Effect of Different Frequency Mappings on Speech Intelligibility for CI listeners

DAGA
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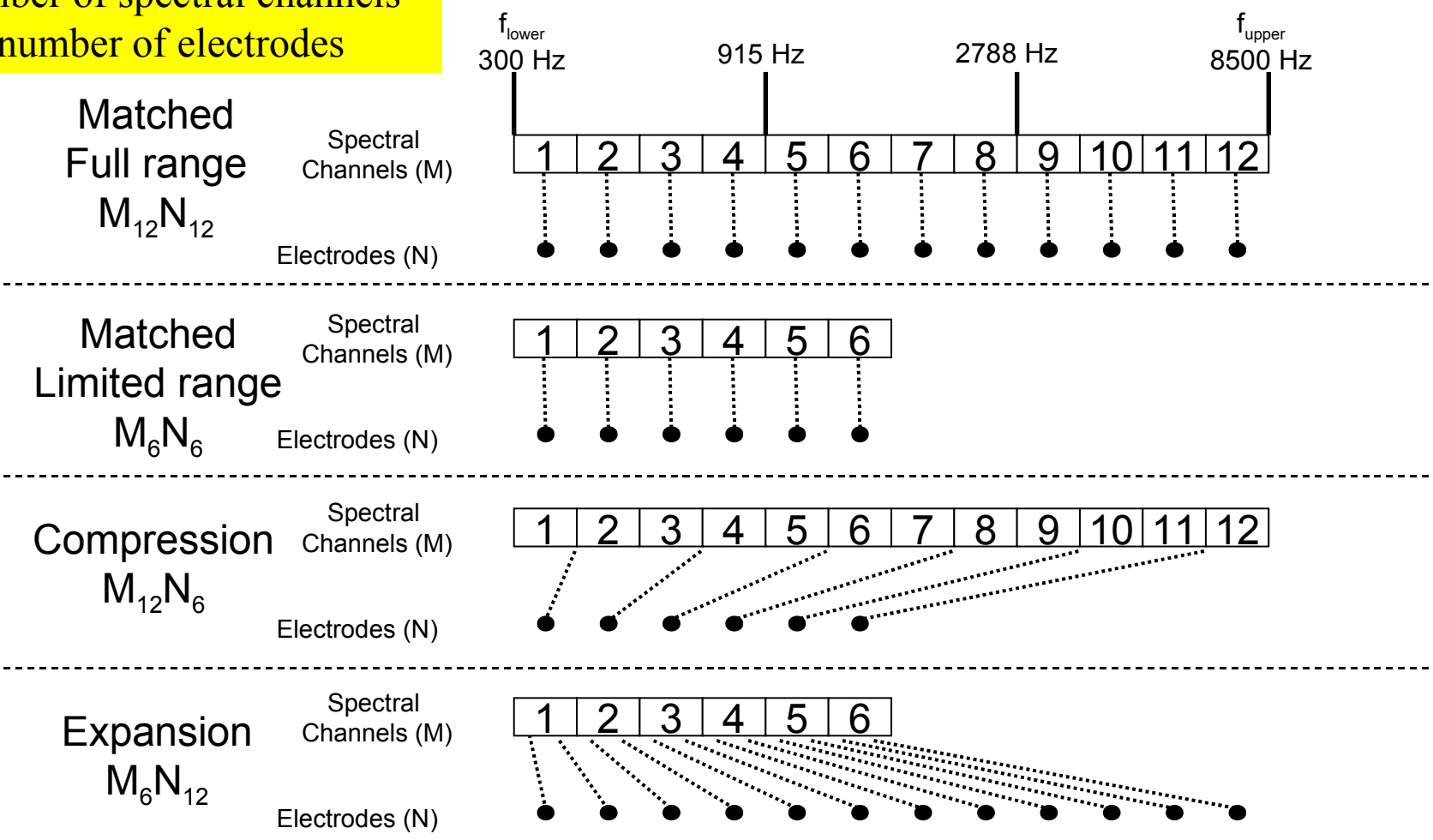
Introduction

- Cochlear implants (CI) are primarily used for speech understanding

- CI have limitations:

  - Reduced spectral resolution

  - High variability in individual performance
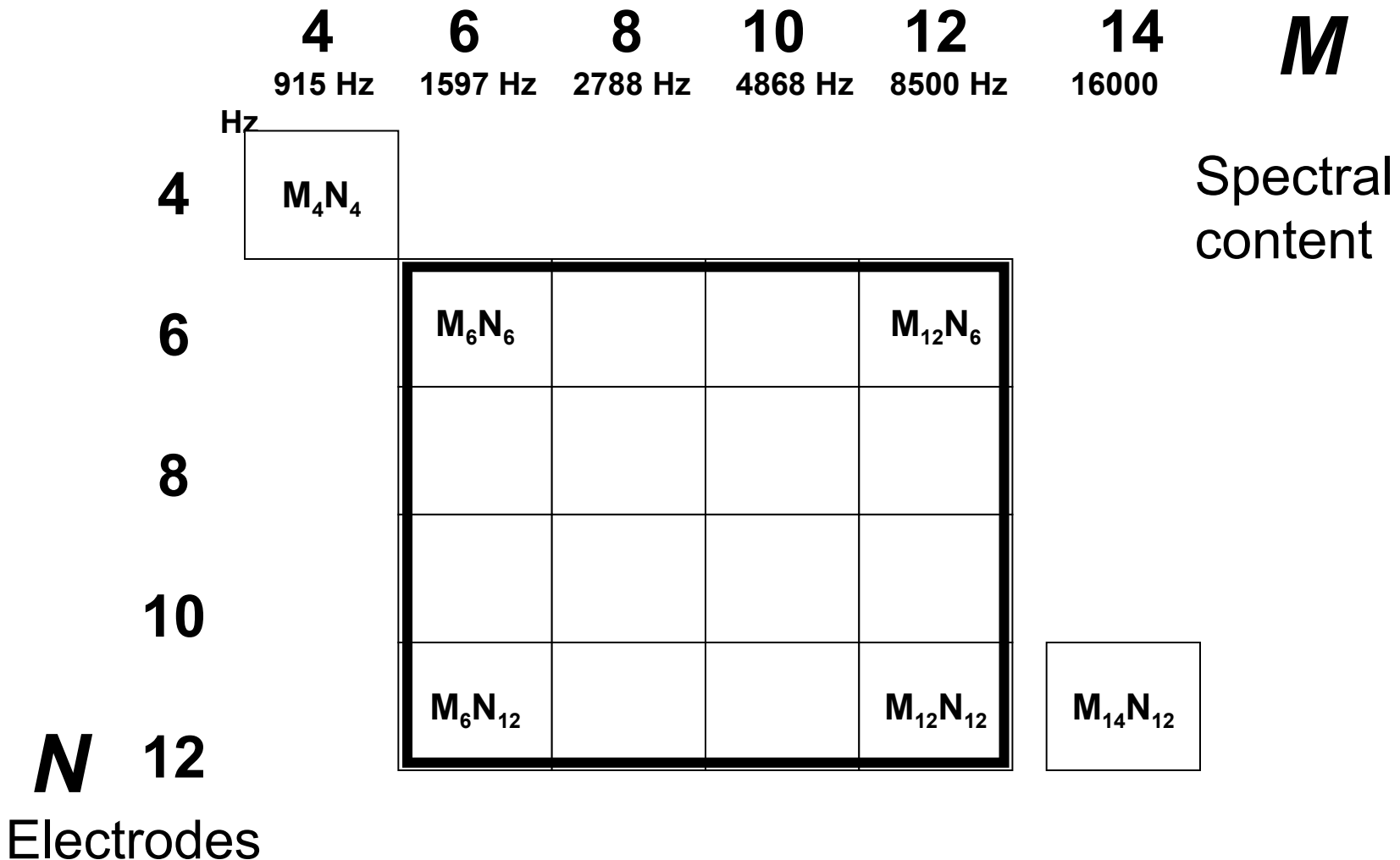
Introduction

- Question: Is it possible to implement a spatialization strategy for CIs without causing a decrease in speech understanding?
  - Recent studies promising for CI interaural cues (horizontal plane localization)
  - Spectral cues are needed for vertical plane localization
- Goals:
  - Find the effect of changing the number of electrodes
  - Find the effect of changing frequency-place maps
  - Is there extra information being presented to CIs? <u>If so, then it may be possible to map spectral cues to extra electrodes.</u>
  - This study is different from similar studies because lower frequency boundary is fixed

Mapping of Spectral Information (M) to Electrodes (N)

M = number of spectral channels
N = number of electrodes

f_{lower} 300 Hz   915 Hz   2788 Hz f_{upper} 8500 Hz

Matched Full range $M_{12}N_{12}$

Spectral Channels (M): 1 2 3 4 5 6 7 8 9 10 11 12

Electrodes (N)

Matched Limited range M_6N_6

Spectral Channels (M): 1 2 3 4 5 6

Electrodes (N)

Compression $M_{12}N_6$

Spectral Channels (M): 1 2 3 4 5 6 7 8 9 10 11 12

Electrodes (N)

Expansion M_6N_{12}

Spectral Channels (M): 1 2 3 4 5 6

Electrodes (N)

18 Conditions Tested

Spectral content — M

Electrodes — N

N \ M	4 (915 Hz)	6 (1597 Hz)	8 (2788 Hz)	10 (4868 Hz)	12 (8500 Hz)	14 (16000 Hz)
4	M_4N_4					
6		M_6N_6			$M_{12}N_6$	
8						
10						
12		M_6N_{12}			$M_{12}N_{12}$	$M_{14}N_{12}$

Experimental Procedure

- OLSA sentences: 5 word nonsense sentences

  - Peter verleiht elf alte Bilder

  - Doris hat zwei grosse Tassen

- Four SNRs: quiet, +10, +5, and 0 dB

- 90 sentences per block

  - 10 sentence warm-up (listener adaptation) in quiet

  - 80 sentences (20 sentences × 4 SNRs)

- Data acquisition

  - Listener repeated sentences

  - Experimenter recorded # of correct words

- Listeners: 7 CIs and 6 NHs

Saturation in performance

(at 0.05 level)

- High-performance CIs:

  N = 8 (all SNRs)

- NHs:
  N = 8 (quiet)
  N = 10 (+10, +5, 0 dB)

- Low-performance CIs:
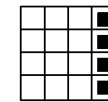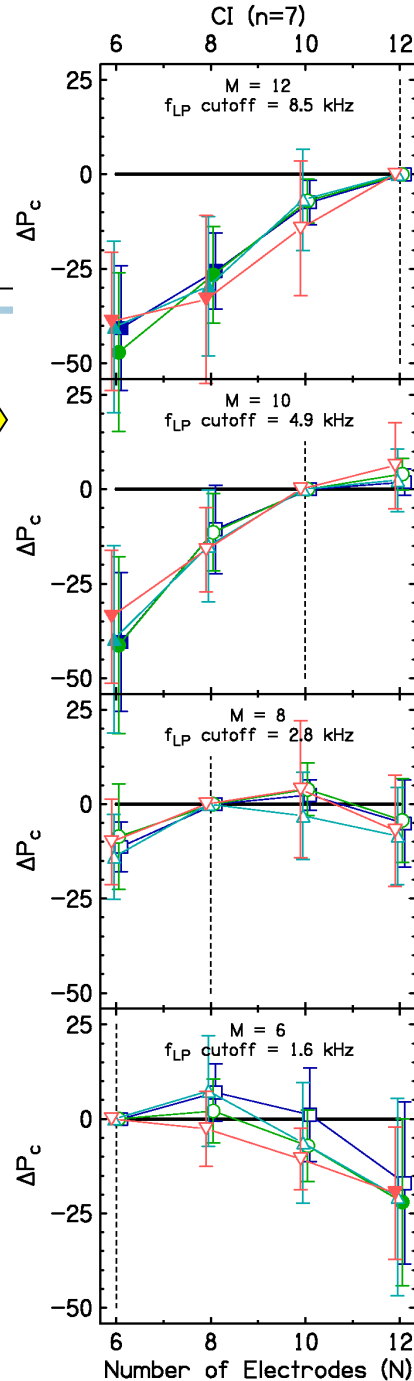 highly variable
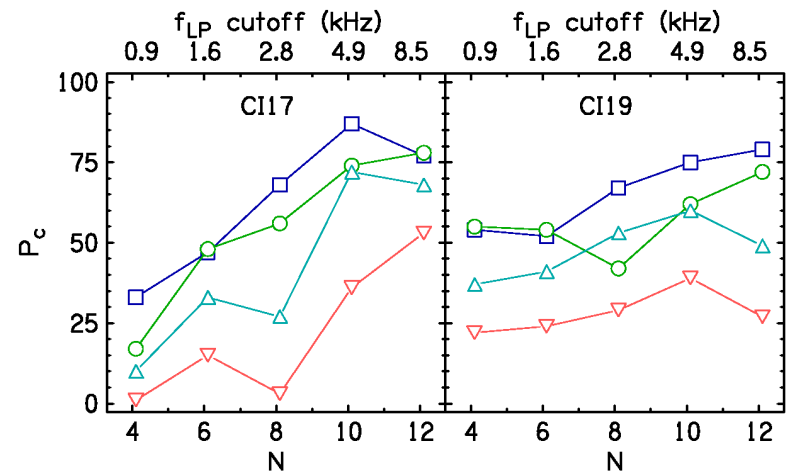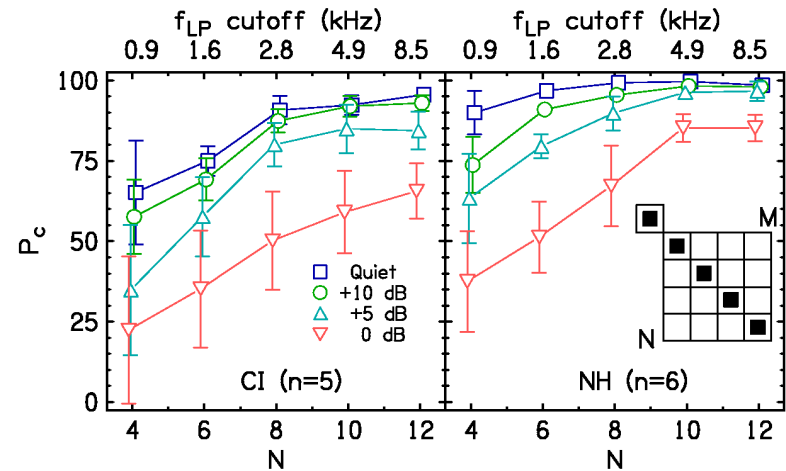
Unmatched "Constant M" (Spectral Content)
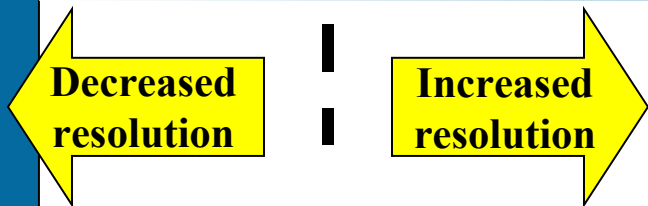
Decreased resolution ◄ | ► Increased resolution

- Normalized P_c

- Matched shown by dotted line

- Filled symbols are significant decreases ($p < 0.05$)

- Asymmetric decrease: left of matched worse
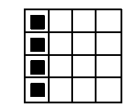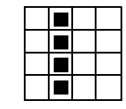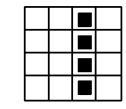
- No significant decreases ±2 electrodes (N)

CI (n=7)

NH (n=6)

$M = 12$, f_{LP} cutoff = 8.5 kHz

$M = 10$, f_{LP} cutoff = 4.9 kHz

$M = 8$, f_{LP} cutoff = 2.8 kHz

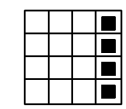$M = 6$, f_{LP} cutoff = 1.6 kHz
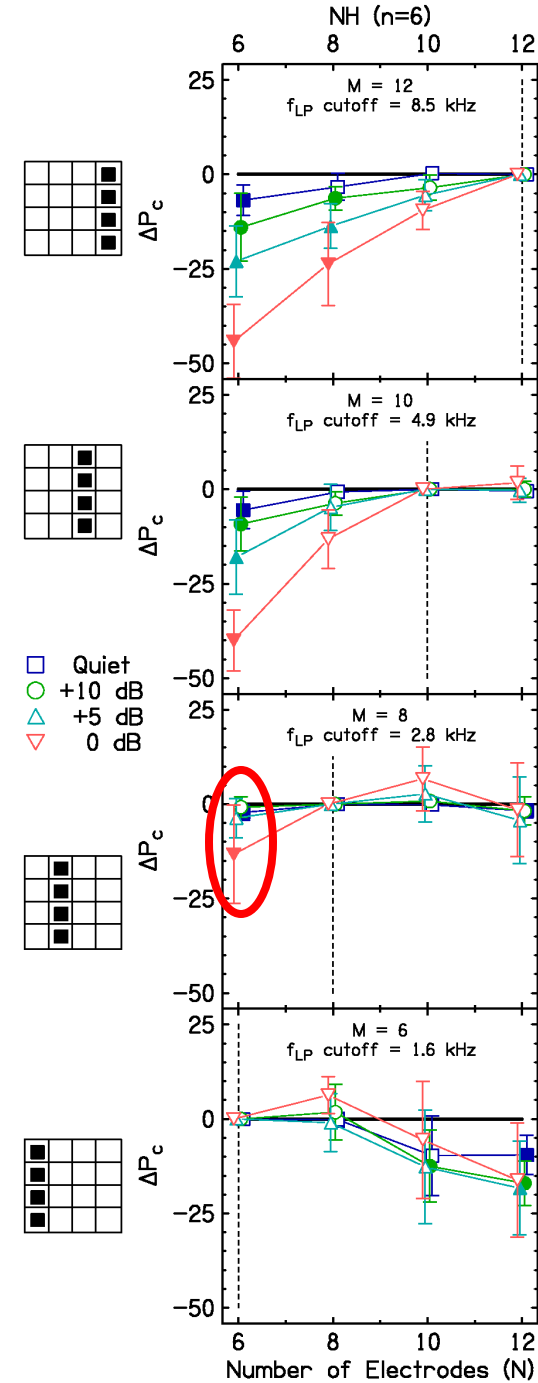
Quiet
+10 dB
+5 dB
0 dB

Number of Electrodes (N)

Unmatched "Constant M" (Spectral Content)

Decreased resolution ← | → **Increased resolution**
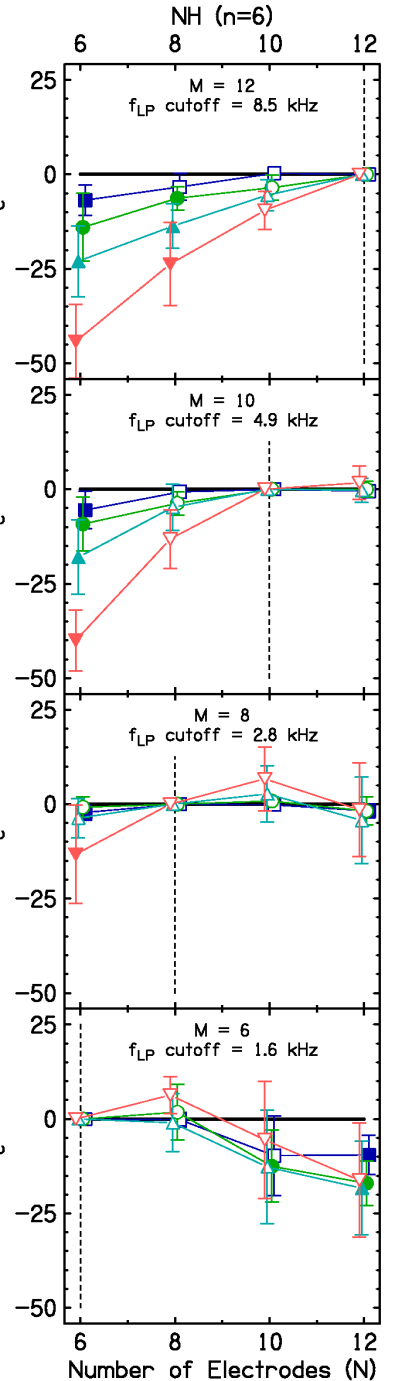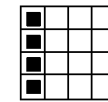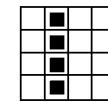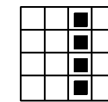
- Normalized P_c

- Matched shown by dotted line

- Filled symbols are significant decreases ($p < 0.05$)

- Asymmetric decrease: left of matched worse

- No significant decreases ±2 electrodes (N)

- Except these two…
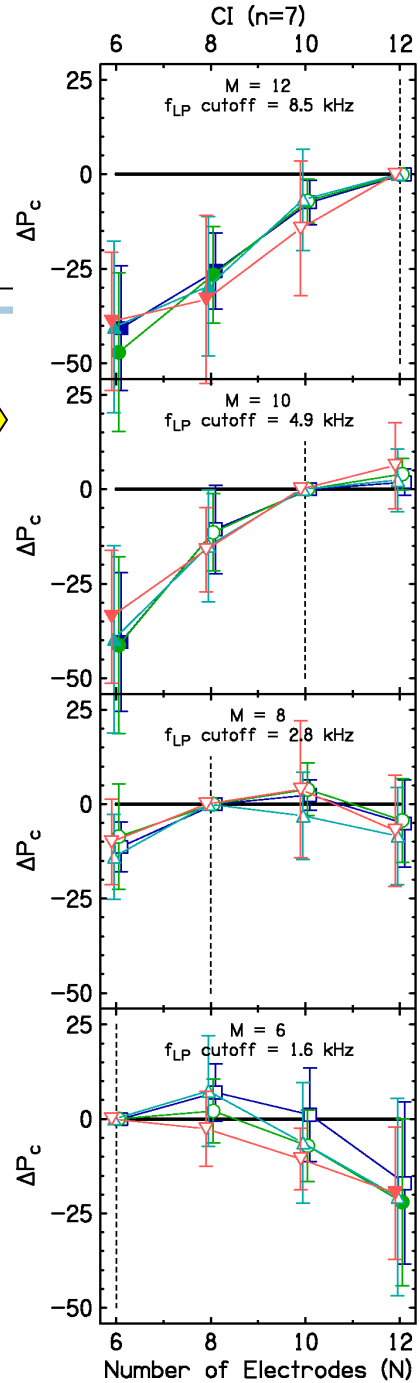
CI (n=7)

M = 12, f_{LP} cutoff = 8.5 kHz
M = 10, f_{LP} cutoff = 4.9 kHz
M = 8, f_{LP} cutoff = 2.8 kHz
M = 6, f_{LP} cutoff = 1.6 kHz

NH (n=6)

M = 12, f_{LP} cutoff = 8.5 kHz
M = 10, f_{LP} cutoff = 4.9 kHz
M = 8, f_{LP} cutoff = 2.8 kHz
M = 6, f_{LP} cutoff = 1.6 kHz

Quiet
+10 dB
+5 dB
0 dB

Number of Electrodes (N)

Unmatched "Constant N" (Electrodes)

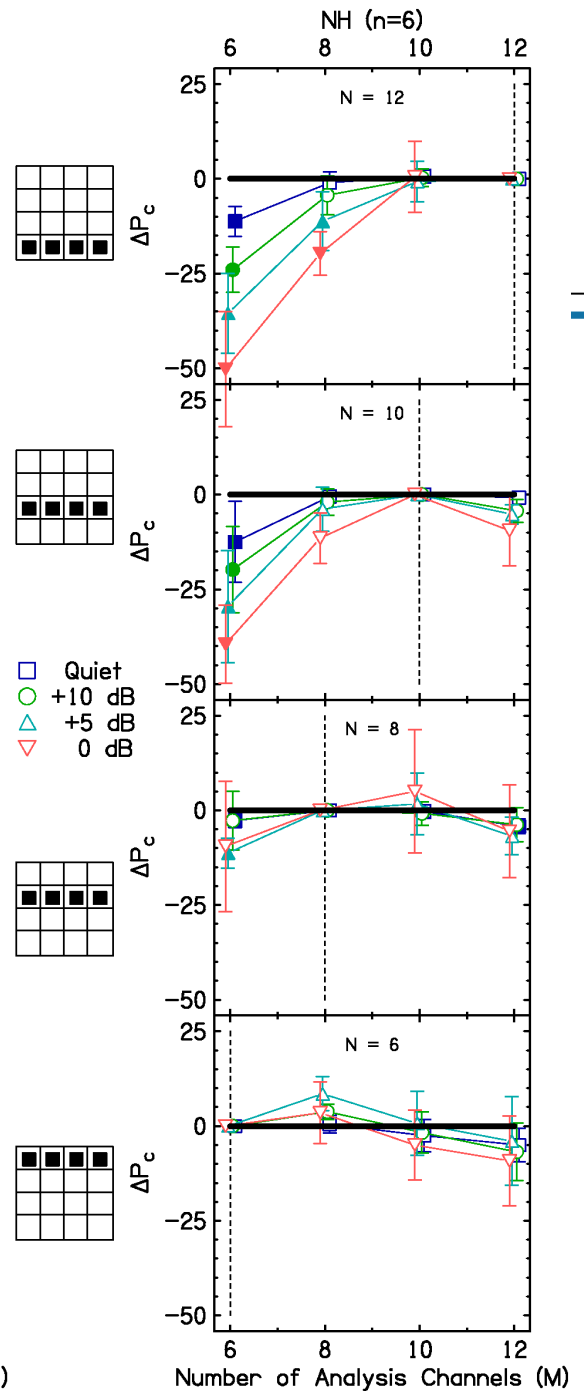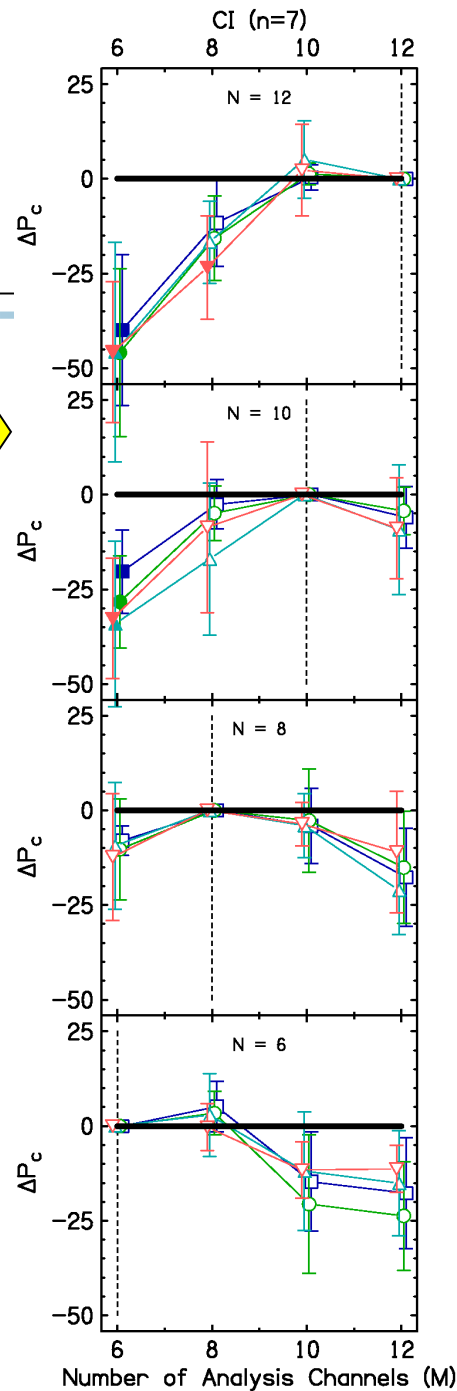**Decreased Freq. range** ← | → **Increased Freq. range**

- Normalized P_c

- Matched shown by dotted line

- Filled symbols are significant decreases ($p < 0.05$)

- Asymmetric decrease: left of matched worse

- No significant decreases ±2 analysis channels (M)

Unmatched "Constant N" (Electrodes)

Decreased Freq. range ⬅ ➡ **Increased Freq. range**

- Normalized P_c

- Matched shown by dotted line

- Filled symbols are significant decreases ($p < 0.05$)

- Asymmetric decrease: left of matched worse

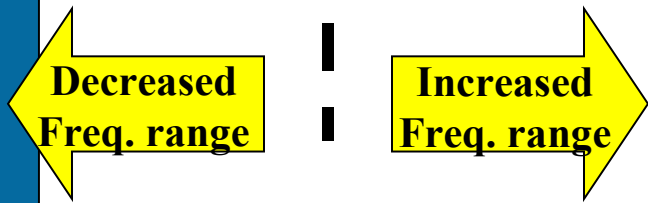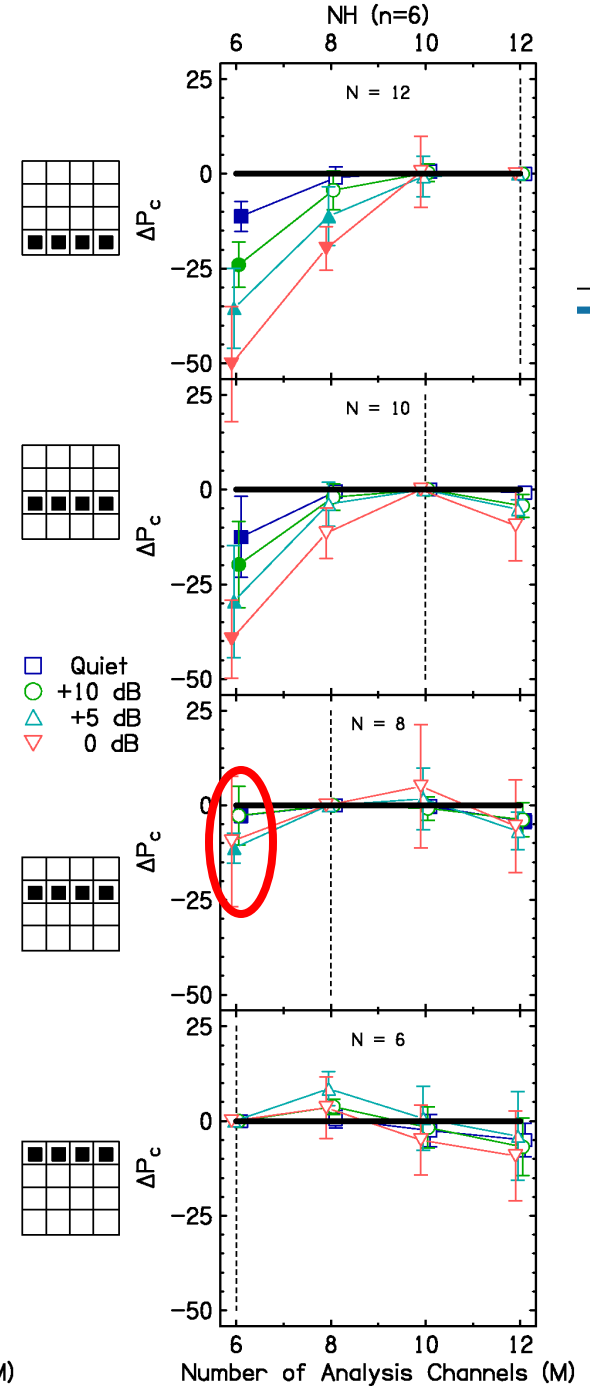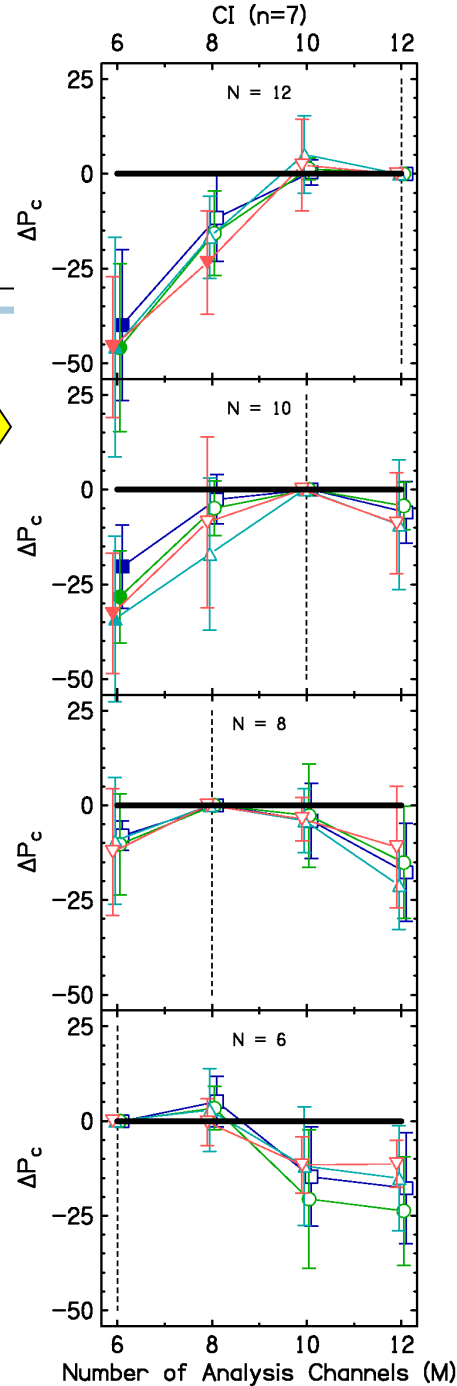- No significant decreases ±2 spectral channels (M)

- Except these two…

Unmatched Conditions Summary

- Asymmetric decrease implies spectral shift not dominant over amount of information presented

- "±2 Rule":

  - Both analysis channels (M) and electrodes (N)

- However, can't apply "±2 Rule" to matched results (which showed we only need 8 electrodes)

- Conditions not different from $M_{12}N_{12}$:

  - CIs: $M_{10}N_{12}$, $M_{12}N_{10}$, $M_{10}N_{10}$, M_8N_8, M_8N_{10} (total = 5)

  - NHs: same, minus M_8N_{10} (total = 4)

Conclusions

1. Only need 8 electrodes for maximum speech understanding

2. "±2 Rule" allows for slight changes in frequency-place map

   - 5-6 of 18 conditions yield maximum speech understanding

   - May be beneficial to CI listeners with deactivated electrodes or individuals who show improvement from increased spectral resolution

3. Possible to use some electrodes for spectral cues in CI localization strategy