The Effects of
Cochlear Implant Processing on Vocal Reproduction of Music

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December 11th, 2014
American Cochlear Implant Alliance
14th Symposium on Cochlear Implants in Children
Nashville, TN

Acknowledgements

- Dr. René Gifford

- Dr. Devin McCaslin

- Dr. Erin Picou

- The Vanderbilt Bill Wilkerson Cochlear Implant Research Lab

- Jane Burton, Kelly Jahn and Sarah Kahan
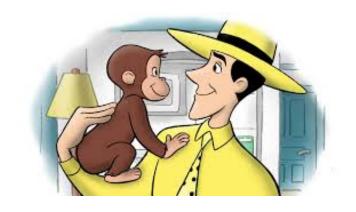
Go Team!

Music… Cochlear Implants…

- Perception (Kang et al., 2009; Zhu et al., 2011; Zend et al., 2014)

- Appreciation/Enjoyment (Wright and Uchanski, 2012)

- What about singing?

15-channel vocoder
(Litvak et al., 2007)

Questions

- How "in tune" do we sing?

- Do musicians have an advantage over non-musicians?

- Does musical "context" have an effect?

Methods

- Musical Context
  - Single Notes
  - Unfamiliar Melodies
  - Familiar Melodies
    - With and without lyrics
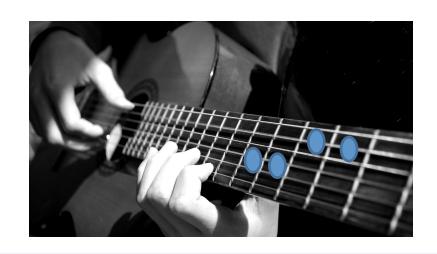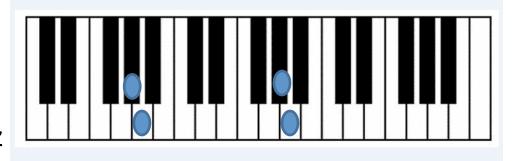 - Popular Songs

- Litvak's vocoder:

- Subjects (n=20)
  - 14 women / 6 men
  - 10 musicians / 10 not
  - Normal Hearing

- Acclimatize
- CI Processed recordings
- Normal recordings

- Sound Forge Pro
- CantOvision Sing & See
- Microsoft Excel

Music 101: Semitones

- A4 = 440 Hz
- G#4 = 415 Hz
  - 1 semitone = 25 Hz

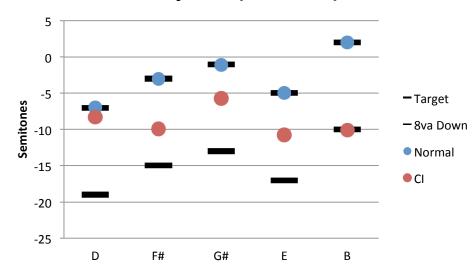- A3 = 220 Hz
- G#3 = 208 Hz
  - 1 semitone = 12 Hz

Single Tones

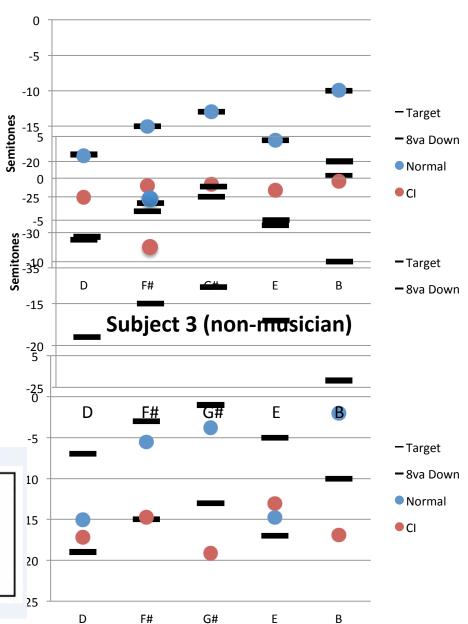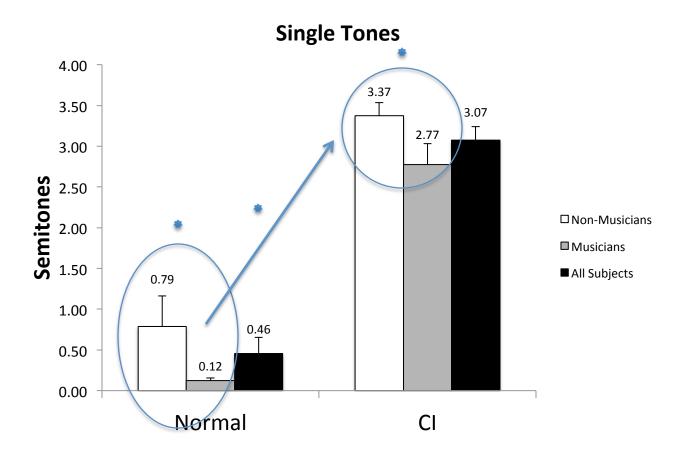## Subject 6 (musician)

Subject 4 (non-musician)

Subject 3 (non-musician)

Single Tones
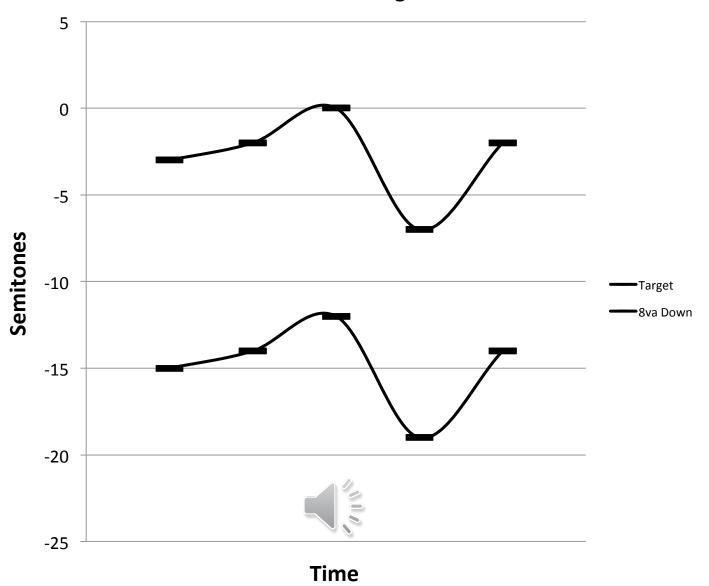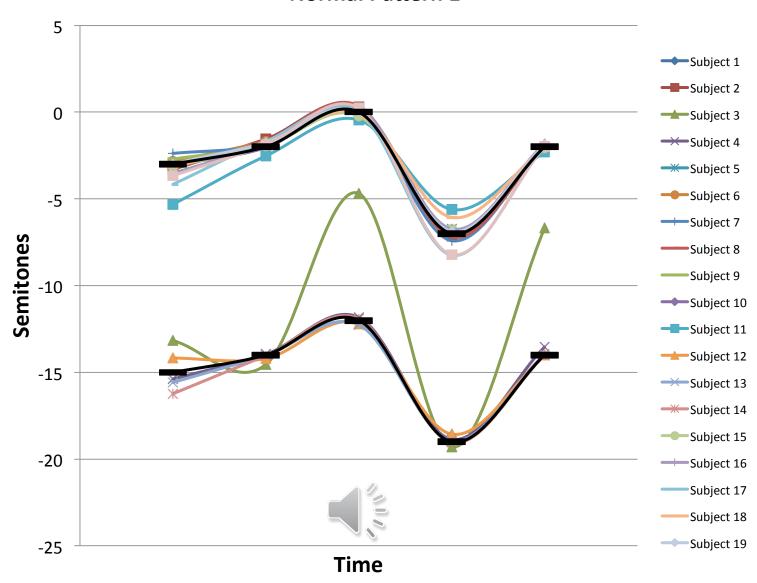
Group difference across both conditions (p = 0.025)
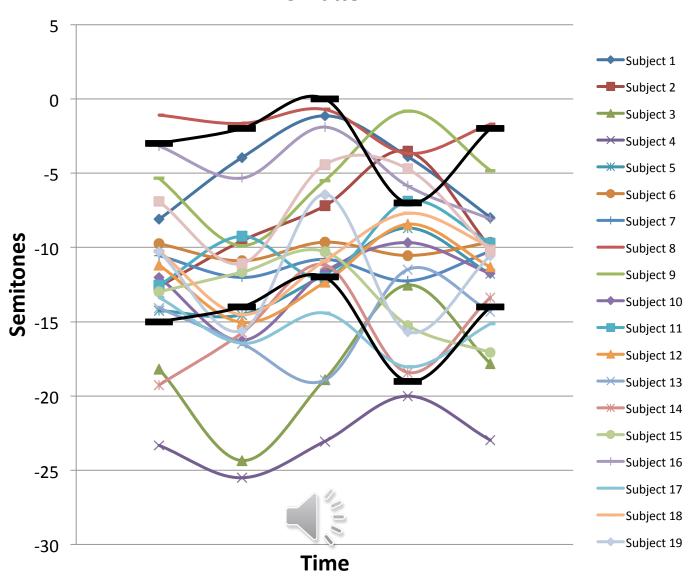
Pattern 1 Targets
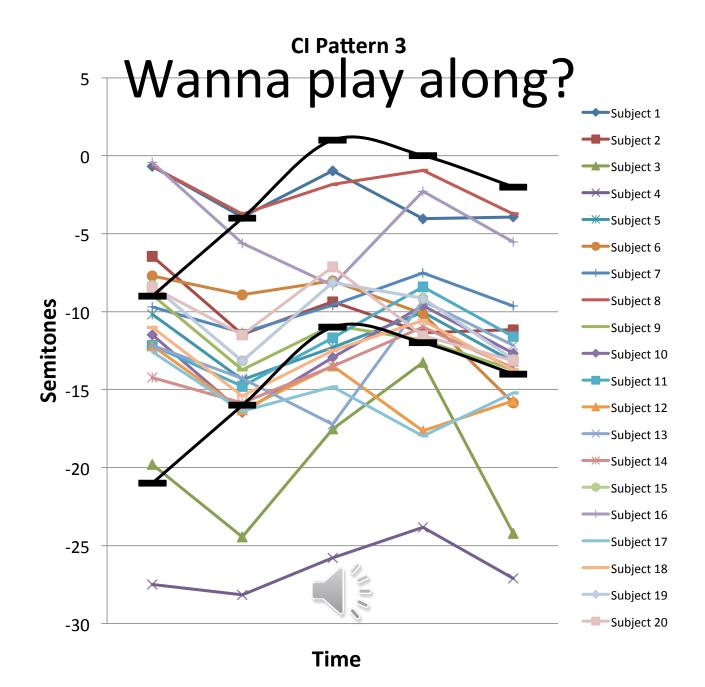
Normal Pattern 1
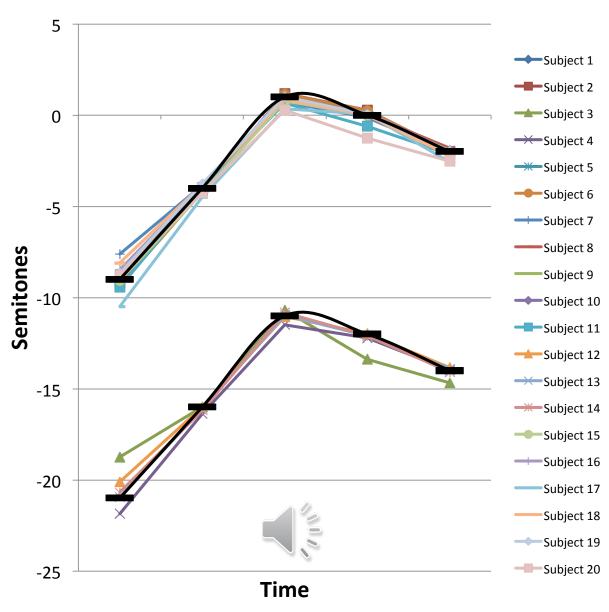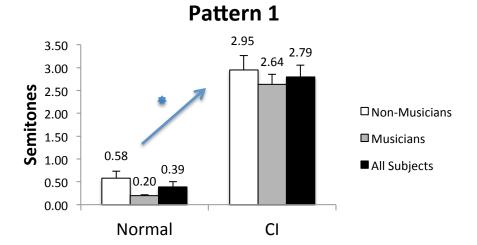
CI Pattern 1

Normal Pattern 3

Pattern 1

Pattern 2
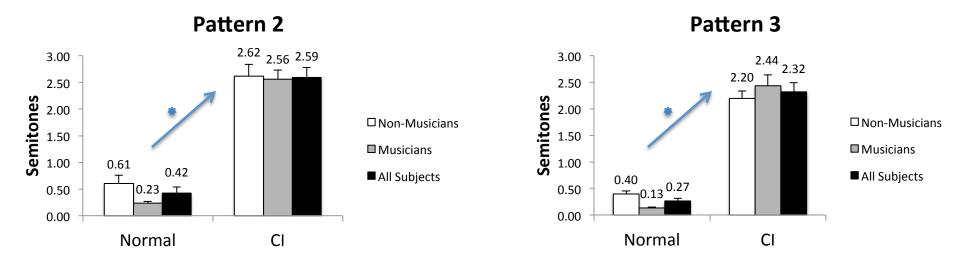
Pattern 3

Conclusions

- Musicians match pitch more accurately than non-musicians, on average.
  - High variability in the non-musician population

- CI processing makes it significantly more difficult to match pitch accurately for all subjects.

What about songs?

Nursery Rhymes (with lyrics)

Popular Songs

- 15 were selected for listening only
  - Acclimatization

- Of those 15, 3 were selected for singing
  - Data collection

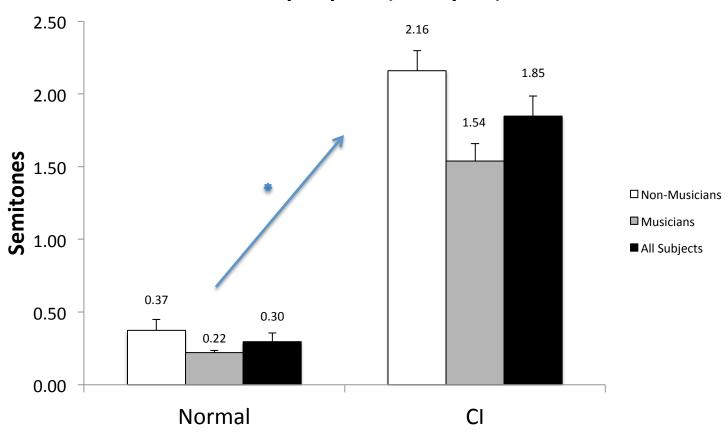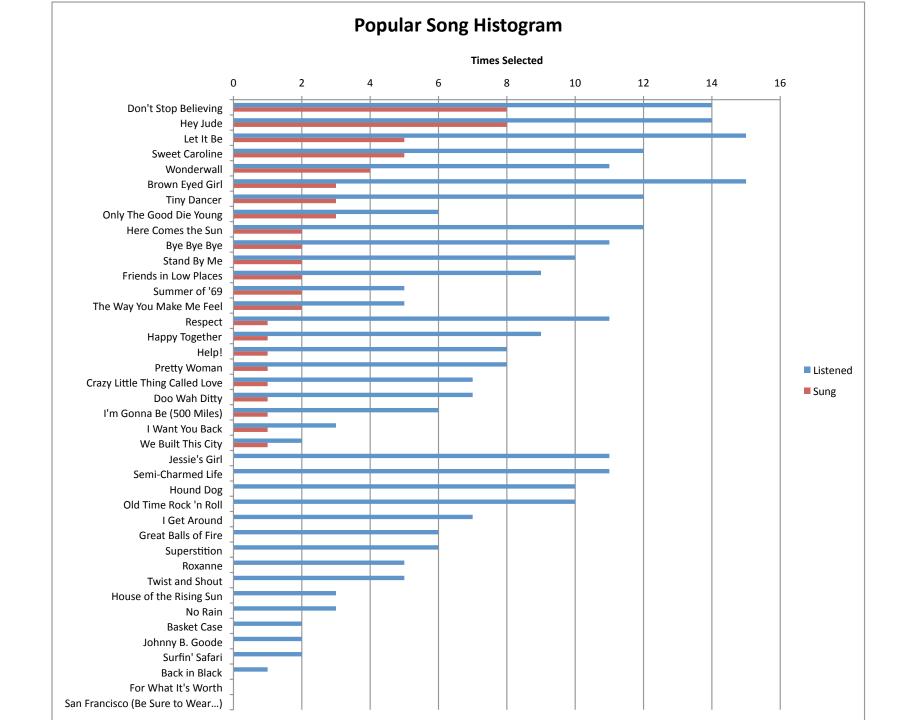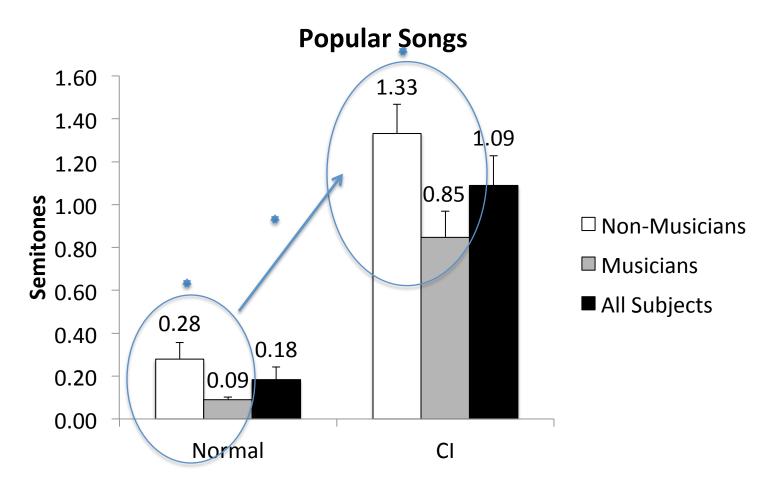| Song	Artist
Back in Black	AC/DC
Basket Case	Green Day
Brown Eyed Girl	Van Morrison
Bye Bye Bye	NSYNC
Crazy Little Thing Called Love	Queen
Don't Stop Believin'	Journey
Doo Wah Ditty	Manfred Mann
For What It's Worth	Buffalo Springfield
Friends In Low Places	Garth Brooks
Great Balls of Fire	Jerry Lee Lewis
Happy Together	The Turtles
Help!	The Beatles
Here Comes the Sun	The Beatles
Hey Jude	The Beatles
Hound Dog	Elvis Presley
House of the Rising Sun	The Animals
I Get Around	The Beach Boys
I Want You Back	Jackson 5
I'm Gonna Be (500 Miles)	The Proclaimers
Jessie's Girl	Rick Springfield
Johnny B. Goode	Chuck Berry
Let It Be	The Beatles
No Rain	Blind Melon
Old Time Rock and Roll	Bob Seger
Only The Good Die Young	Billy Joel
Pretty Woman	Roy Orbison
Respect	Aretha Franklin
Roxanne	The Police
San Francisco (Be Sure to Wear Flowers in Your Hair)	Scott McKenzie
Semi-Charmed Life	Third Eye Blind
Stand By Me	Ben E. King
Summer of '69	Bryan Adams
Superstition	Stevie Wonder
Surfin' Safari	The Beach Boys
Sweet Caroline	Neil Diamond
The Way You Make Me Feel	Michael Jackson
Tiny Dancer	Elton John
Twist and Shout	The Beatles
We Built This City	Jefferson Starship
Wonderwall	Oasis

Popular Song Histogram

Times Selected

Song		
	Listened	**Sung**

Legend: Listened (blue), Sung (red)

Song list (top to bottom):
- Don't Stop Believing
- Hey Jude
- Let It Be
- Sweet Caroline
- Wonderwall
- Brown Eyed Girl
- Tiny Dancer
- Only The Good Die Young
- Here Comes the Sun
- Bye Bye Bye
- Stand By Me
- Friends in Low Places
- Summer of '69
- The Way You Make Me Feel
- Respect
- Happy Together
- Help!
- Pretty Woman
- Crazy Little Thing Called Love
- Doo Wah Ditty
- I'm Gonna Be (500 Miles)
- I Want You Back
- We Built This City
- Jessie's Girl
- Semi-Charmed Life
- Hound Dog
- Old Time Rock 'n Roll
- I Get Around
- Great Balls of Fire
- Superstition
- Roxanne
- Twist and Shout
- House of the Rising Sun
- No Rain
- Basket Case
- Johnny B. Goode
- Surfin' Safari
- Back in Black
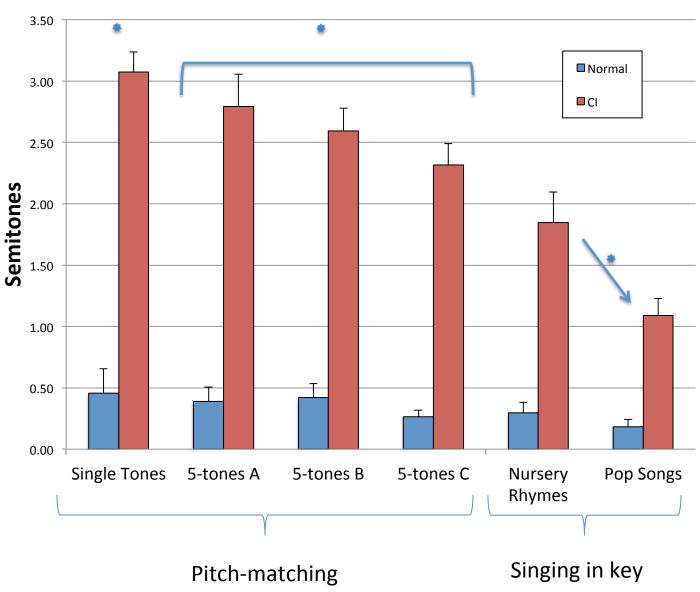- For What It's Worth
- San Francisco (Be Sure to Wear…)
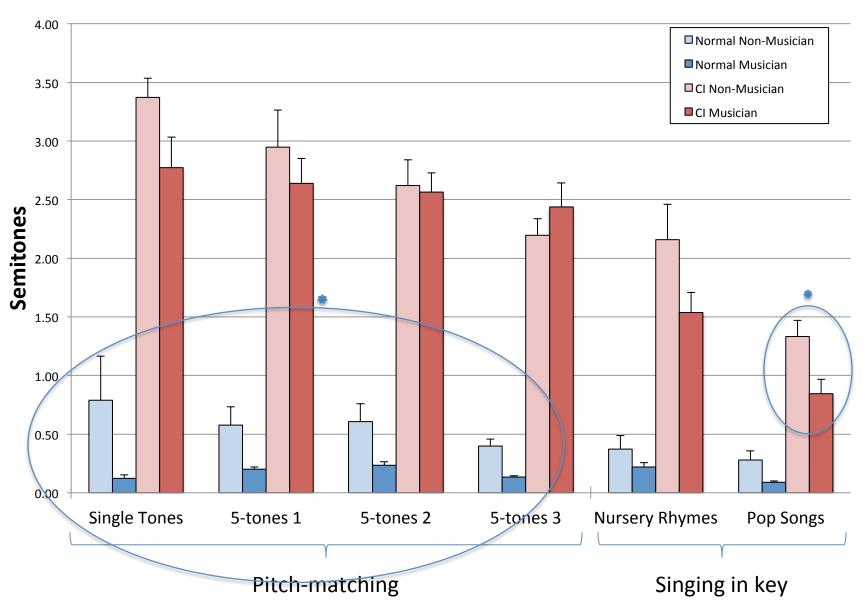
Popular Songs

Group difference across both conditions (p = 0.033)

All Subjects

Musicians vs. Non-Musicians Across Stimuli

Summary

- On average, musicians match pitch more accurately than non-musicians.

- Increased musical context can improve pitch accuracy when listening through CI processing
  - esp. with auditory/vocal memory at play

Future Studies

- What about real CI patients?
  - Various musical backgrounds/experience

- Postlingually vs. prelingually implanted?

Thank you for listening!

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CI Simulation

- 15-channel vocoder (≈ Litvak, 2007)

- Test Materials
  - Single Tones
  - 5-Tone Patterns
  - Nursery Rhyme Melodies
    - (with and without lyrics)
  - Selected Popular Songs

Testing Procedure

1. Acclimatization Period
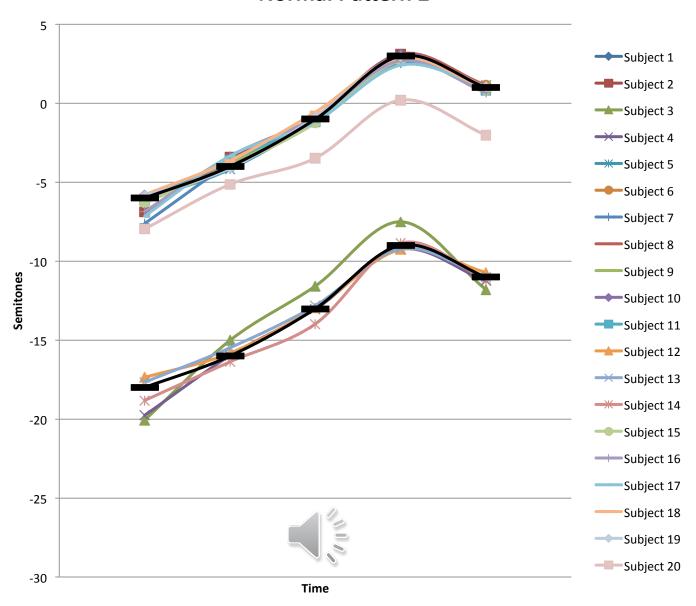   - Get used to the processed signal
2. CI condition
   - Popular Songs
   - Single Tones
   - 5-Tone Patterns
   - Nursery Rhyme Melodies without lyrics
   - Nursery Rhyme Melodies with lyrics

3. Normal condition
   - Single Tones
   - 5-Tone Patterns
   - Nursery Rhyme Melodies without lyrics
   - Nursery Rhyme Melodies with lyrics
   - Popular Songs

- Always sing "na"

Normal Pattern 2

CI Pattern 2