- **Speech perception—**
  Some fundamental concepts

Optional reading (for more information):

- *AAP* Ch 5, sec 5.2.1, "Categorical perception"
- *AAP* Ch 5, sec 5.3, "Linguistic knowledge shapes speech perception"
- *AAP* Ch 5, sec 5.4, "Perceptual similarity"

0. Course information and updates

- Results of partner group check-in survey
  - More concerns this year than I have ever seen!
  - Possible reasons?
    - Pandemic and remote-learning disruptions / stress?
    - *More* time provided in class for group work may have led to *less* planning and coordination outside of class time?
- Response: See amended partnership work plan
  - If any group has a completely unresponsive or non-participating group member, please email or talk to me ASAP

0. Today's plan

- Acoustics vs. perception — some important differences
- How to determine when or how acoustic properties are relevant for perception?
- Categorical perception
-

1. Acoustics vs. perception

- In this course, we have been focusing on the **acoustics** of speech sounds
- But human listeners filter the acoustics of speech through the human **perceptual** system — this has some important implications

1. Acoustics vs. perception

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  - **Human perception is not linear**; there is "distortion"
  - **Normalization:** Acoustic properties (such as formants, f_0, duration) are interpreted differently when produced by different speakers
  - The **sound categories (phonemes) of the listener's native language** affect speech perception

1. Acoustics vs. perception

- **Human perception is not linear**; there is "distortion"
- Example: Pure tones (200 Hz-475 Hz)
  H. Timothy Bunnell, University of Delaware
  - Each successive tone is 25 Hz higher
  - Does increasing the **frequency** by equal amounts produce tones that are equal steps apart in perceived **pitch**?

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    No! — Equal steps in frequency are perceived to be "closer together" at higher frequencies

1. Acoustics vs. perception

- **Normalization:** Acoustic properties (such as formants, f_0, duration) are interpreted differently when produced by different speakers
  - Is it a high or low value *for that speaker*?
  - Example: the "Please say what this word is" experiment

1. Acoustics vs. perception

- The **sound categories (phonemes) of the listener's native language** affect speech perception
  - Two phones sound "more different" if they are contrastive in the listener's language

2. Acoustics — relevant for perception?

- Given that acoustics does not map linearly onto perception…

  and given that humans do not necessarily use all available information in forming conceptual categories…

  What are some ways we can determine whether a particular **acoustic** property is *relevant* for speech **perception**?

2. Acoustics — relevant for perception?

- What are some ways we can determine whether a particular **acoustic** property is *relevant* for speech **perception**?
  - Is the acoustic property **always/usually present** (for the relevant class of sounds)?
  - If the acoustic property is **removed or altered**, does this **affect** perception?
  - Does the presence or absence of the property correlate with the **perceptual distance** between speech sounds? (see below)

2. Acoustics — relevant for perception?

- Is the acoustic property **always/usually present** (for the relevant class of sounds)?
  - Experiments show that if an acoustic property is consistent, it is usually expected by listeners — so this might tell us what to investigate with perception experiments
  - Example: "spit spikes" in lateral fricatives

2. Acoustics — relevant for perception?

- If the acoustic property is **removed or altered**, does this **affect** perception?
  - Method: Experiments with synthesized speech or manipulated natural speech

    V&C demonstration of different "components" of a synthesized sentence

    Early experiments with synthesized speech at Haskins Laboratores: Pattern Playback
    - The Pattern Playback machine
    - Examples of synthesized sentences
    - A synthesized /b/-/d/-/g/ continuum

2. Acoustics — relevant for perception?

- Does the presence or absence of the property correlate with the **perceptual distance** between speech sounds? → *see below*

3. Categorical perception

- What is **categorical perception**?
  - Speech stimuli are on a **continuum** for some physical/acoustic property
  - But, listeners perceive the stimuli as though they belong to a small number of **categories**

3. Categorical perception

- How can categorical perception be **experimentally demonstrated**?

  Compare the results of **two kinds of experiments**:

  - **Identification** task: Which stimuli are consistently identified with the same label?
  - **Discrimination** task: Which stimuli are easy vs. hard to discriminate?

- The results show categorical perception when identification performance goes *down* **at the point(s) where** discrimination goes *up*

3. Categorical perception

- How can categorical perception be **experimentally demonstrated**?
- The results show categorical perception when identification performance goes *down* **at the point(s) where** discrimination goes *up*
  - What is the explanation for this relationship?

3. Categorical perception

- Sample categorical-perception experiment: Vowel length in English *bat/bad* (V&C)
  - Try it

3. Categorical perception

- What does categorical perception mean for phonetics and phonology?

3. Categorical perception

- Categorical perception has been found in humans for various properties of speech, including:
  - Consonant place of articulation
  - Consonant manner of articulation: stop vs. affricate
  - VOT
  - Presence vs. absence of a stop in a [sCL] cluster
  - Vowel length as a cue for final consonant voicing (see *V&C* Ch 10, sec 10.1)
- But vowel quality seems *not* to be strongly categorically perceived

3. Categorical perception

- Categorical perception for (human) speech sounds has also been found in:
  - Chinchillas
  - Japanese quail (*uzura*)

  ...so it's not a *human-specific* property

3. Categorical perception

- The effects of categorical perception are generally stronger for categories that are distinctive in the listener's language
  - May be an effect of the phonological (mental) grammar
  - May be an effect of having more practice assigning acoustic stimuli to those categories
  - May be both

3. Categorical perception

- Categorical perception therefore allows us to explore questions like…
  - Where do typological universals come from? (stop place, VOT, …)
  - To what extent is human language unique in the animal world?
  - Can language exposure enhance or inhibit categorical perception?

  …

4. Perceptual similarity / perceptual distance

- Basic idea: If two sounds are frequently confused, they are **perceptually similar** to each other
  - "Perceptually similar" has **universal** (acoustic) and **language-particular** aspects
- Metaphor: We can model perceptual similarity as a kind of **distance** in a multi-dimensional space

4. Perceptual similarity / perceptual distance

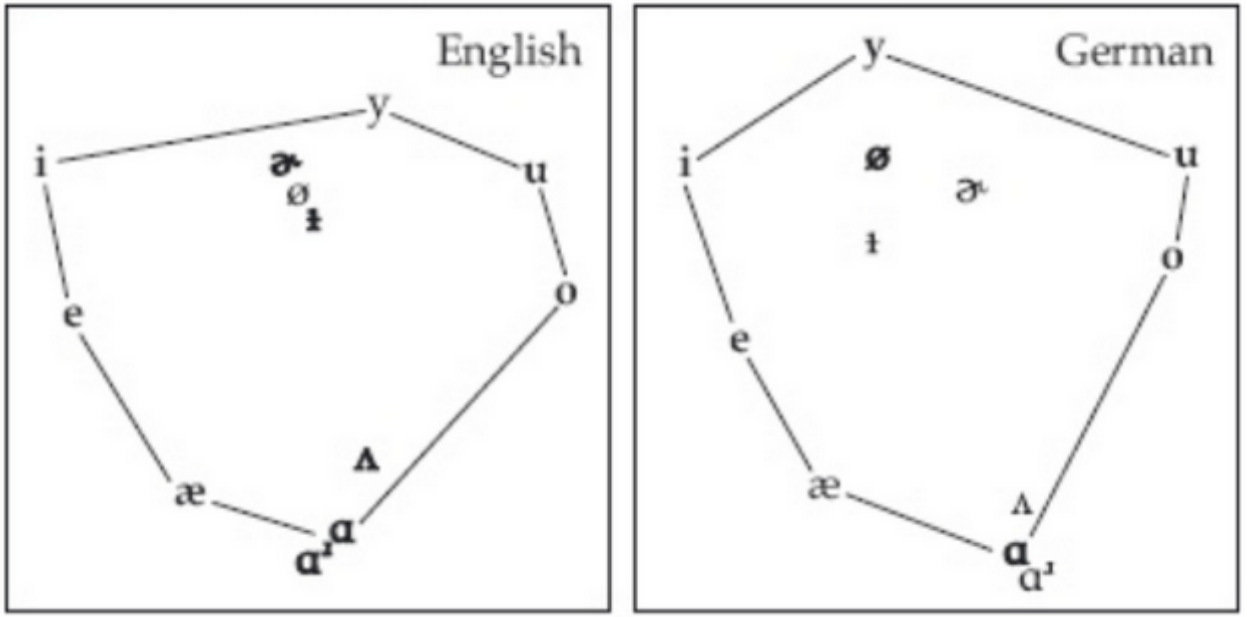
- How to do this [Note: you are not required to work with the formulas, but do understand the ideas]
  - Run a perception experiment comparing a set of sounds
  - Determine how often each pair of sounds is confused
  - Calculate S_{ij}, a **similarity value** for a pair of sound categories *i* and *j* :

    [Proportion of *i* plus proportion of *j* incorrectly perceived as each other] *divided by* [proportion of correctly perceived *i* plus proportion of correctly perceived *j*]
  - **Perceptual distance** between *i* and *j* = $\mathbf{-\ln(S_{ij})}$
    (the negative natural log *ln* of the similarity value)

4. Perceptual similarity / perceptual distance

- Examples (*AAP* Fig 6.11, p 147; data from Terbeek (1977))

  Perceptual distance **by language** (same stimuli)



- How distinct is [y], and what is it similar to?
- How distinct is [ʌ]? What about [æ]?

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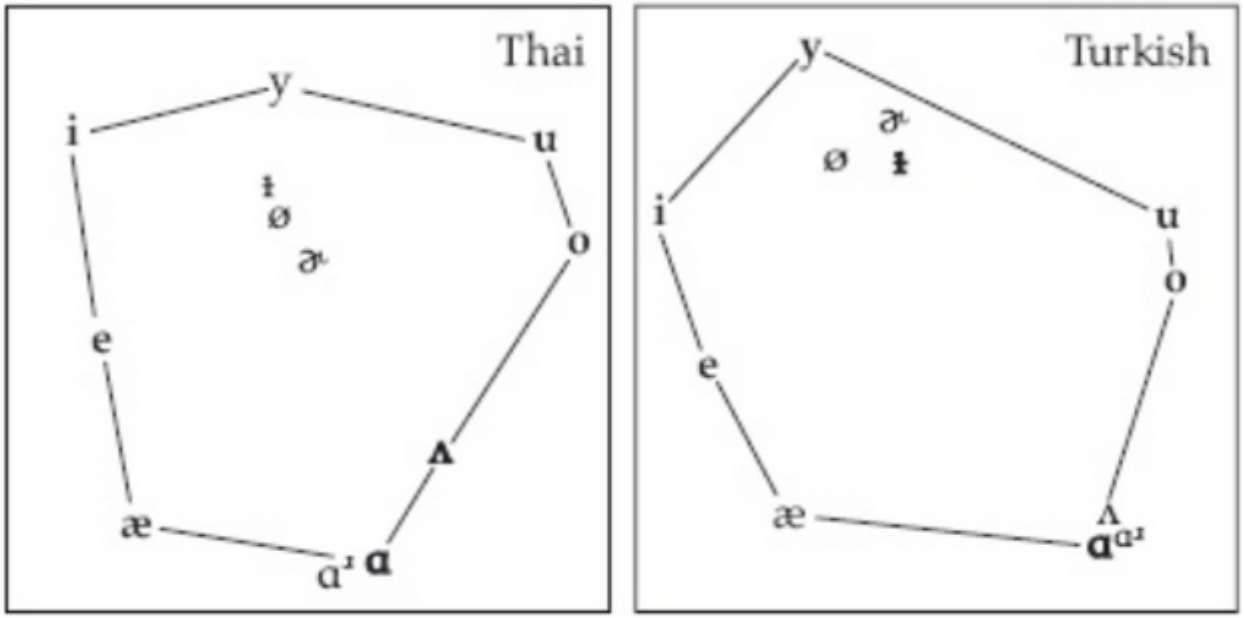

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4. Perceptual similarity / perceptual distance

- How is **categorical perception** related to **perceptual distance**?
- How can we use perceptual similarity experiments to explore some of the questions raised above?