

# Auditory categorization: Cue weighting and dimension bias

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## Learning Complex Auditory Categories

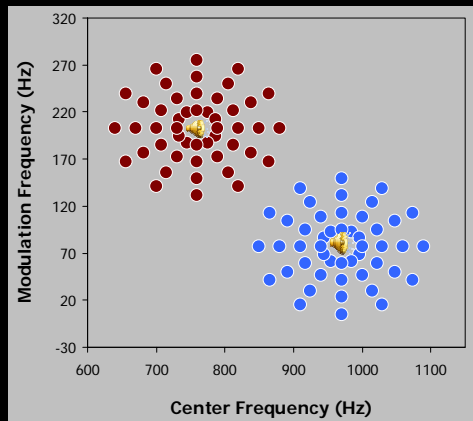
- The ability to integrate and weight information across dimensions is central to perception.
- Even when cues co-exist in an acoustic signal and are equally informative to a given task, they may not be equally weighted in perception.
- Relatively little is known about how listeners weight acoustic information in auditory categorization tasks.
  - Such processes may be important for speech categorization, second language acquisition, etc.
- Four experiments to investigate this issue

## Stimuli

Stimuli were drawn from a 2-d acoustic space defined by

**CF** = Center frequency of a sine-wave tone

**MF** = Modulation frequency of the sine-wave



Step size across the dimensions was determined by psychophysical pre-testing

Stimuli were approximately equally discriminable across the dimensions

Distributions were such that each dimension was equally informative to the task

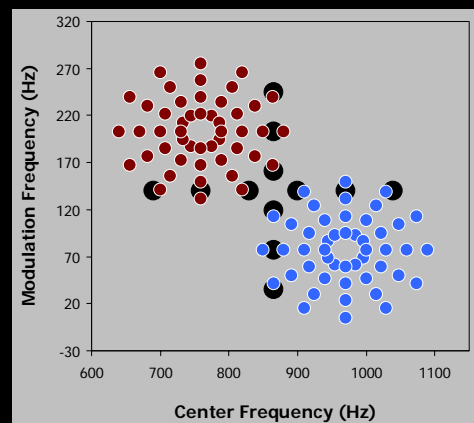
## Experiment 1

### TRAINING:

10 Blocks Training (w/ feedback)  
(each stim in distribution heard 10x)

### GENERALIZATION:

5 Blocks Training (w/ feedback)  
+ Novel Stimuli (no feedback)

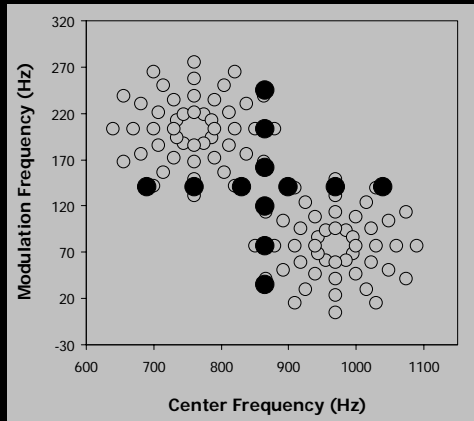


Dimensions were uncorrelated

Category distributions were equally informative in categorization decisions

Either, or both, could be used to accurately categorize the stimuli

## Analyses of Generalization Data



Conducted regression analyses on the % A categorization responses to novel stimuli in the Generalization segment

Responses collapsed across listeners within the analysis groups

For the novel stimuli, CF and MF are orthogonal

Thus, this analysis is equivalent to a simple correlation between the acoustic cue and the categorization response.

The %A responses correlated with MF and CF values.

## Experiment 1: Response/Cue Correlations

Regression analysis of the contribution of each acoustic dimension to categorization of the novel stimuli

### $r$ Values

CF = -.846

MF = .464

- Dimensions were uncorrelated
- Equally informative to categorization

Either, or both, could be used to accurately categorize the stimuli

Listeners weighted CF more in categorization responses than MF

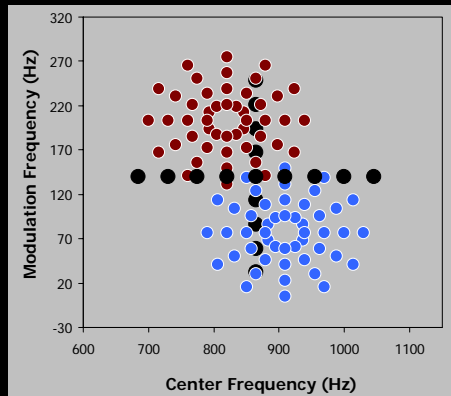
The normalized acoustic cues did not contribute equally to auditory categorization

### Cue Weighting

## Experiment 2:

Rendering CF Less Informative  
as a Categorization Cue

Experiment 2



Distributions shifted along the  
CF dimension

CF less informative about  
category identity

Effect on cue weighting?

**EXPERIMENT:**  
Procedures identical to  
Experiment 1

## Experiment 2: Response/Cue Correlations

Regression analysis of the contribution of each acoustic  
dimension to categorization of the novel stimuli

### EXPERIMENT 1

#### r Values

CF = -.846  
MF = .464

#### MF was more informative to categorization

Even so, listeners relied on CF more than MF  
in categorization responses

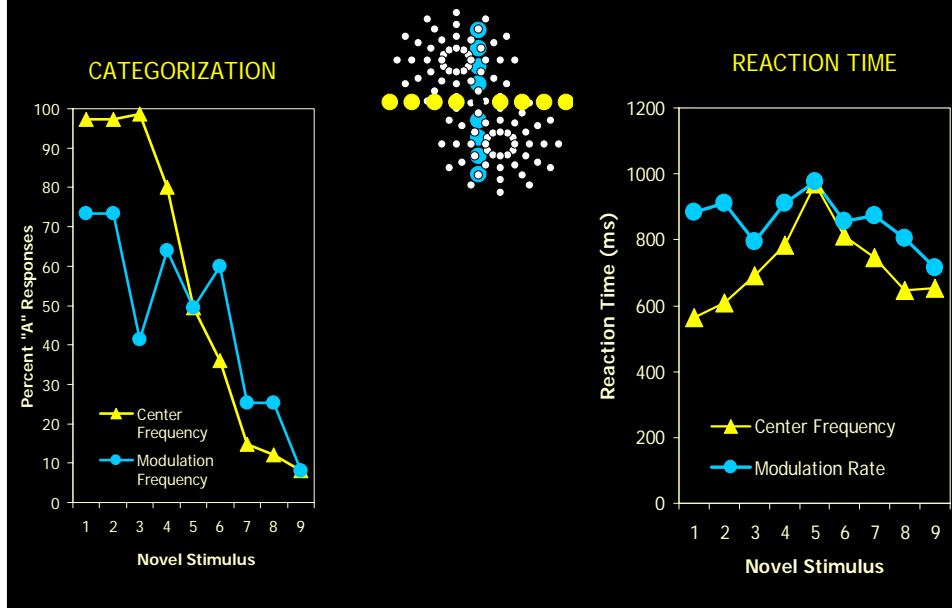
### EXPERIMENT 2

#### r Values

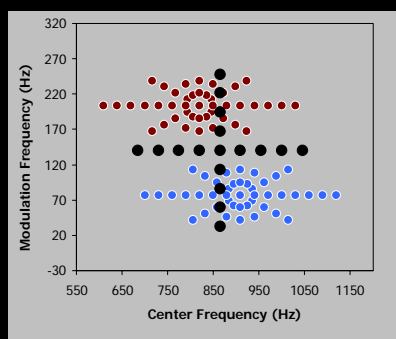
CF = -.821  
MF = .439

Again, the normalized acoustic cues did not  
contribute equally to auditory categorization

## Experiment 2: Comparison of Cue Use



## Experiment 3: Altering Cue Weighting by Manipulating Distribution Characteristics



Increasing the variability of the distributions along CF renders MF the more reliable cue

Do listeners adjust their cue weightings?

**EXPERIMENT:**  
Procedures identical to Experiment 1

Distribution centroid stimuli are identical to those of Experiment 2 (shifted closer along CF)

## Experiment 3: Response/Cue Correlations

Regression analysis of the contribution of each acoustic dimension to categorization of the novel stimuli

### EXPERIMENT 1

#### r Values

CF = -.846  
MF = .464

### EXPERIMENT 2

#### r Values

CF = -.821  
MF = .439

### EXPERIMENT 3

#### r Values

CF = -.551  
MF = .781

CF was less discriminable than MF

Distribution variance rendered MF more informative to categorization

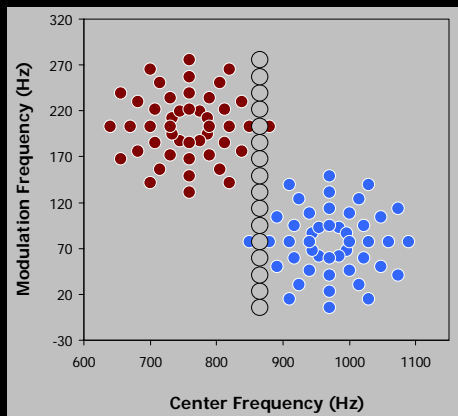
Cue weighting shifts  
Listeners now weight MF more

Listeners are sensitive to sound distribution characteristics

Greater variance is detrimental to cue weighting when it occurs during feedback training and is uncorrelated with category label.

## Experiment 4:

Altering Cue Weighting through Exposure



Same distributions/task as Exp 1  
But,...

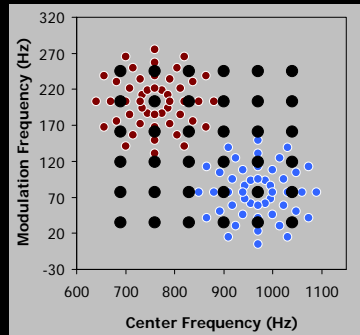
Listeners were passively exposed  
to a stimulus set before training

Stimuli varied in MF with  
constant, intermediate CF

320 trials / Approximately 15 min

All subjects trained on the Exp 1  
distributions for 10 blocks (with  
feedback)

## Experiment 4: Response/Cue Correlations



Only the pre-exposure differentiated EXPERIMENT 4 from EXPERIMENT 1

Generalization was assessed with a grid of novel stimuli

### EXPERIMENT 1

#### r Values

CF = -.888

MF = .344

### EXPERIMENT 4

#### r Values

CF = -.776

MF = .528

Pre-training exposure to variance along the weaker cue shifts  
CUE WEIGHTING

## Conclusions

- **Acoustic cues are not “created equally”**
  - Even when psychophysically matched
  - BIAS toward CF: Preferential cue use
  - Perhaps CF is more reliable cue to category identity across the history of experience within the acoustic environment?
- **Acoustic cue weighting can be altered by**
  - ...manipulating the variability of input distributions such that the “weaker” cue provides greater *information*
  - ...passively exposing listeners to variability along the “weaker” acoustic cue
- **Listeners are sensitive to the distributions of sounds in categorization tasks**

## Conclusions

- Variance is essential determiner of cue weighting
- The function of variance is moderated by feedback when it occurs
- Additional variance along an acoustic cue...
  - decreased its weight in categorization responses when presented with feedback
  - increased its weight in categorization responses when presented prior to explicit training with feedback

## For More Information

- Please visit:
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