Speech Category Learning across the Lifespan

Ghazal Koohkansaadi, Christopher C. Heffner, Brett Gibson, Casey L. Roark

University at Buffalo

Background

What are speech categories?

- E.g., /b/ in “bear” and /p/ in “pear”
- Highly variable across speakers and contexts (Holt & Lotto, 2010)
- Different languages have different speech categories
- Learning a second language requires learning new speech categories
  - E.g., Japanese → English /r/ vs. /l/
  - E.g., English → German /ç/ vs. /x/


/b/ bear


/p/ pear

Learning new categories relies on cognitive abilities that change with development

- Category learning changes across the lifespan (Rabi et al., 2015; Reetzke et al., 2016; Roark & Holt, 2019; Roark et al., 2024)
- Learning new categories relies on executive functions like working memory, attention, and cognitive flexibility (Diamond, 2013)
- These abilities depend on maturation of brain regions like the prefrontal cortex (Casey et al., 2005)
- Some kinds of learning may rely more on these abilities than others (Heffner et al., 2019; Shepard et al., 1961)

How does speech category learning change across the lifespan?

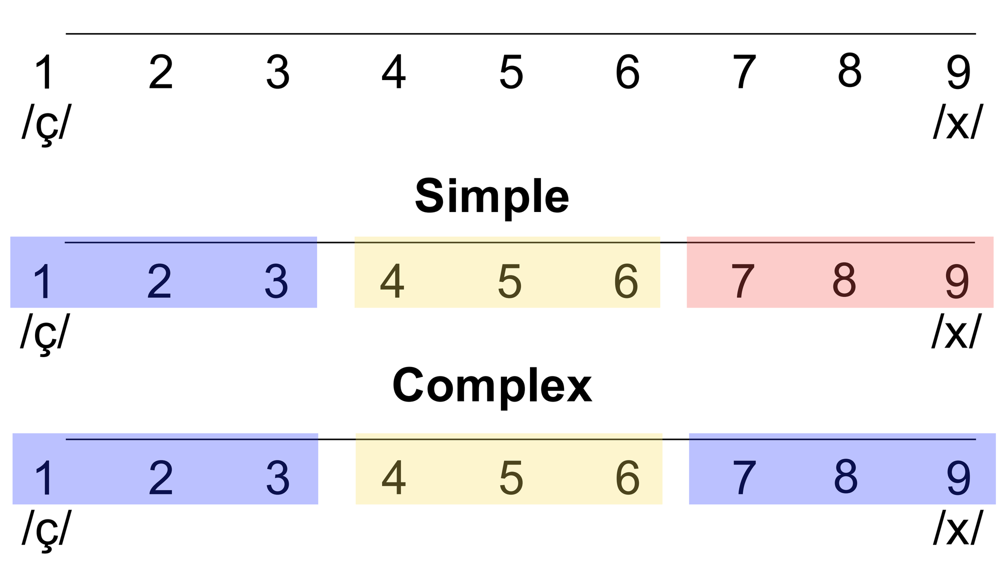
Method

Participants

- N = 99, ages 7-69 years
- Rochester Museum of Science and communities in Rochester and Buffalo, NY
- Native English speakers, no prior history of German, no language/communication disorders

Stimuli and categories

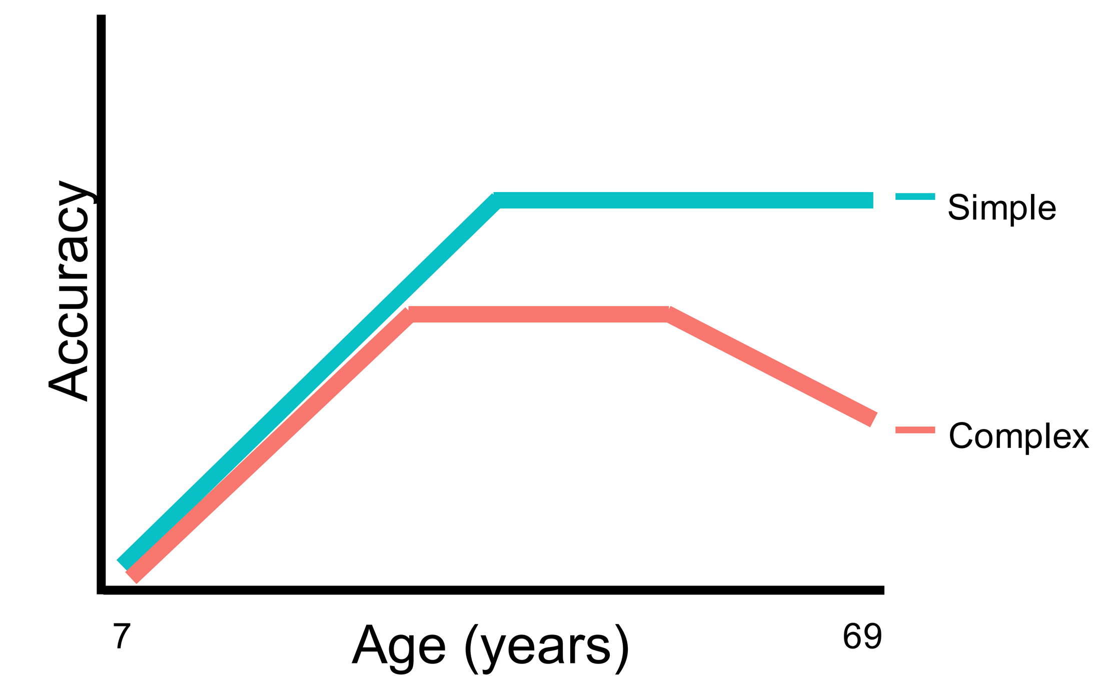
- German fricative sounds /ç/ and /x/
- 9-step continuum between the best /ç/ sound and the best /x/ sound
- Conditions: split the continuum into different categories
  - **Simple** (N = 48): sounds adjacent to each other (Category A: 1, 2, 3, Category B: 4, 5, 6, Category C: 7, 8, 9)
  - **Complex** (N = 51): sounds non-adjacent to each other (Category A: 1, 2, 3, 7, 8, 9, Category B: 4, 5, 6)



Procedure

- “Alien Ranger” game cover story
- Learn to associate sounds with aliens
- 243 trials across 4 blocks, received feedback (correct or incorrect)

Predictions



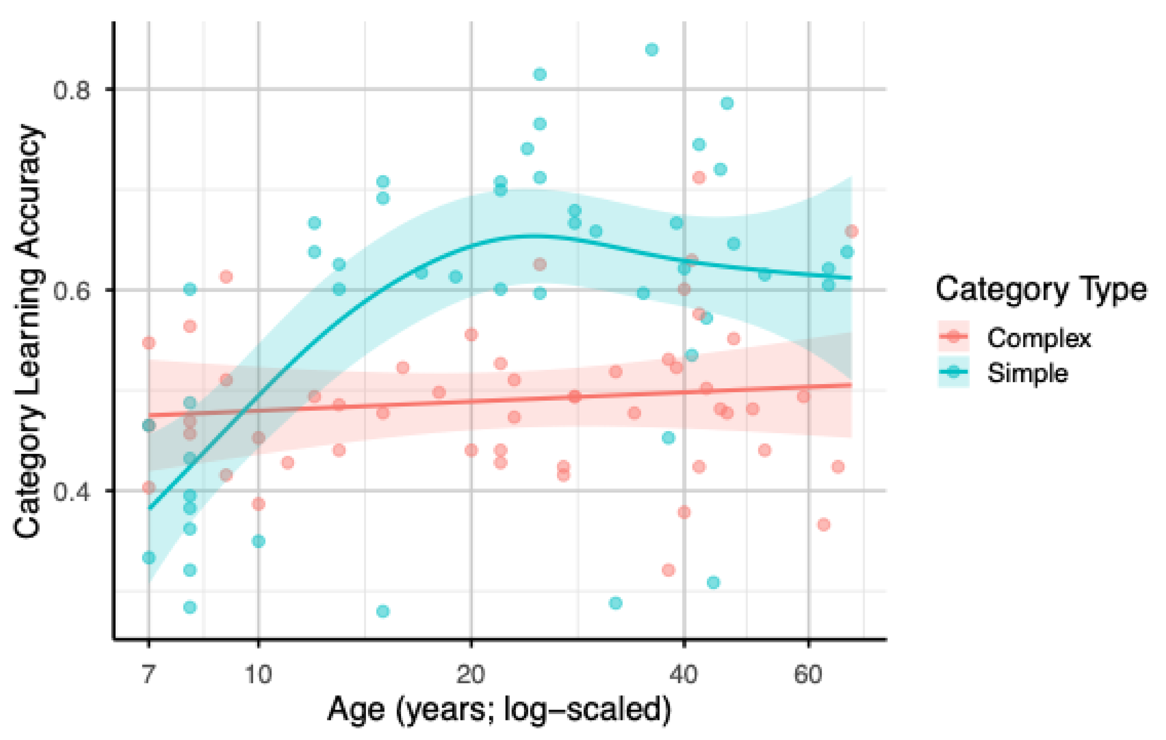
Simple categories

- Follow trajectory of executive function and brain maturation
- Improve in childhood until young adulthood (e.g., Reetzke et al., 2016)
- Plateau in adulthood (e.g., Casey et al., 2005)

Complex categories

- Lower accuracy than simple categories (Heffner et al., 2019)
- Improve in childhood until young adulthood (e.g., Reetzke et al., 2016)
- Decline in older adulthood (e.g., Rabi & Minda, 2016)

Results



- Developmental trajectories of learning accuracy differed across category types
  - **Simple categories:** nonlinear, follows the trajectory of executive function and brain maturation
    - Improves in childhood to adolescence (~7-18 years)
    - Plateaus after ~20 years
  - **Complex categories:** linear and did not vary across ages (slope estimate = 0.031, p = .401)

Analysis Approach

- Used Generalized Additive Models (GAMs) to examine possible non-linear relationships between **age** and category learning **accuracy** for the two **category types**

Accuracy = Age * Category Type

- Age was log-transformed due to skew
- Accuracy was computed as the average proportion of correct responses across all trials
- GAMs showed better fits (BIC = -141.5, R^2 = .36) than a model assuming a linear relationship (BIC = -128.26, R^2 = 0.19)
- Accuracy was computed as the average correct responses across all trials

Conclusions

- Category complexity shapes how speech learning changes across the lifespan
  - Learning of simple categories improves in childhood and adolescence, while learning of complex categories does not
  - Learning of simple categories may be supported by development of executive functions as the brain matures
  - Comparable performance in complex categories suggests differences in underlying strategies across age groups
  - Older adults may rely more on prototype-based representations
- **Future directions**
  - Examine which strategies older adults rely on more when learning speech categories
  - Test whether manipulating task difficulty would reveal age differences in complex category learning

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Acknowledgements This work was supported by start up funds provided to C.C.H. from the University at Buffalo.