

Effects of Hearing Loss on Self-Hearing During Speech Production

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Speech

Reception

- comprehension
(new information)
- listen only
- auditory input
input (*air-born*)
conducted)

Production

- expression
(known message)
- listen + speak
- auditory + haptic
(*air-born* + *bone-*
conducted)

Self-generated speech feedback

- development and maintenance of
“speaking skill”
- speech regulation

What is the Role of Self-Hearing in Speech Regulation?

Significance of the question

Practical

- speech training
- acceptance of hearing technology

Theoretical

- perception–production link
- phonetics–phonology relationship

Research Program

Q1: How is speech feedback perceived?

Q2: How does self-hearing affect speech production?

➤ Effects of reduced access to auditory feedback

How do we go about investigating self-hearing and its role in speech regulation?

Introduce speech feedback
alterations

- Temporal (asynchrony re articulation)
- Spectral (loss of intelligibility)
- Level (loudness change, breaks in the signal)

➤ Test *awareness* of the changes
(*perception studies*)

➤ Measure speech *performance*
(*production studies*)

Perception Studies

Approach

Psycho-physics of self-hearing

- S-R relationship
- *Minimal* perceptible feedback delay

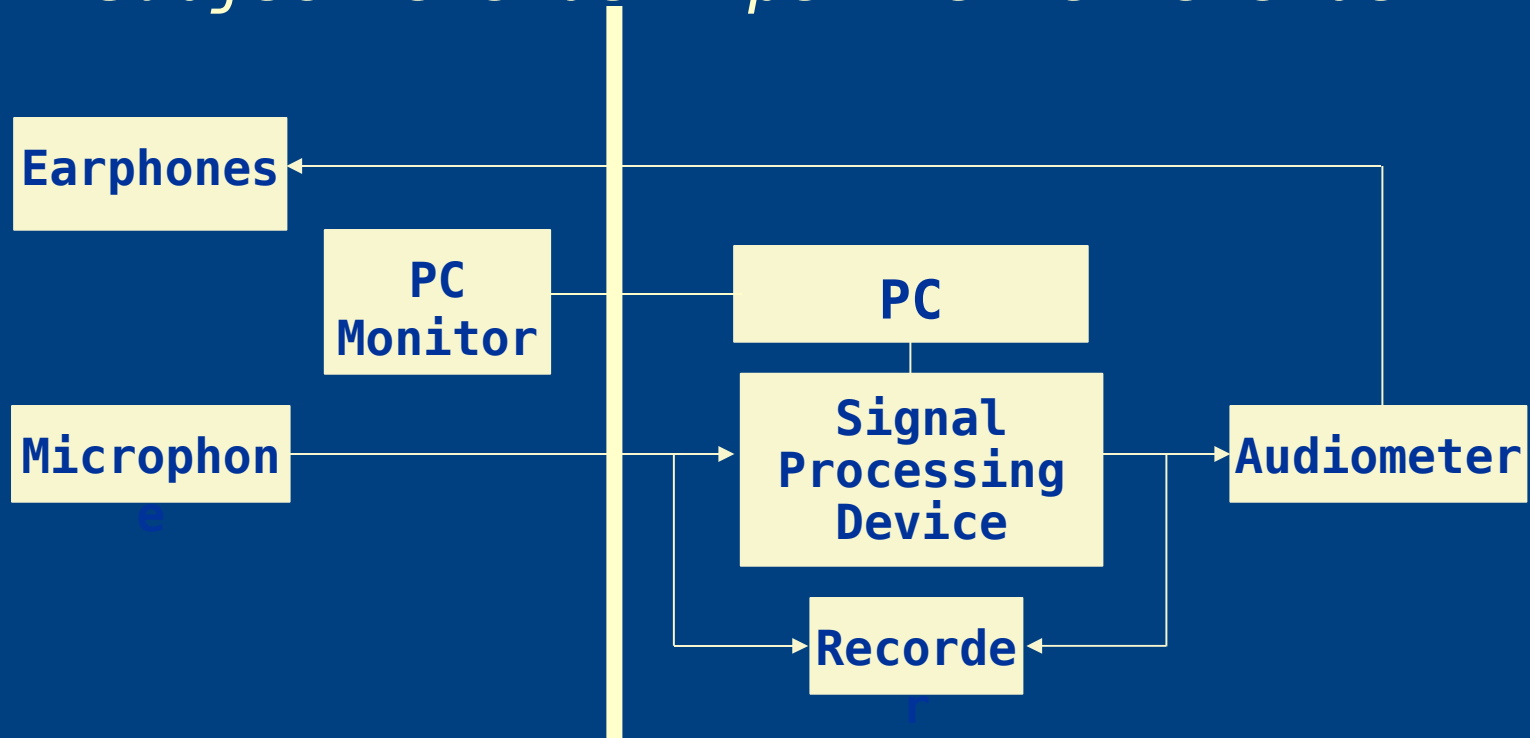
➤ Develop and automate procedures for:

- (1) Real-time alterations of speech feedback
- (2) Subject testing

Perception Studies

Experimental Setup

Subject's side | *Experimenter's side*



Perception Studies

Testing Procedure

➤ Two Interval Forced Choice Procedure



➤ Stimuli

- self-paced utterances of a pre-selected syllable
- muted onset & limited duration (1800 ms) of the speech feedback

➤ Response: Choose interval with *delayed* feedback

Perception Studies

Delay Detection

Procedures

3 groups:

Cochlear Implant (CI) users (4 participants)

Hearing Aid (HA) users (6 participants)

Hearing (9 participants)

Repeated testing

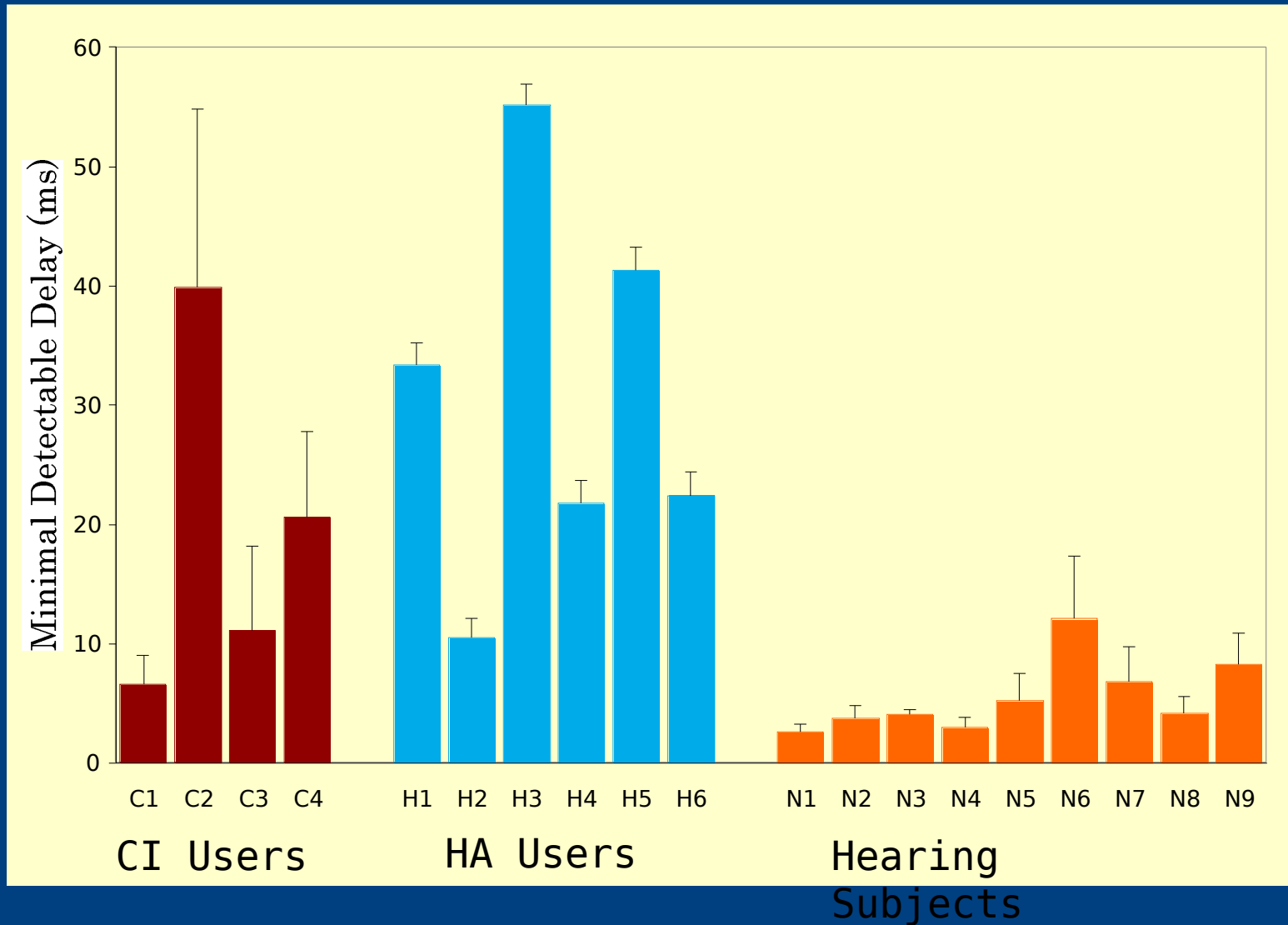
9 tests per participant

Minimal detectable delay

71% correct identification

Perception Studies

Delay Detection



Production Studies

Speaking with altered auditory feedback

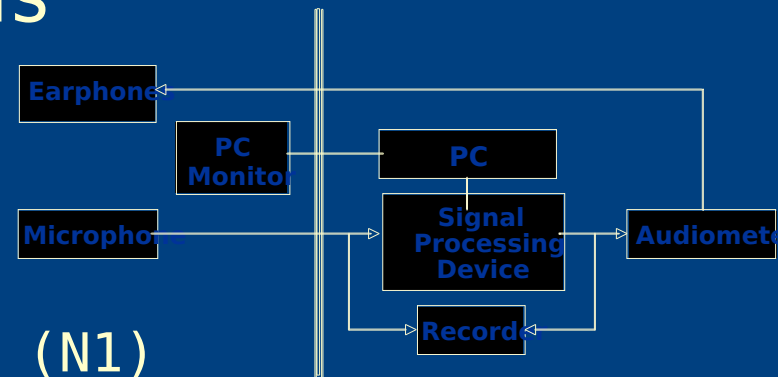
Feedback alterations

– Delay

25, 50, 100, 200 ms
+ no delay (0 ms)

– Spectral Smearing

4 band (N4) & 1 band (N1)
noise + speech (SP)



5 HA and 5 CI users: Reading task

Speech production analyses

- Acoustic measurements: *speech rate*, *voice pitch*
- Evaluation of *speech quality*

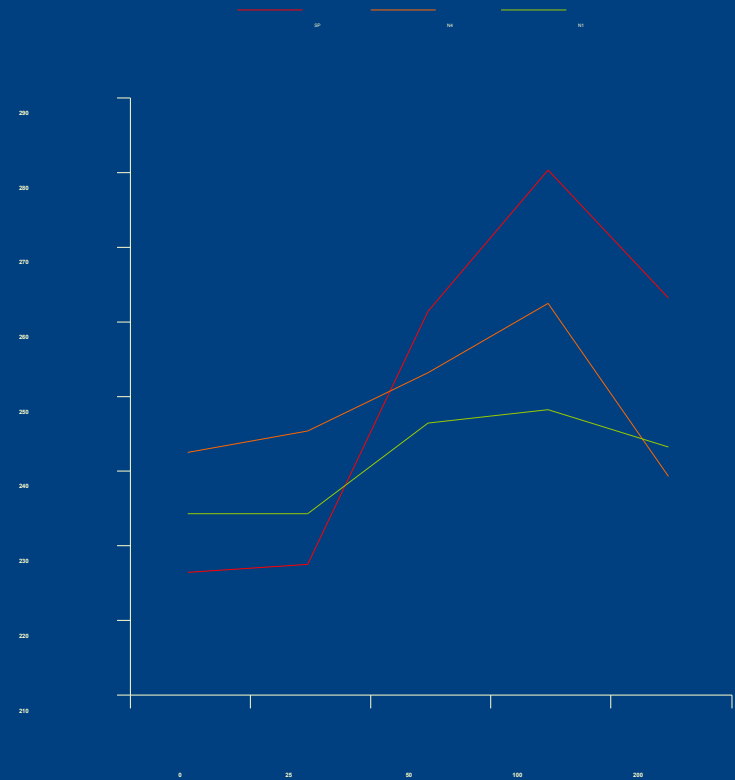
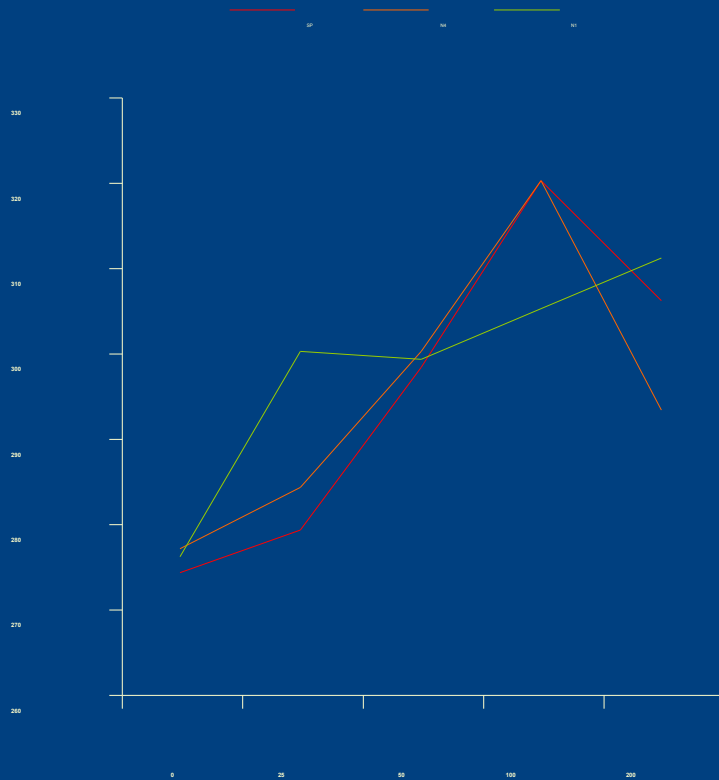
Production Studies

Speech Rate

CI group

HA group

Average Syllable Duration (ms)



Delay (ms)

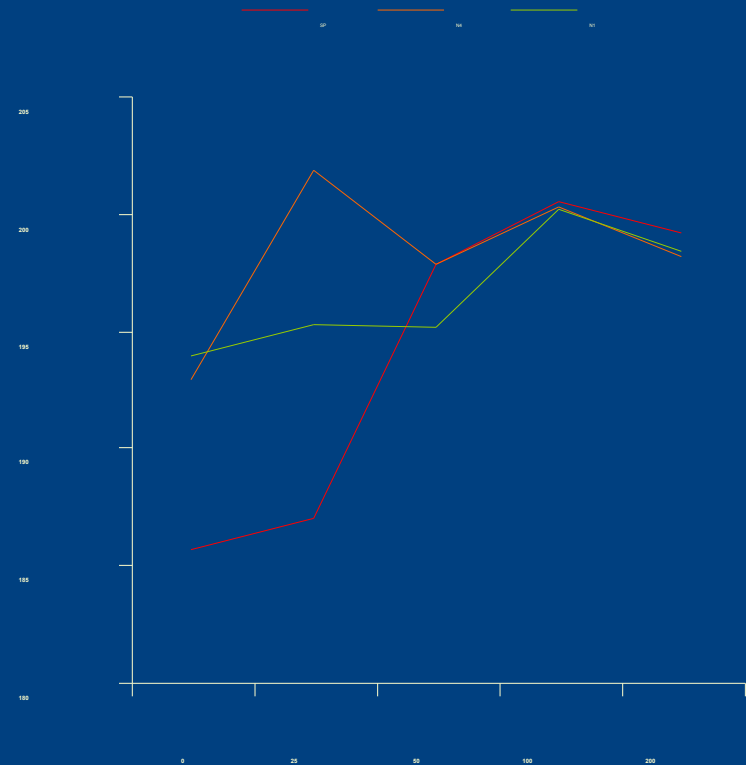
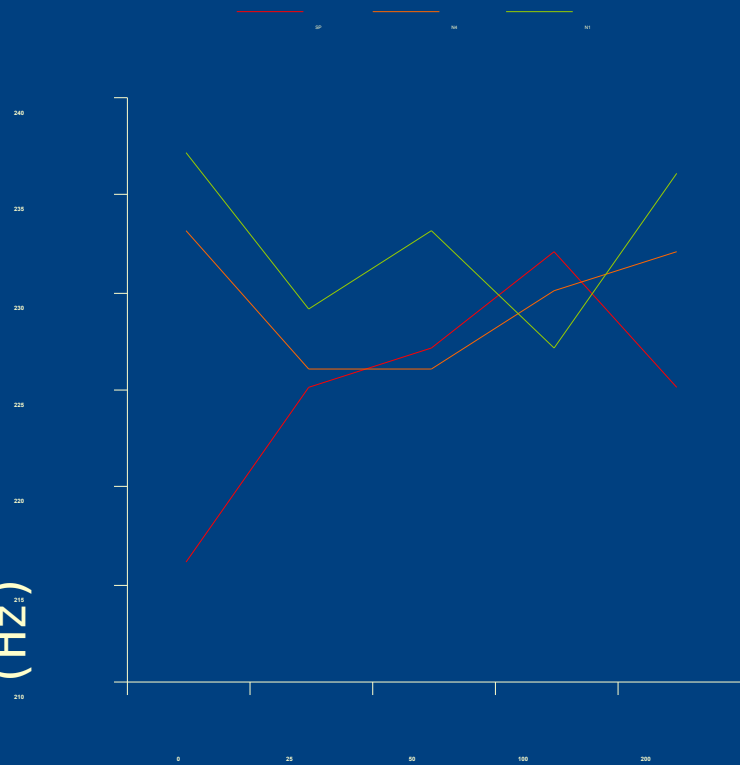
Production Studies

Voice Pitch

CI group

HA group

Fundamental Frequency (Hz)



Delay (ms)

Production Studies

Can a listener perceive the changes in speech that are due to poor speech feedback?

Speech samples from 4 feedback conditions

Unaltered feedback (SP)

Spectrally degraded signal (N4 and N1)

Babble noise (BN)

Speakers: 5 HA and 5 CI Users

Evaluation of speech quality: Paired comparisons

6 possible combinations (SP–N4, SP–N1, SP–BN, N4–N1, N4–BN, N1–BN)

Individual sentences (5 per condition; equal content in the pair)

“Choose utterance that sounds better”

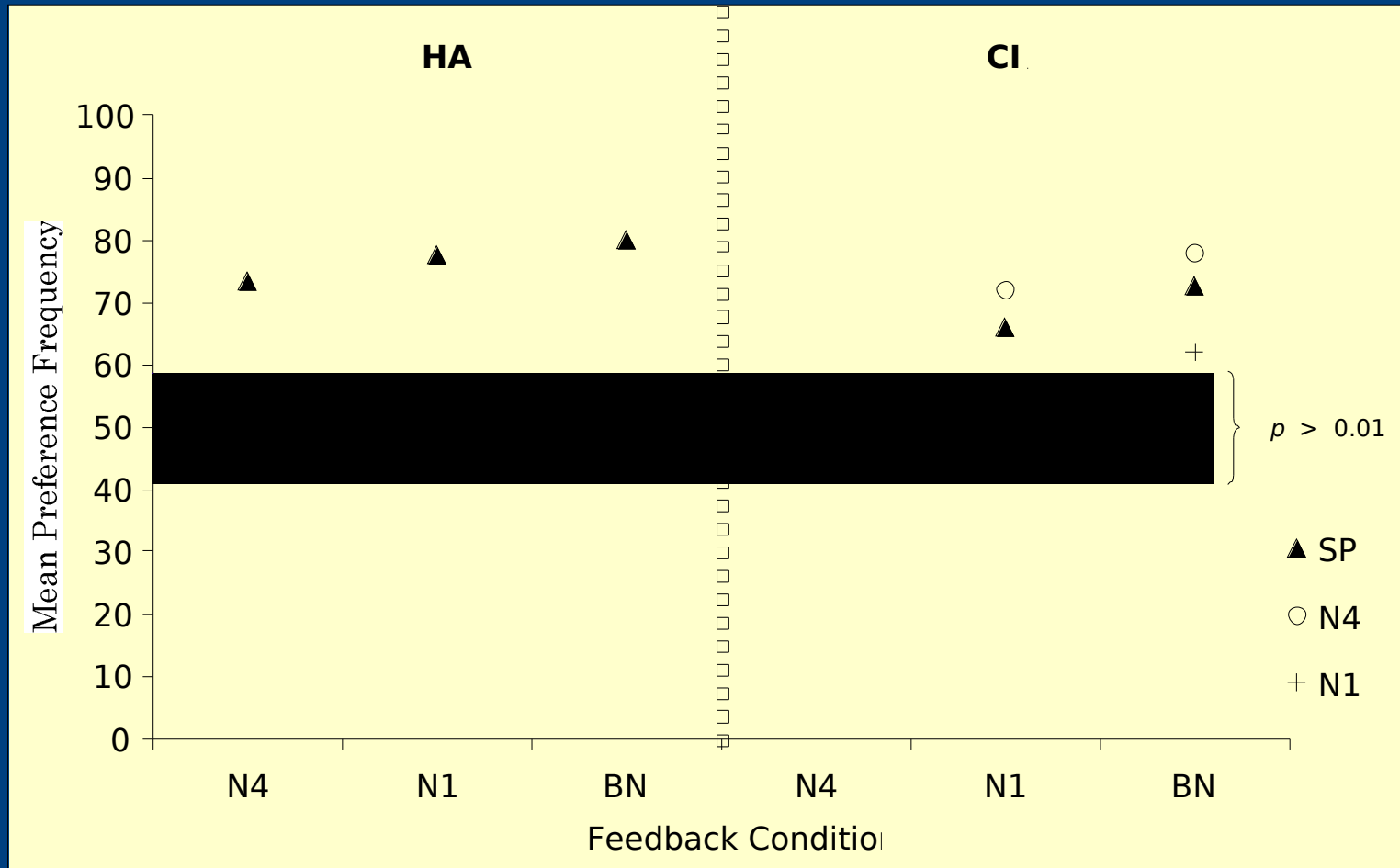
10 judges (all hearing)

Preference frequency (PF) for the better (SP > N4 > N1 > BN) feedback condition

$PF_{\max} = 100$ per comparison (10 judges * 5 sentences * 2 repetitions)

Production Studies

Speech Quality Evaluation



Sign Production: Role of Self-Generated Visual and Haptic Feedback

Effect of *visual* feedback alterations

- altered view-point: top, front and mirror views
- control conditions: natural and no view

Effect of *haptic* feedback alterations

- altered mass/moment of inertia of the fingers and hand

Connected utterances

- based on the *picture* or *signed description* of a scene

Native signers versus novices

Sign production analyses

- error analyses
- kinematic measurements

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