EFFECTS OF SHORT-TERM EXPERIENCE ON AUDITORY CATEGORIZATION
AN EVENT-RELATED POTENTIAL STUDY

Ran Liu[1,2] & Lori L. Holt[1]

1) Psychology, Carnegie Mellon University; 2) Neuroscience, Weill Cornell Medical College

Background

Experience plays a major role in shaping the way the brain learns to categorize speech sounds, but the specific mechanisms by which this occurs are not well understood.

The big questions:

What type of experience leads supports speech categorization?

How specialized are the neural representations underlying speech categories?

Training listeners on *complex non-speech stimuli* to which they are naïve:

- **Makes it possible to strictly control the amount and type of experience received**
- **Provides insight into the domain-specificity of speech categorization**

Prior non-speech training studies: explicit feedback, lack ecological validity

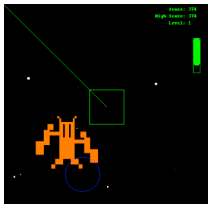
IRFBAT game training paradigm (Wade & Holt, 2005)

- **Implicit learning**
- **Captures some of the challenges faced in natural speech category acquisition**
- **Behavioral results show that listeners can be trained to reliably categorize complex non-speech sounds (both trained & novel stimuli)**

How is this learning reflected at the neural level?

The IRFBAT Video Game

Interactive Robot Figure-Based Auditory Training



Players navigate through a 3D space, perform different actions based on which character they see

Each character associated with a distinct movement pattern and experimenter-defined sound category

6 different sound stimuli in each category

Players not explicitly asked to form audio-visual or audio-motor associations, but these associations are highly beneficial to performance

The Mismatch Negativity (MMN) Response

Frontocentrally negative component of auditory event-related potentials (ERPs), typically peaks around 100–250 ms following stimulus onset

Invoked pre-attentively by a perceptually distinct, infrequent oddball stimulus in a train of frequent stimuli

X X X Y X X X X X Y X X X Y X X

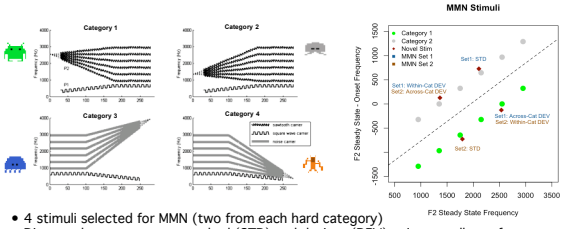
Varies in magnitude to reflect the degree to which the repeated & oddball sounds are "distinct" from each other

Pairs of stimuli that are within the same learned speech category show little to no MMN; pairs that are across two categories show a distinct MMN (Näätänen, 2001)

Methods

STIMULI

- Two components:
  - Square wave
  - Sawtooth (hard categories) or noise (easy categories)
- Easy categories: components moving in the same direction within category
- Hard categories: components moving in different directions within category
- Stimuli capture some of the structure of speech categories but do not sound at all like speech



- 4 stimuli selected for MMN (two from each hard category)
- Distance between every standard (STD) and deviant (DEV) pair, regardless of category membership, is equated in the higher-dimension space that separates the two hard categories

SUBJECTS

- 16 volunteers affiliated with Carnegie Mellon and University of Pittsburgh
- 9 male, 7 female
- Ages 18-45 (median = 21)

TRAINING LAYOUT

- Day 1: Pre-training ERP recording, 30 min of videogame
- Days 2, 3, 4: 30 min of videogame
- Day 5: 30 min of videogame, Post-training ERP recording

Results

BEHAVIORAL

- **Participants learn**

  Overall post-test categorization accuracy is above chance ($p<0.001$) and also above 50% ($p<0.01$), indicating learning beyond distinguishing between "easy" and "hard" categories

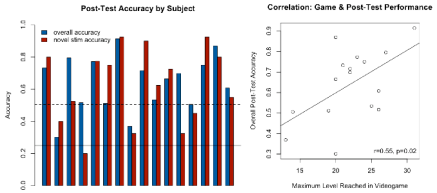
- **Participants generalize**

  Post-test categorization accuracy on novel stimuli are above chance ($p<0.001$) and above 50% ($p<0.05$), reflecting clear distinction between the hard categories for stimuli never heard in the game

- **Individual variability in level of learning**

  Most listeners learned categories successfully, a few did not. For the non-learners, we expect little-to-no MMN change.

- **Post-test results correlate with videogame performance**

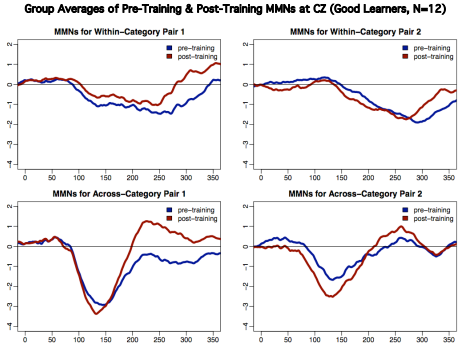


MISMATCH NEGATIVITY

- **GROUP RESULTS**

  T-tests between pre-test and post-test show acquired similarity between trained within-category stimuli and acquired distinctiveness between trained across-category stimuli.

  - Stim Set 1: decrease in within-cat peak amplitude ($p<0.01$), earlier across-cat peak latency ($p<0.05$)
  - Stim Set 2: increase in across-cat peak amplitude ($p<0.01$)



- **RESULTS FOR "GOOD LEARNERS" (indexed by post-test categorization accuracy, N=12)**

  The same patterns seen in the overall group results are even stronger when only including participants who show evidence of successful category acquisition.

  - Stim Set 1: decrease in within-cat peak amplitude ($p<0.001$), increase in across-cat peak amplitude ($p<0.05$), earlier across-cat peak latency ($p<0.05$)
  - Stim Set 2: increase in across-cat peak amplitude ($p<0.001$)

Conclusions

Successful learning of non-speech categories evident at the behavioral level may be reflected in neural changes resembling those of natural speech category acquisition.

- Stimuli learned through functionally-defined categories to be in the *same* category are perceived to be more similar; stimuli learned to be in *different* categories are perceived to be more distinct

Features of the IRFBAT training paradigm promote acquisition of complex auditory categories and thus may be important mechanisms in learning speech categories.

- Multi-sensory association, functional equivalence of different stimuli, implicit learning, reward

References

Leech, R., Holt, L. L., Devlin, J., & Dick, F. (2008). Changes in functional organization following naturalistic training on complex auditory categories. *Cognitive Neuroscience Society Annual Meeting, San Francisco, CA.*

Näätänen, R. (2001). The perception of speech sounds by the human brain as reflected by the mismatch negativity (MMN) and its magnetic equivalent (MMNm). *Psychophysiology, 38*, 1-21.

Wade, T. & Holt, L. L. (2005b). Incidental categorization of spectrally complex non-invariant auditory stimuli in a computer game task. *Journal of the Acoustical Society of America, 118*, 2618-2633.