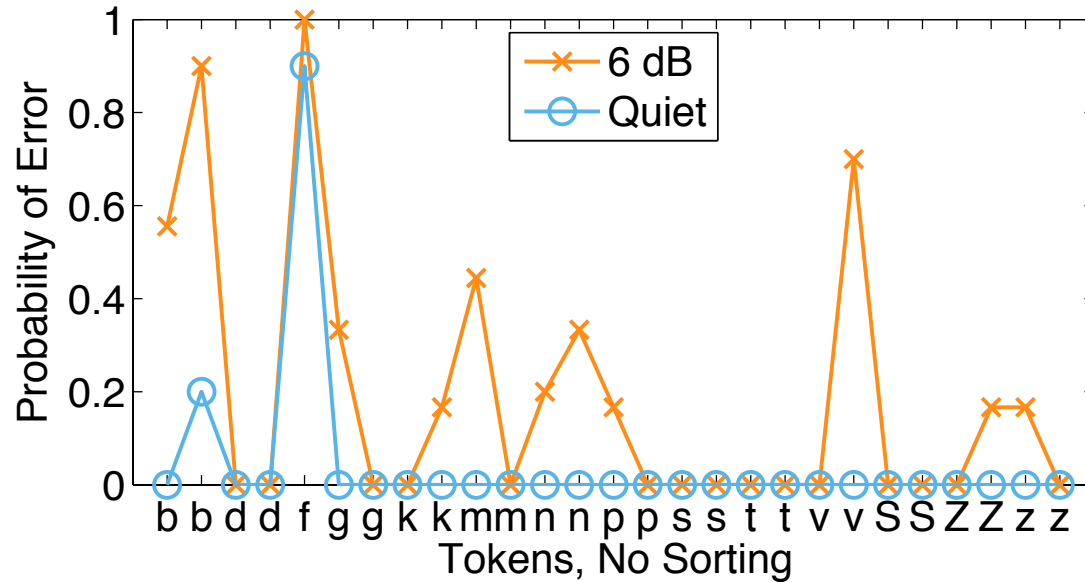


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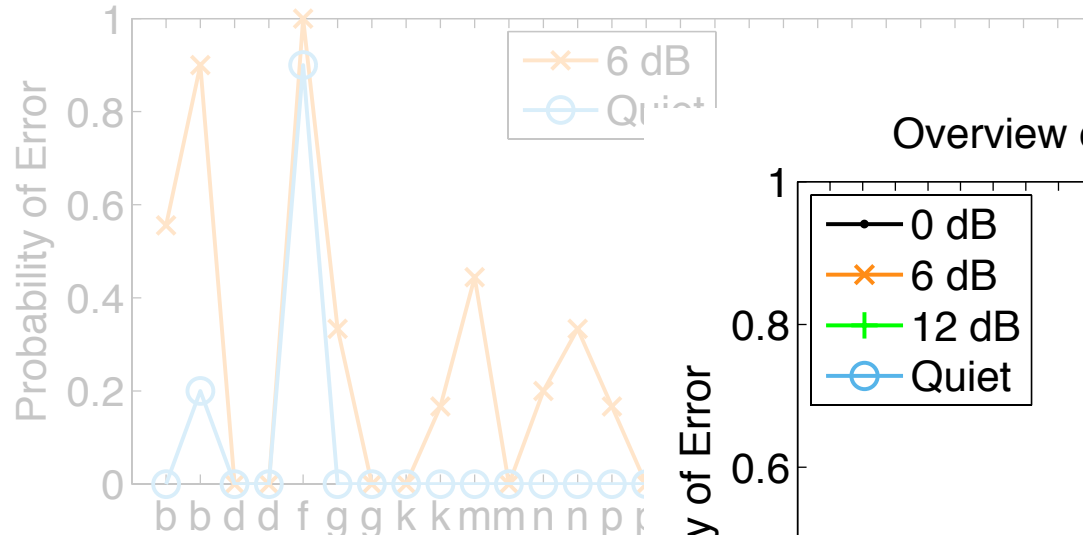
# Error Overview

Overview of Token Errors, Quiet, Listener 40L

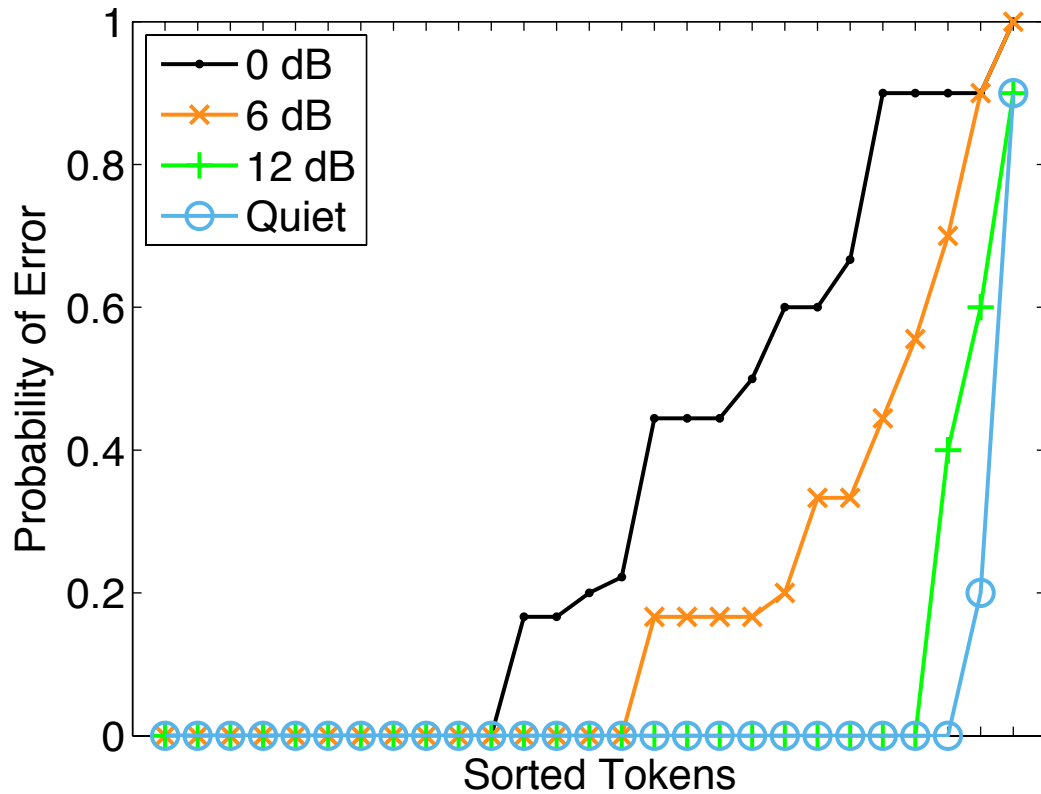


# Error Overview

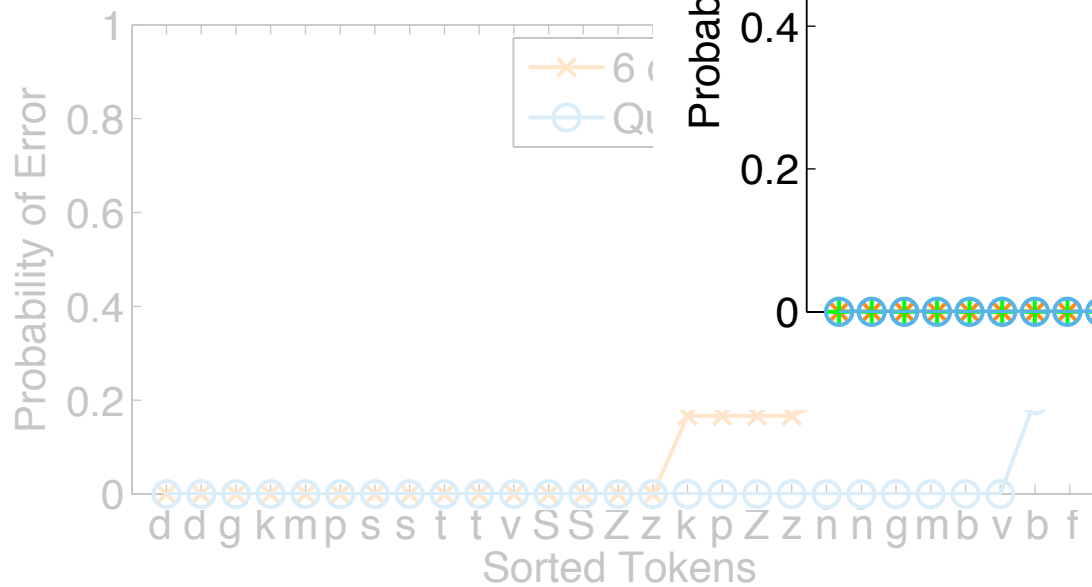
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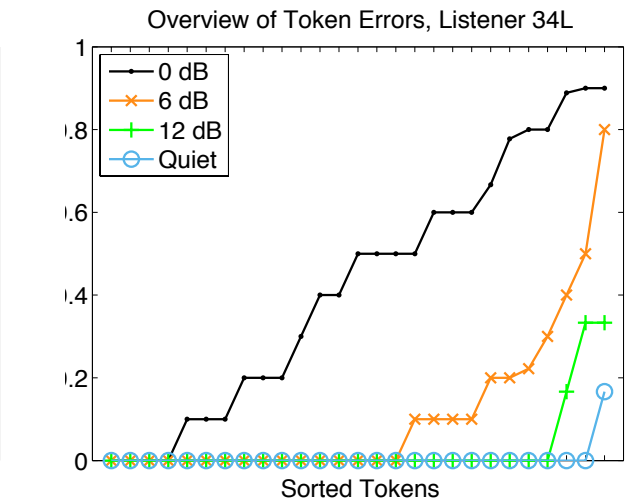
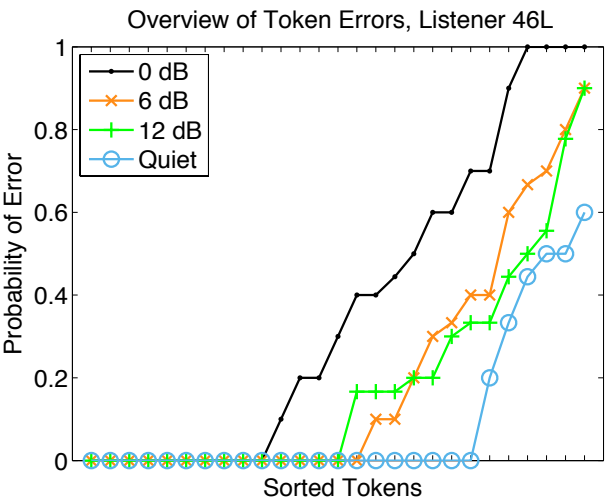
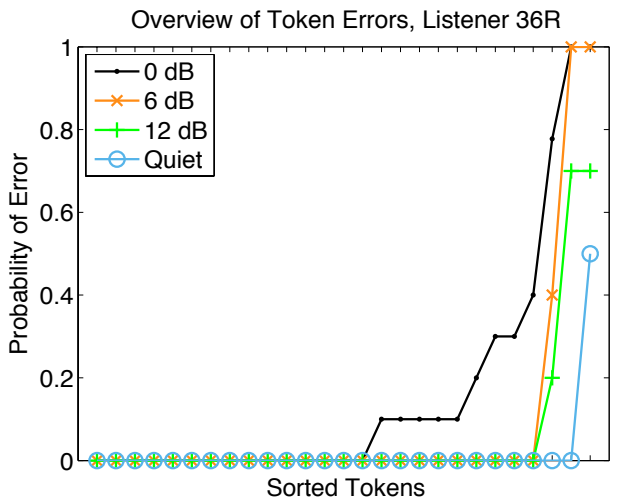
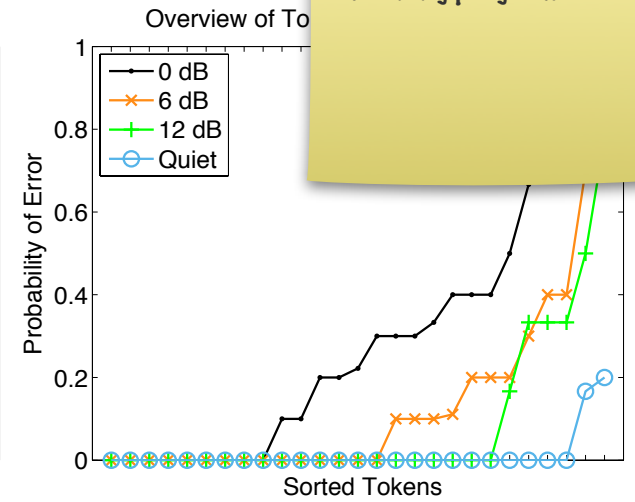
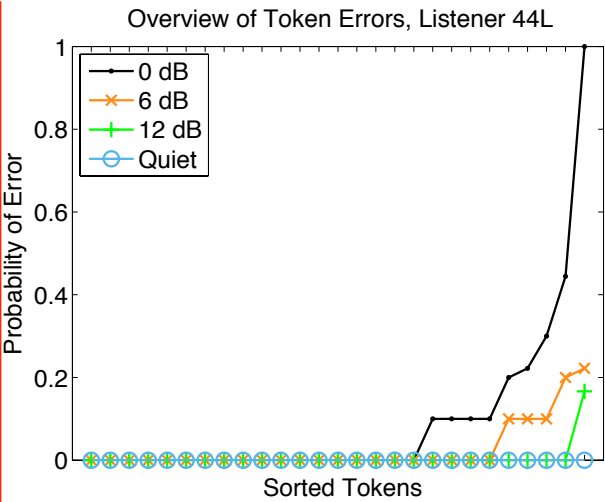
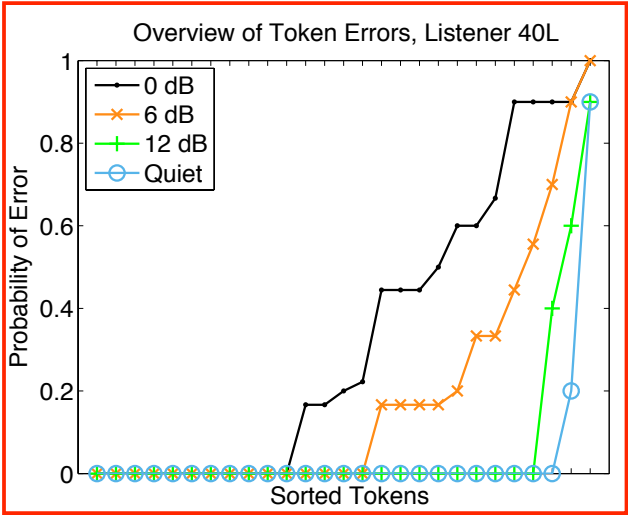


Overview of Token Error



# Error Overview - 6 HI ears

Implications for understanding an average. Or planning a training program.

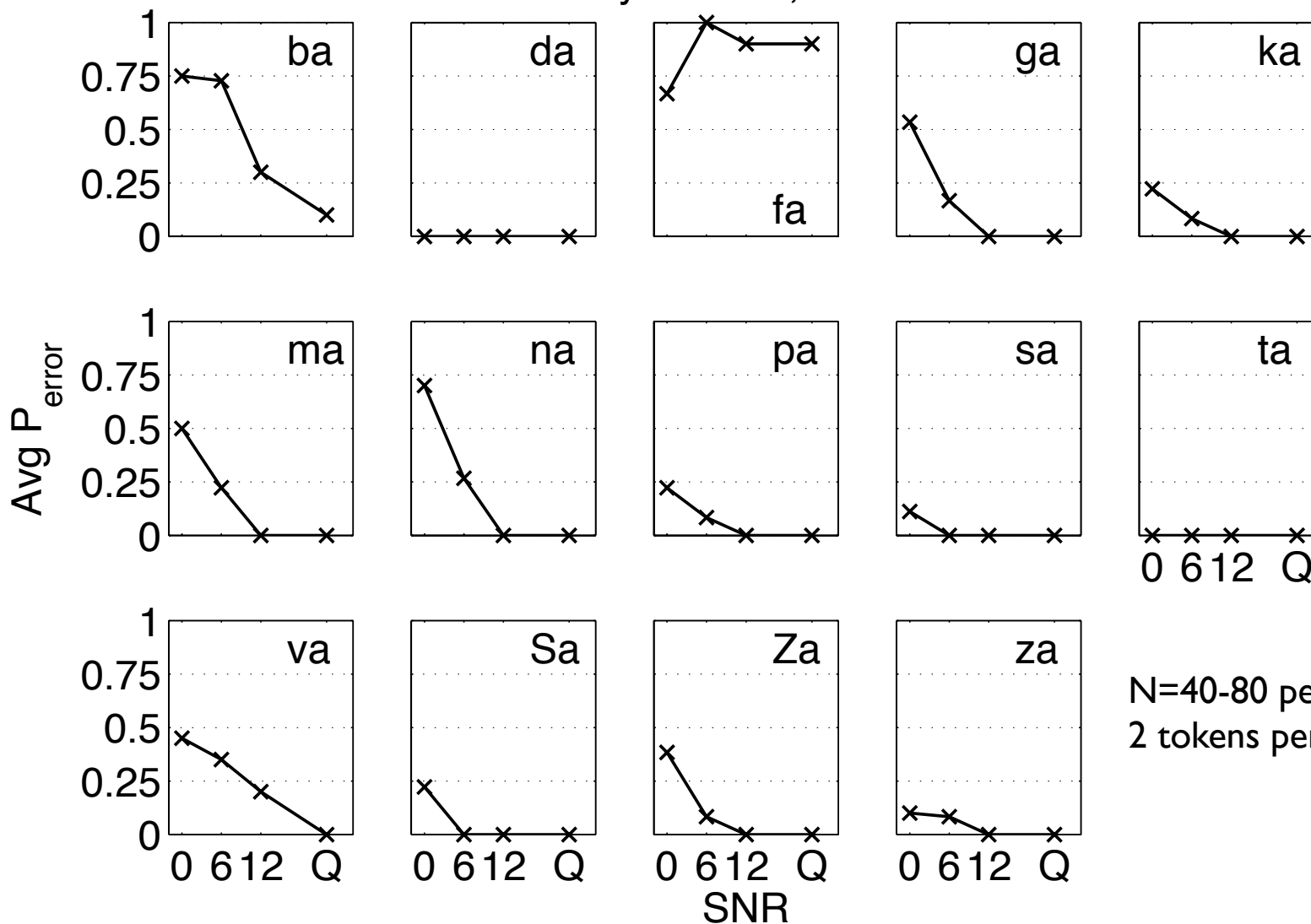


Concentration of error to a subset of tokens observed across HI ears, in both Quiet and Noise

# HI Within-Consonant Differences: Noise Robustness

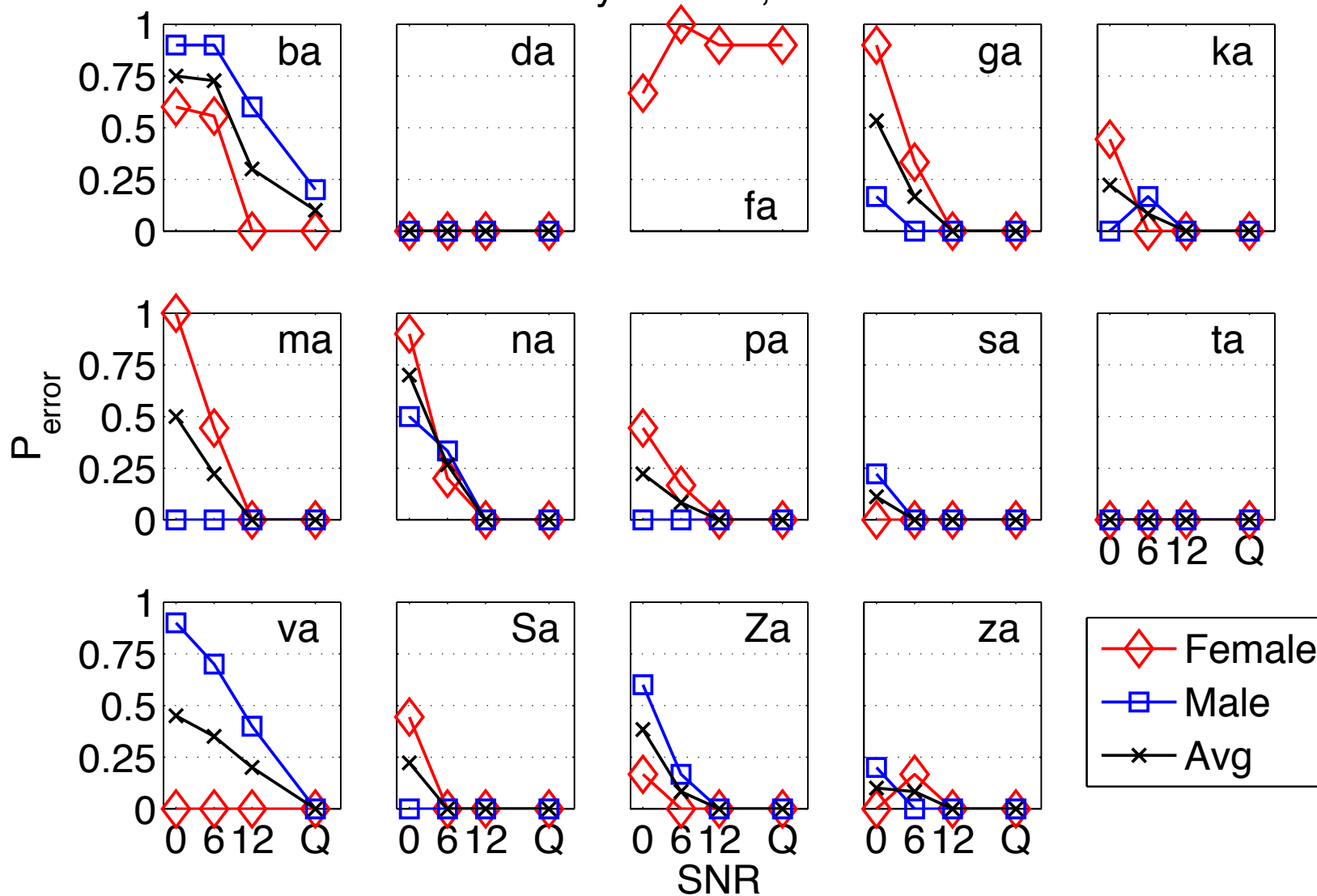


Probability of Error, Listener: 40L



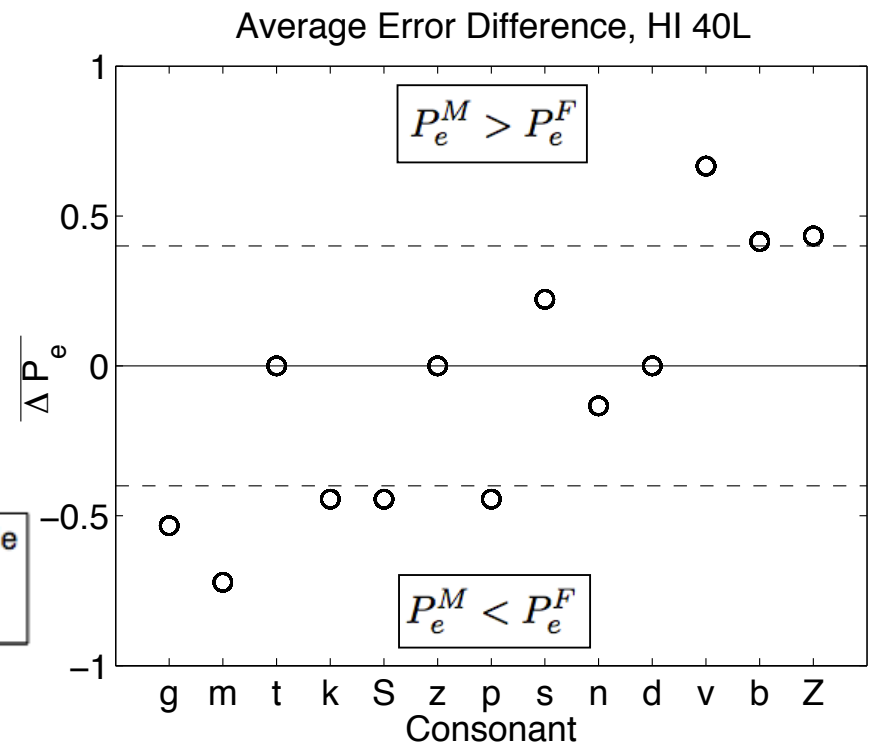
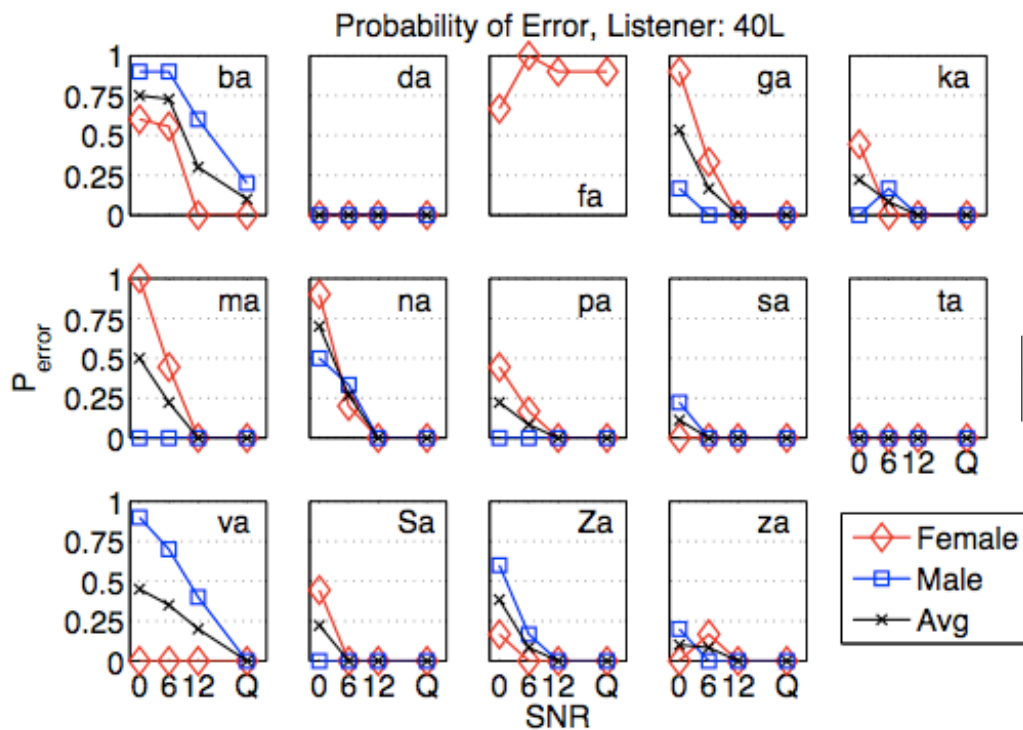
N=40-80 per consonant  
2 tokens per consonant

Probability of Error, Listener: 40L



Individual token differences in noise robustness

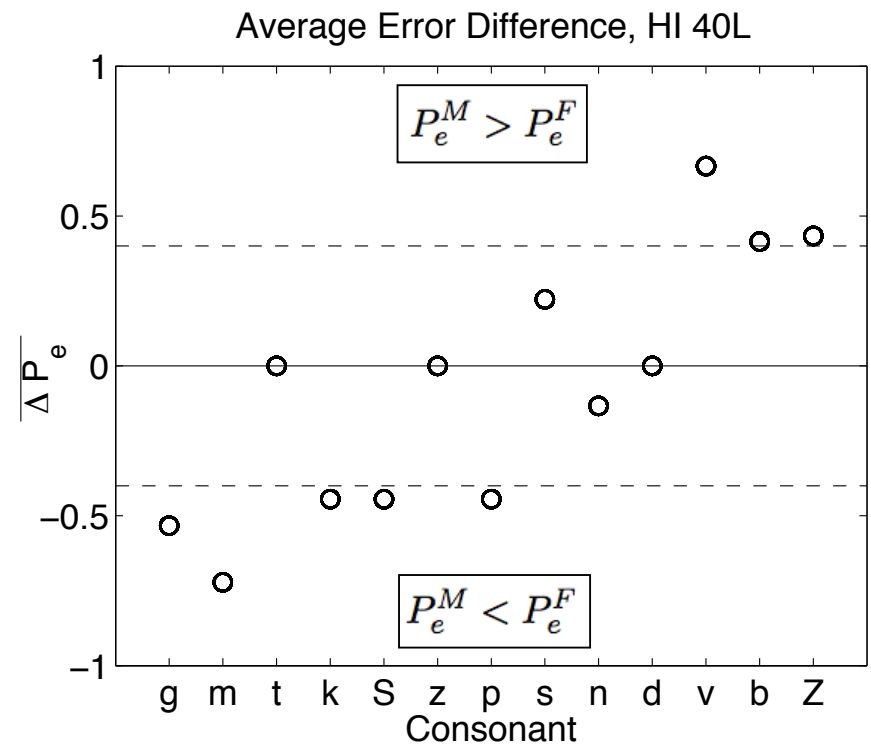
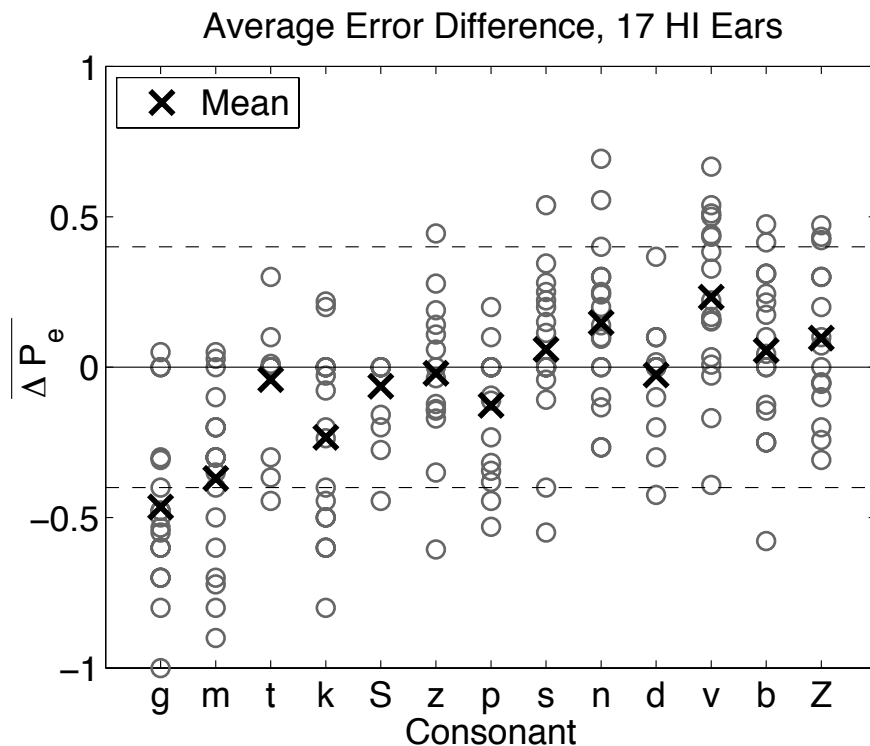
# HI Within-Consonant Differences: Noise Robustness



$$\overline{\Delta P_e} = \frac{1}{n(S)} \sum_{s \in S} (P_e^M(s) - P_e^F(s))$$

$$S = \{s \in \{0, 6, 12, \text{Quiet}\} : s \leq s^*\}$$

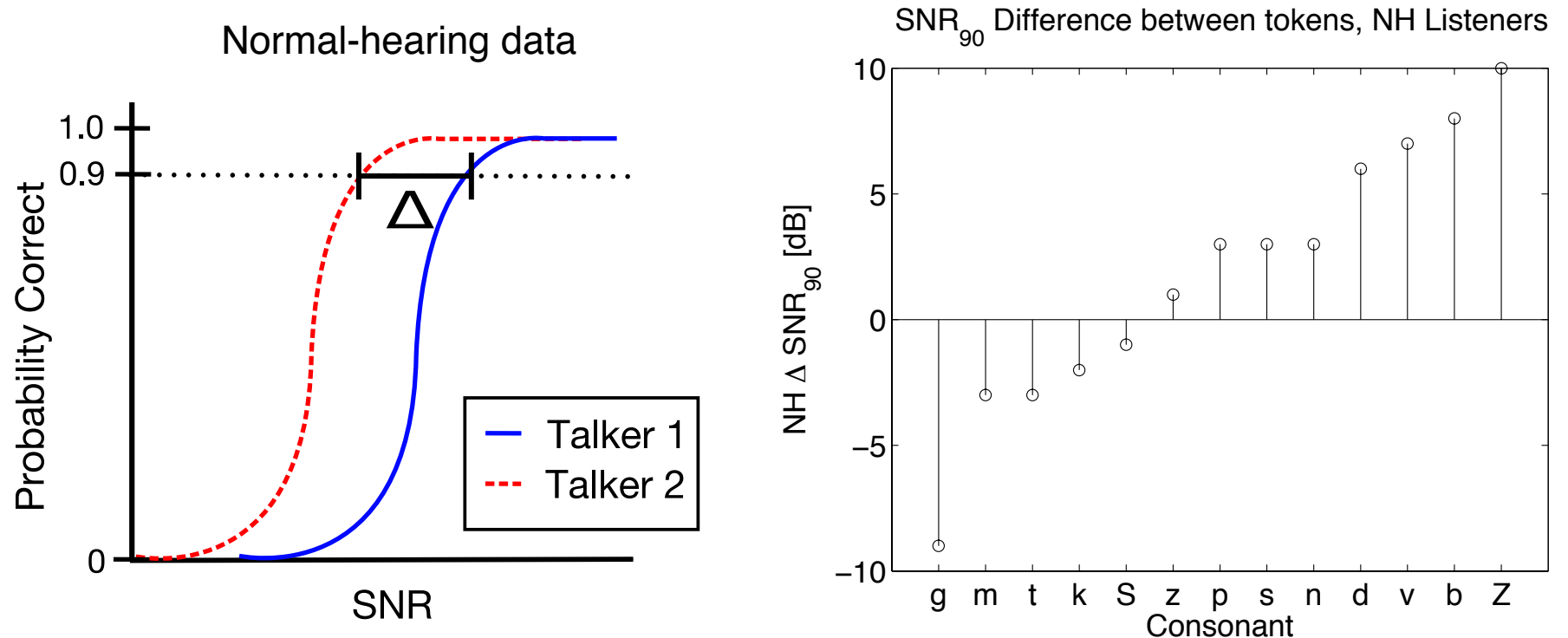
# HI Within-Consonant Differences: Noise Robustness



Differences in noise-robustness are observable across 17 HI ears

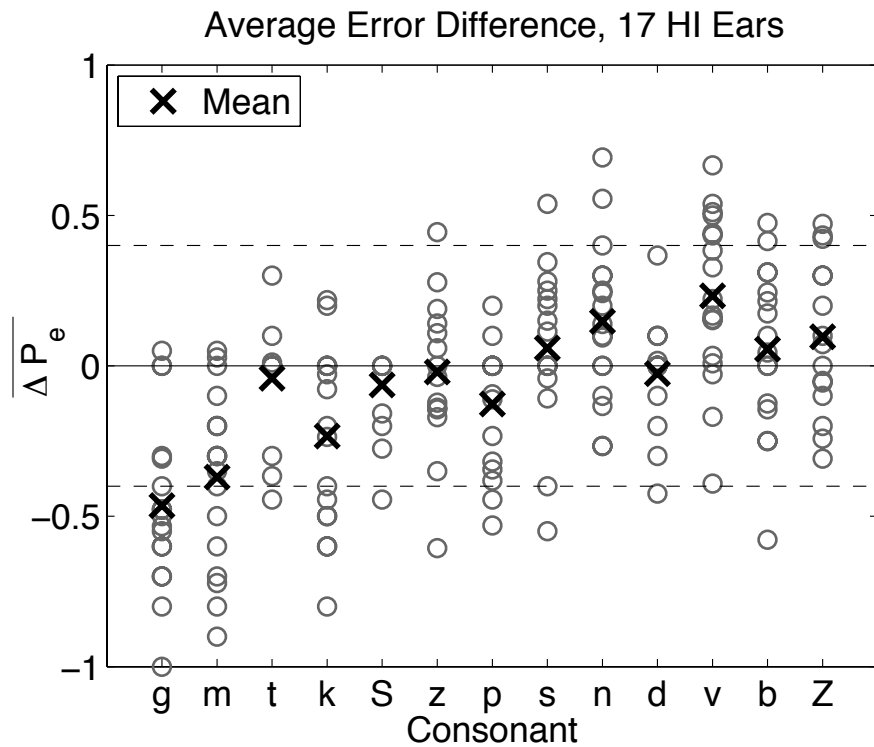
Consistencies across HI ears suggest that each token's acoustic cues play a role

# Characterizing Token Variability with Normal-Hearing (NH) psychoacoustic data

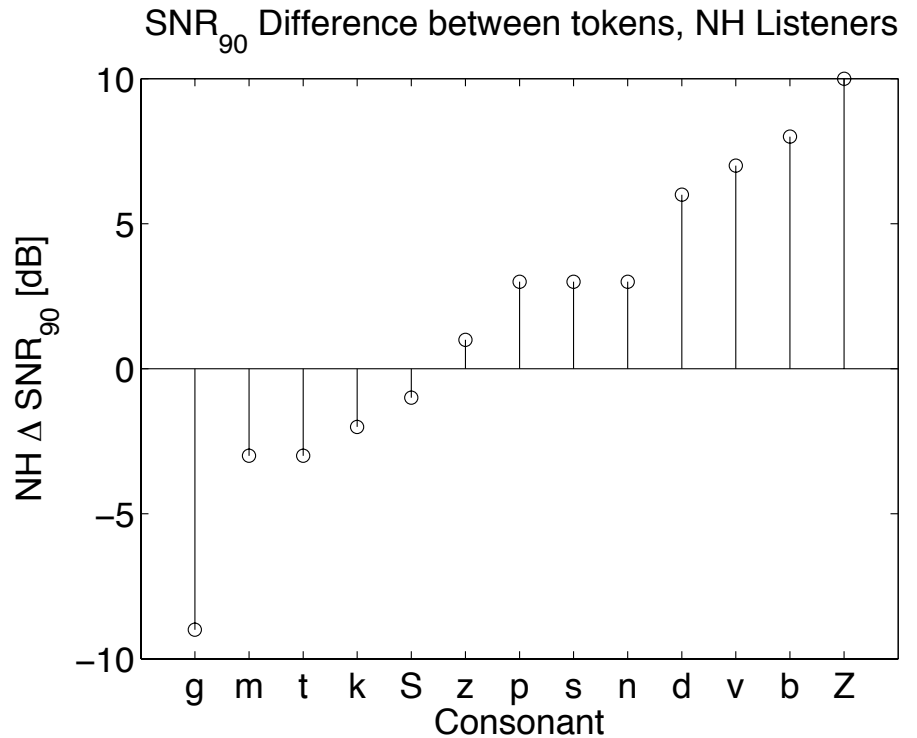


The psychoacoustic noise-masked threshold (NH SNR<sub>90</sub>) is correlated with the intensity of the token's acoustic cue region (Régnier, 2008). Compare the 2 tokens of each consonant.

# HI vs. NH Noise Robustness



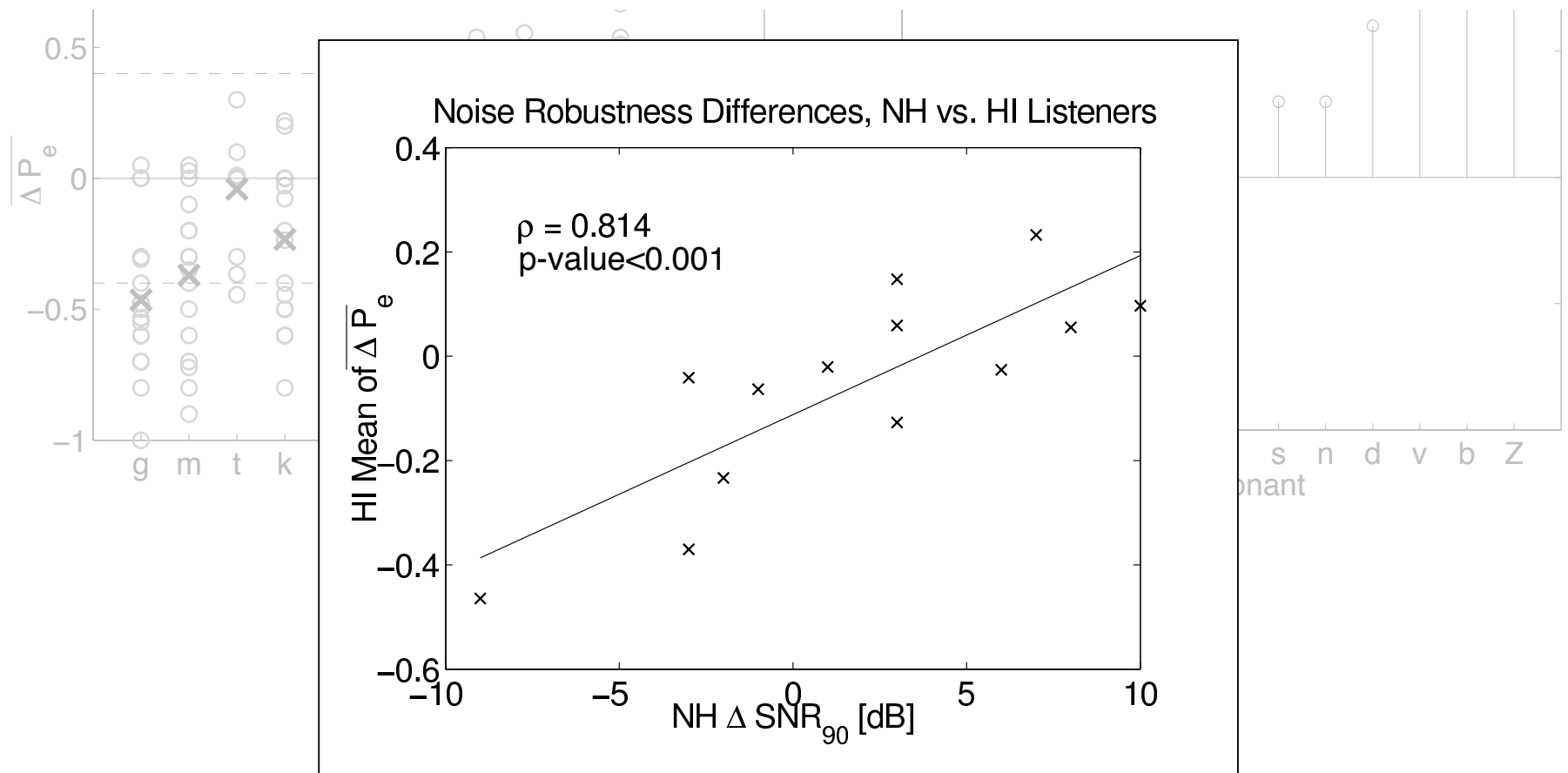
Hearing Impaired  
data



Normal Hearing  
data

# HI vs. NH Noise Robustness

Implies that natural variability of cue intensity, characterized by the NH-listener noise-masking data, is strongly related to the HI within-consonant differences in noise-robustness.



# Conclusion

There is a correlation between HI and NH consonant perception.

Supports the hypothesis that the HI and NH listeners  
are using the same primary cues.



# HI Within-Consonant Differences: Confusion groups



# Summary

Multiple tokens of the same consonant can be perceptually different for HI listeners in terms of noise-robustness and confusion groups

Systematic behavior on a token basis:

- HI and NH listeners show agreement in noise-robustness
- Different HI listeners share token-dependent confusions

Systematic responses suggest that common cues are being used

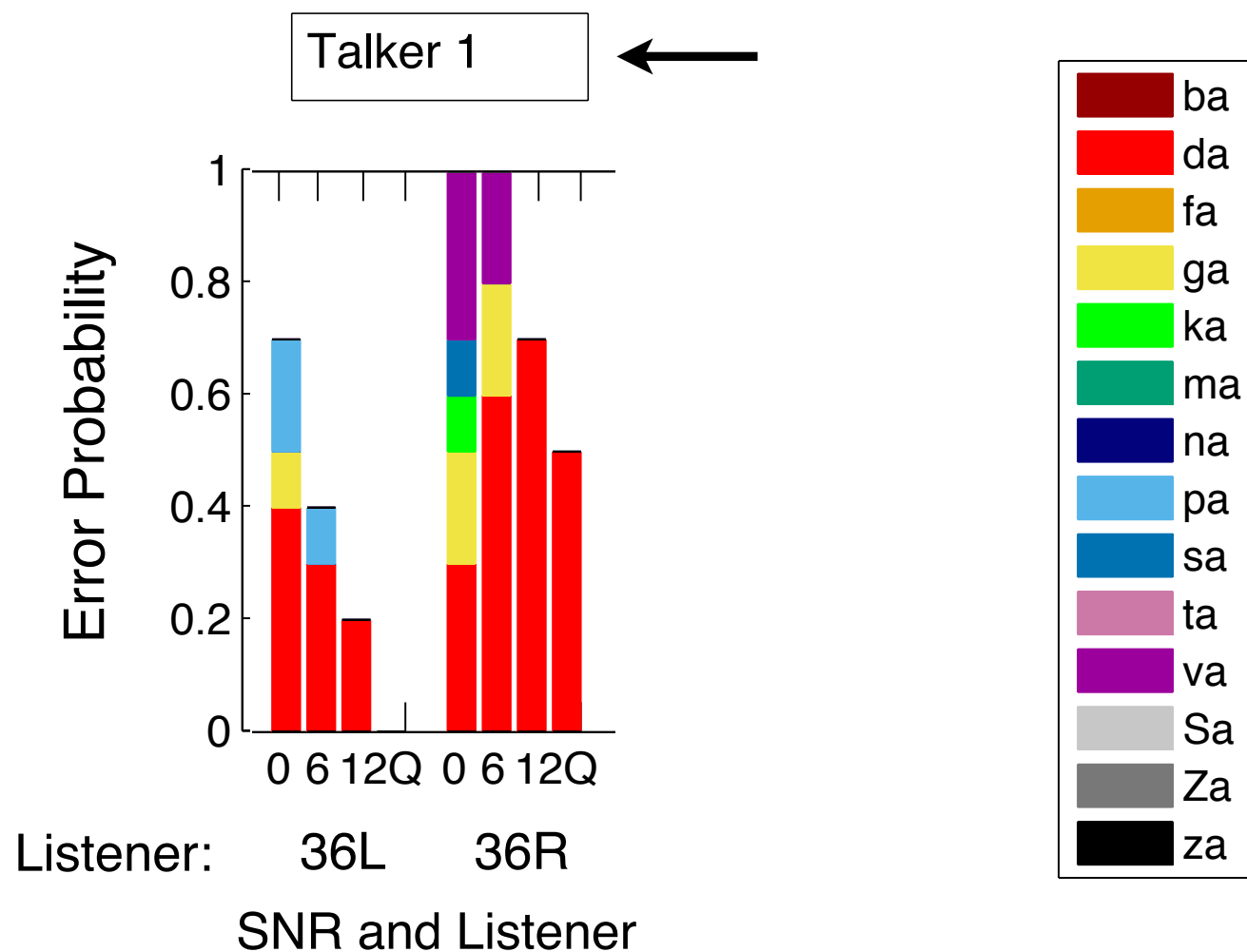
Consistent (low-entropy) token-specific confusions imply that the HI ears are not guessing

# Conclusions

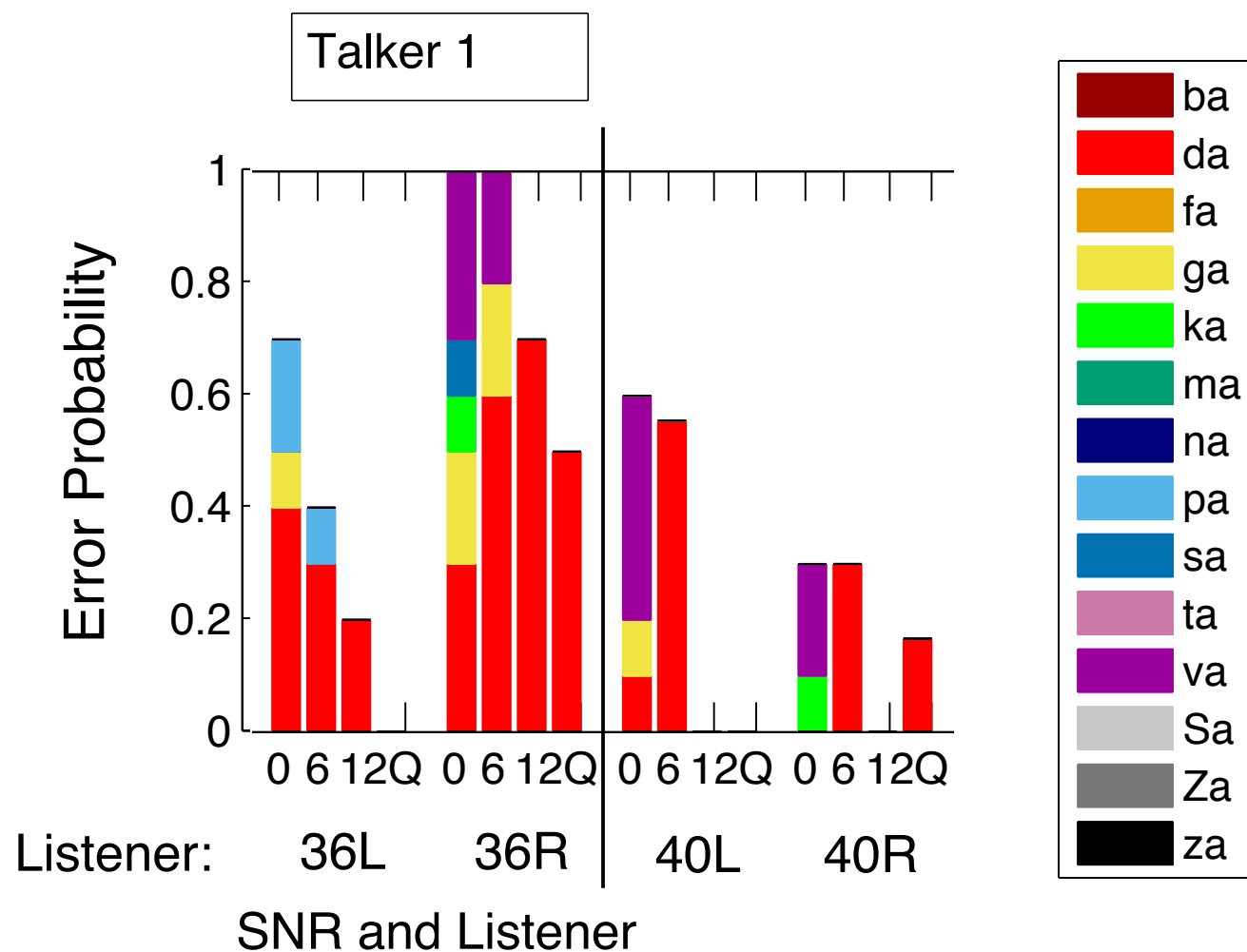
- The average error can have large amounts of underlying individual token error
- Analysis at the token level reveals systematic patterns in the HI confusions
- NH psychoacoustic data can characterize the cue variability of individual tokens, providing tools for understanding HI perception
- The role of naturally-occurring conflicting acoustic cues remains unknown (Li et al. 2010, 2012)

**Thank you**

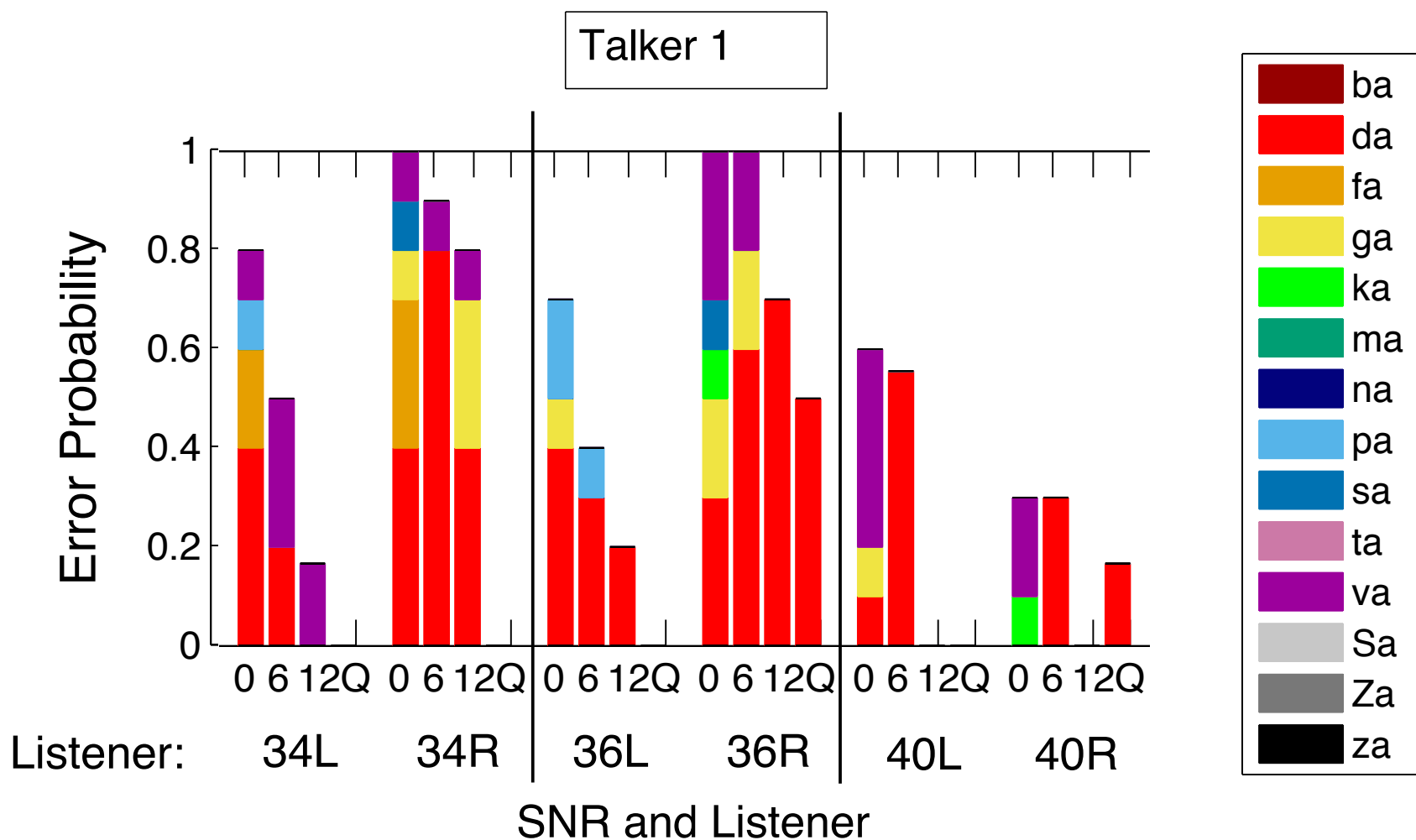
# Token-Specific Confusions /ba/



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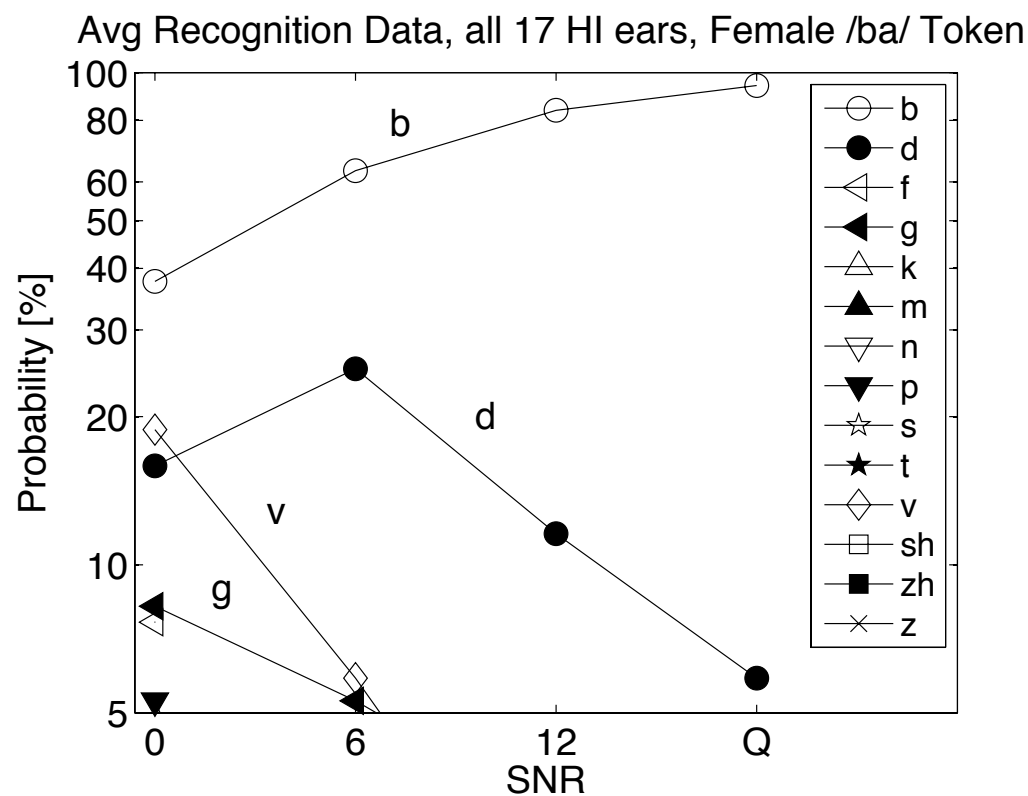
Large proportion of /da, ga, va/ confusions

Trevino, Allen, JASA 2013 (In Review)



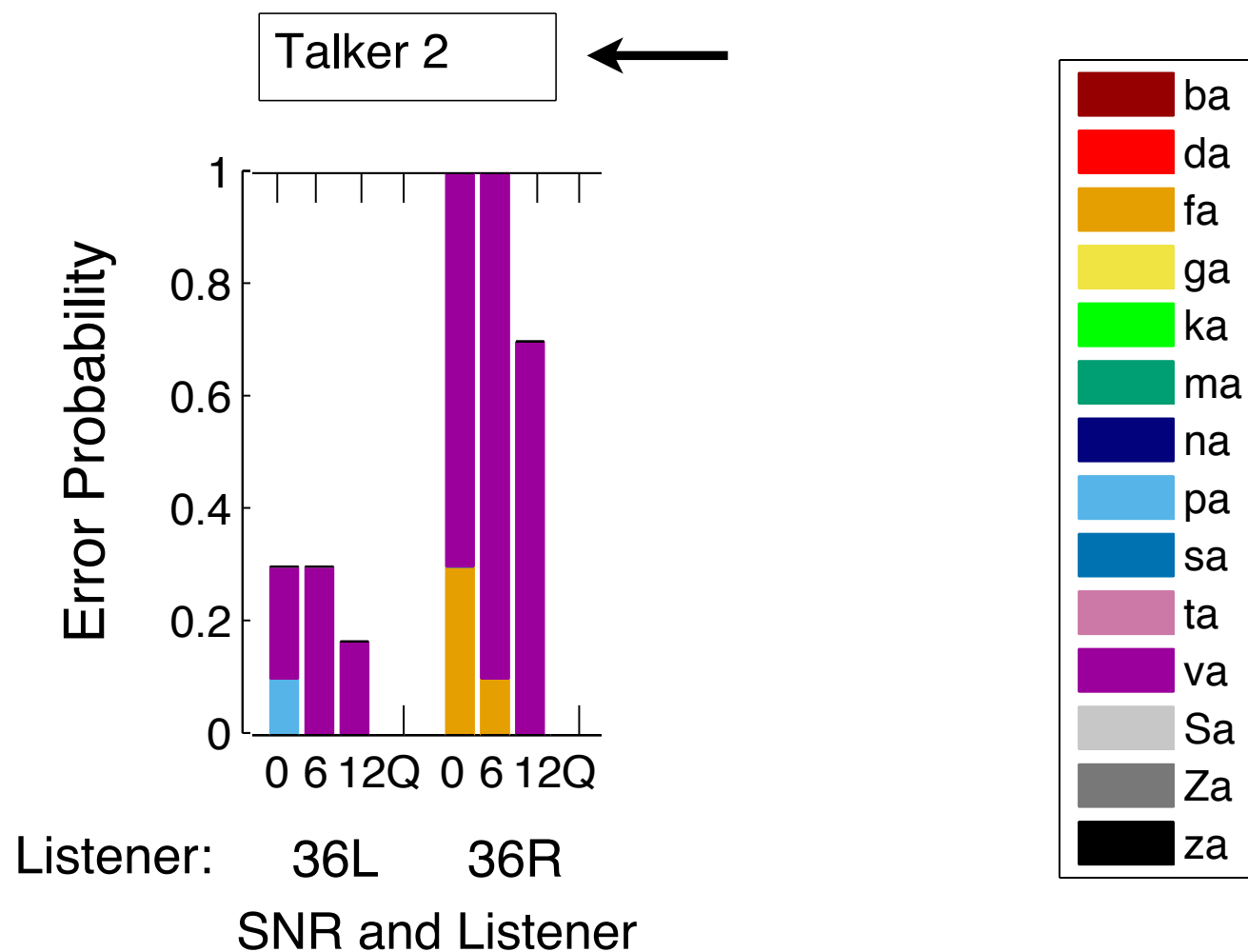
# Token-Specific Confusions /ba/

Talker 1

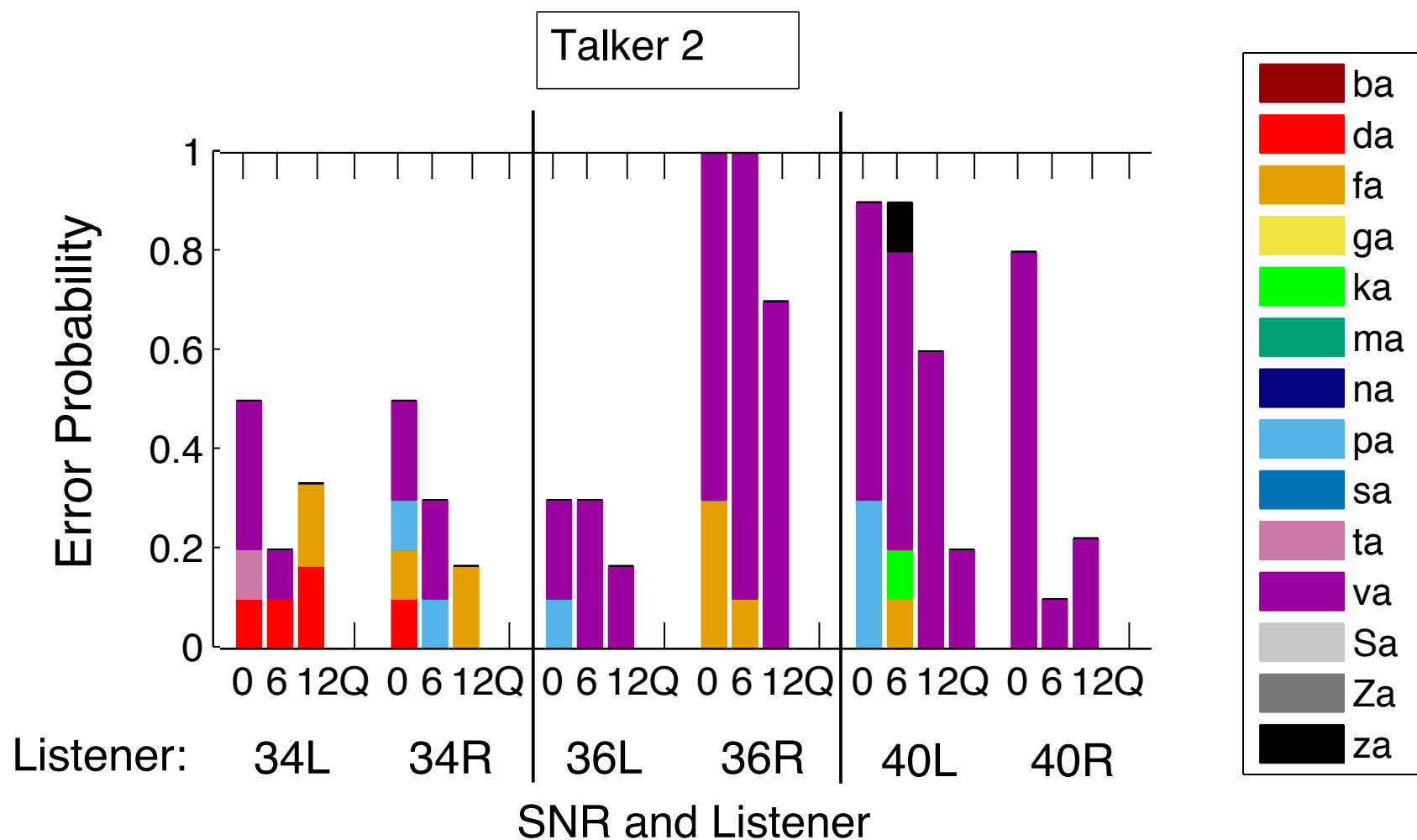


Talker 1: Large proportion of /da, ga, va/ confusions overall

# Token-Specific Confusions /ba/



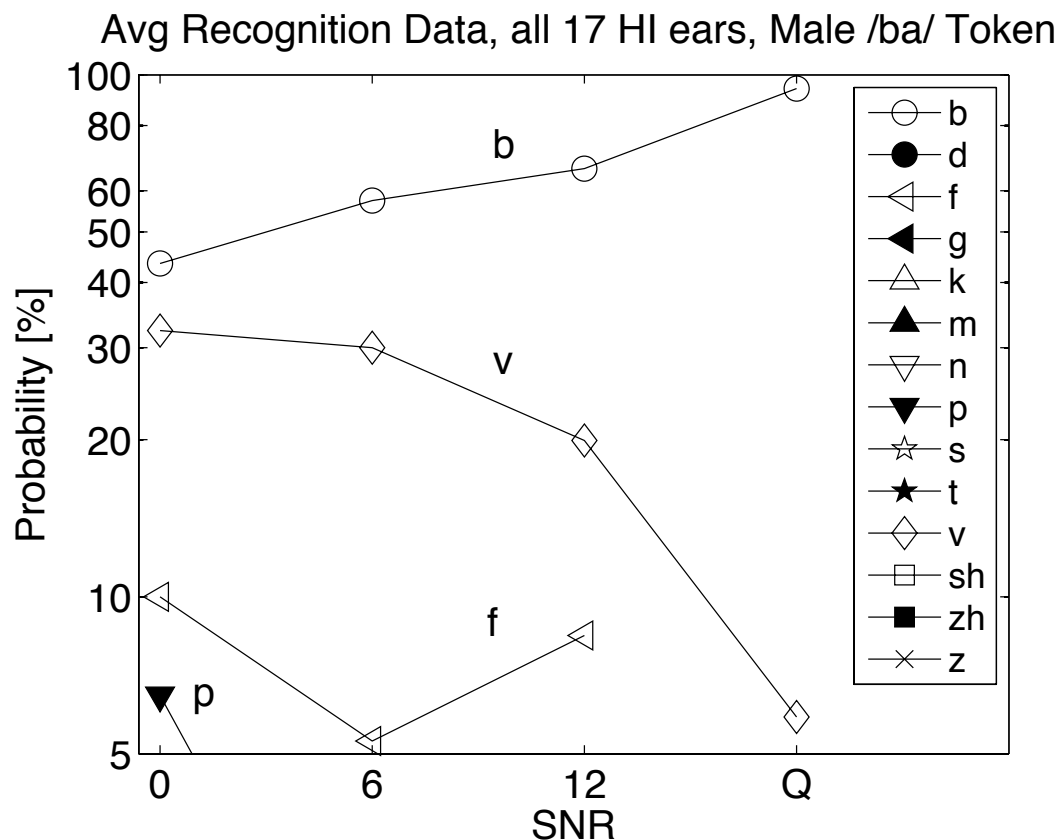
# Token-Specific Confusions /ba/



Talker 2: Large proportion of /fa, va/ confusions overall

# Token-Specific Confusions /ba/

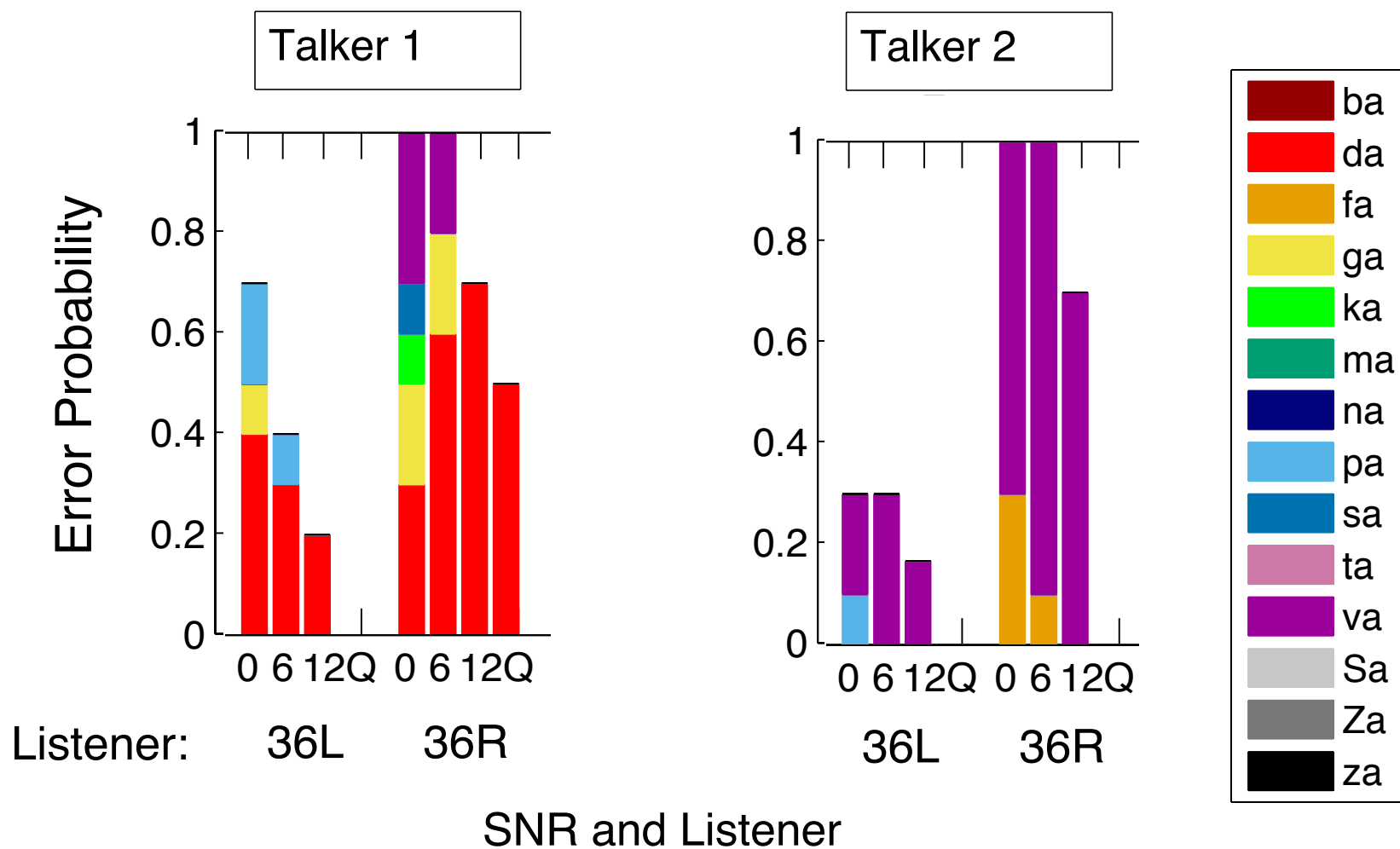
Talker 2



Talker 2: Large proportion of /fa, va/ confusions overall

Trevino, Allen, JASA 2013 (In Review)

# Token-Specific Confusions /ba/



Analysis must be done at the token level