SONORITY SEQUENCING IN POLISH: THE COMBINED ROLES OF PRIOR BIAS & EXPERIENCE

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ANNUAL MEETINGS ON PHONOLOGY
OCT 21-23, 2016, UNIVERSITY OF SOUTHERN CALIFORNIA

HOW DO WE LEARN PHONOTACTIC GENERALIZATIONS?

- Where do phonotactic preferences come from?
  - 'mip' > 'bwip' > 'dlap' > 'bzap'
- Lexicalist Hypothesis: derived from lexical statistics
  - Dominant hypothesis in phonology & language acquisition
- Universals: what shapes languages?
  - To what extent does learning shape/derive universals?
- Unresolved debate: how constrained is LAD?
  - Constraints on representations?
  - Limits to frequency sensitivity?

A UNIVERSALIST CONTINUUM

- Increasingly "Universalist" Hypotheses
  - **Raw statistics**, no generalization/similarity
    - Analogy (Bailey & Hahn 2001)
    - Phoneme co-occurrence (Vitevich & Luce 2004)
  - Frequency Sensitivity with **Class-Based Generalization (CBG)**
    - Abstract representations: features, syllables, tiers, etc.
    - UCLA Phonotactic Learner (Hayes & Wilson 2008)
    - Featural Bigram Model (Albright 2009)
  - **Universal bias** and frequency sensitivity
    - Preferences among abstract representations:
      - VoicedCoda < VoicelessCoda
- This talk
  - Review evidence for CBG and Universals
  - Sonority sequencing preferences in Polish

SUPPORT FOR CBG

- UCLA Phonotactic Learner (Hayes & Wilson 2008)
  - English onsets phonotactic judgments (from Scholes 1966)

Model	*r*
Our model	0.946
Clements and Keyser 1983 constraints with maxent weights	0.936
Coleman and Pierrehumbert 1997	0.893
Our model without features	0.885
N-gram model	0.877
Analogical model	0.833

- This is a CBG & lexicalist model:
  - Constraints constructed and weighted based on lexicon
  - Constraints use features / natural classes
    - *[+son,+dor] - no dorsal nasals
    - See also Albright (2009), Daland et al. (2011), Coetzee & Pater (2008), Albright & Hayes (2003)

SUPPORT FOR UNIVERSALS

- **Poverty** of the Stimulus Arguments
  - Production/perception/acceptability of illicit forms
    - Berent et al. 2007, Berent 2008, Berent et al. 2008; Ren et al. 2010, Berent & Lennertz 2009, Berent et al. 2009, Davidson et al. 2004, Davidson 2006
  - Second language acquisition, loan adaptation
    - Broselow et al. 1998, Broselow & Finer 1991; Eckman & Iverson 1993
  - Substantively biased generalization
    - Wilson 2006, White 2013, White & Sundara 2014, White to appear
- **Surfeit** of the Stimulus Arguments
  - Speakers underlearn unnatural regularities
    - Hayes et al. 2009, Becker et al. 2011, 2012, Hayes & White 2013
- **Defiance** of the Stimulus Arguments
  - Learners reverse lexical tendencies
    - Jarosz 2015, submitted, Garcia 2014, 2016

SONORITY PROJECTION

- **Sonority Sequencing Principle** (SSP; Clements 1988, Selkirk 1984)

[lb]ack < [nb]ack < [bd]ack < [bn]ack < [bɹ]ack < [bj]ack

-2 -1 0 1 2 3

- Consistent findings of **Sonority Projection** in English
  - Preferences between unobserved clusters
    - **#nb** (-1) vs. **#db** (0)
  - Documented using various tasks
    - Production, perception, acceptability; aural, written (Berent et al. 2007, Berent & Lennertz 2009, Berent et al. 2009, Davidson et al. 2004, Davidson 2006, Daland et al. 2011)
- Question:
  - Could these preferences be learned?

ENGLISH: POVERTY OF THE STIMULUS?

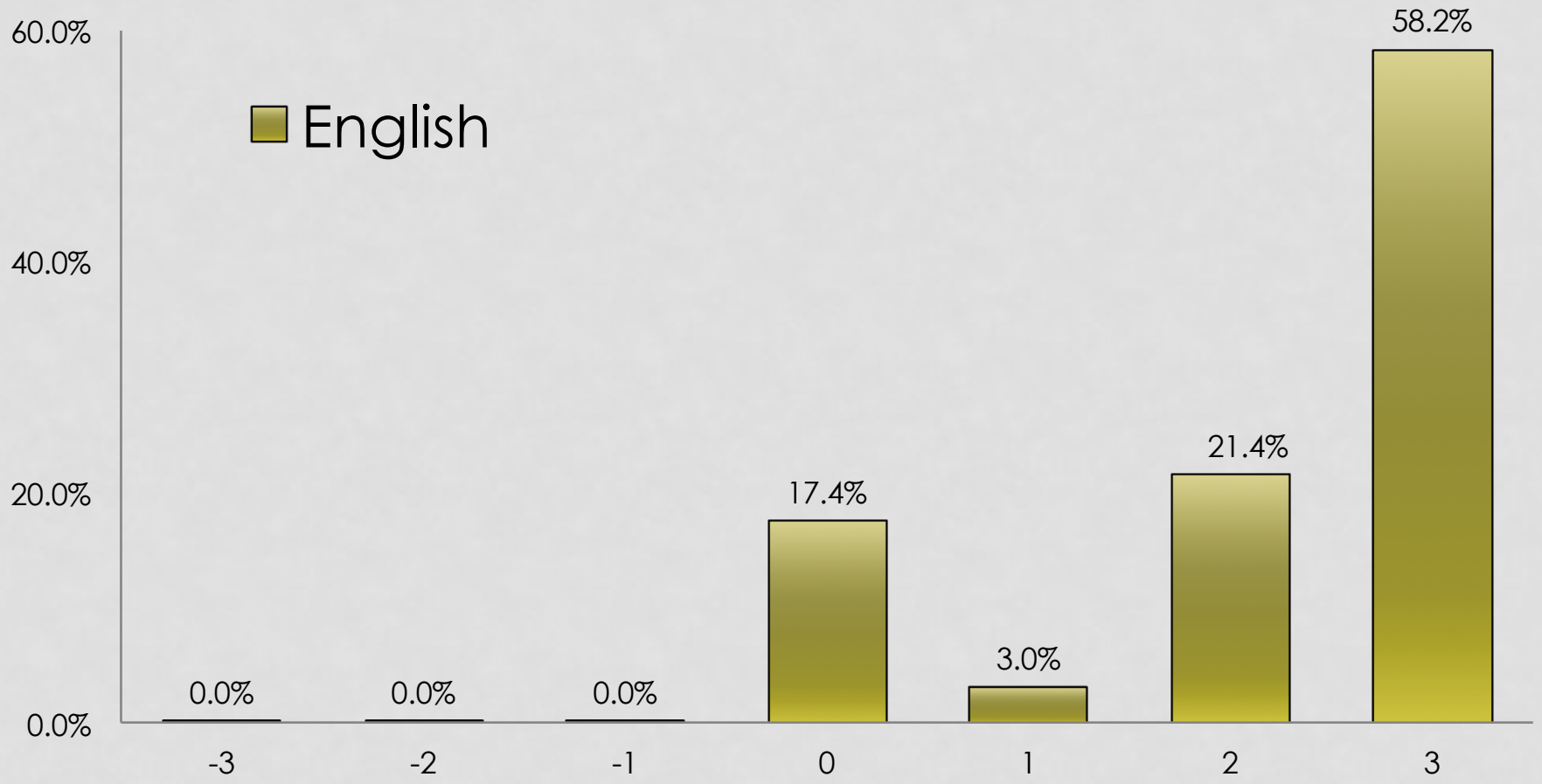
- Berent et al. (2007): Poverty of the Stimulus
  - English speakers exhibit sonority projection effects
    - *[lb]ack (-2) < *[bd]ack (-1) < *[bn]ack (1)
  - Raw lexical statistics don't capture effect
- Daland et al. (2011): No Poverty of the Stimulus
  - Several CBG models derive SSP for English
  - As long as statistical learning has access to
    - **Syllable structure** - [gb] in rug.by may be different
    - **Features** - what sounds are similar to one another
  - Constraints favor more frequent patterns
    - *#[+son][-son] vs. *#[-son][+son]
    - More words like #[**bn**]ack than #[**nb**]ack
- Raw Statistics not sufficient. CBG required.

ENGLISH SYLLABLE ONSETS

OO (0)		ON (1)		OL (2)		OG (3)	
st	521	sn	109	fl	290	pr	1046
sp	313	sm	82	kl	285	tr	515
sk	278			pl	238	kr	387
				bl	213	gr	331
				sl	213	br	319
				gl	131	fr	254
						dr	211
						kw	201
						sw	153
						hw	111
						θr	73
						tw	55
						ʃr	40
						dw	17
						gw	11
						θw	4
(17.4%)		**(3.0%)**		**(21.4%)**		**(58.2)%**	

(data from Hayes & Wilson 2008)

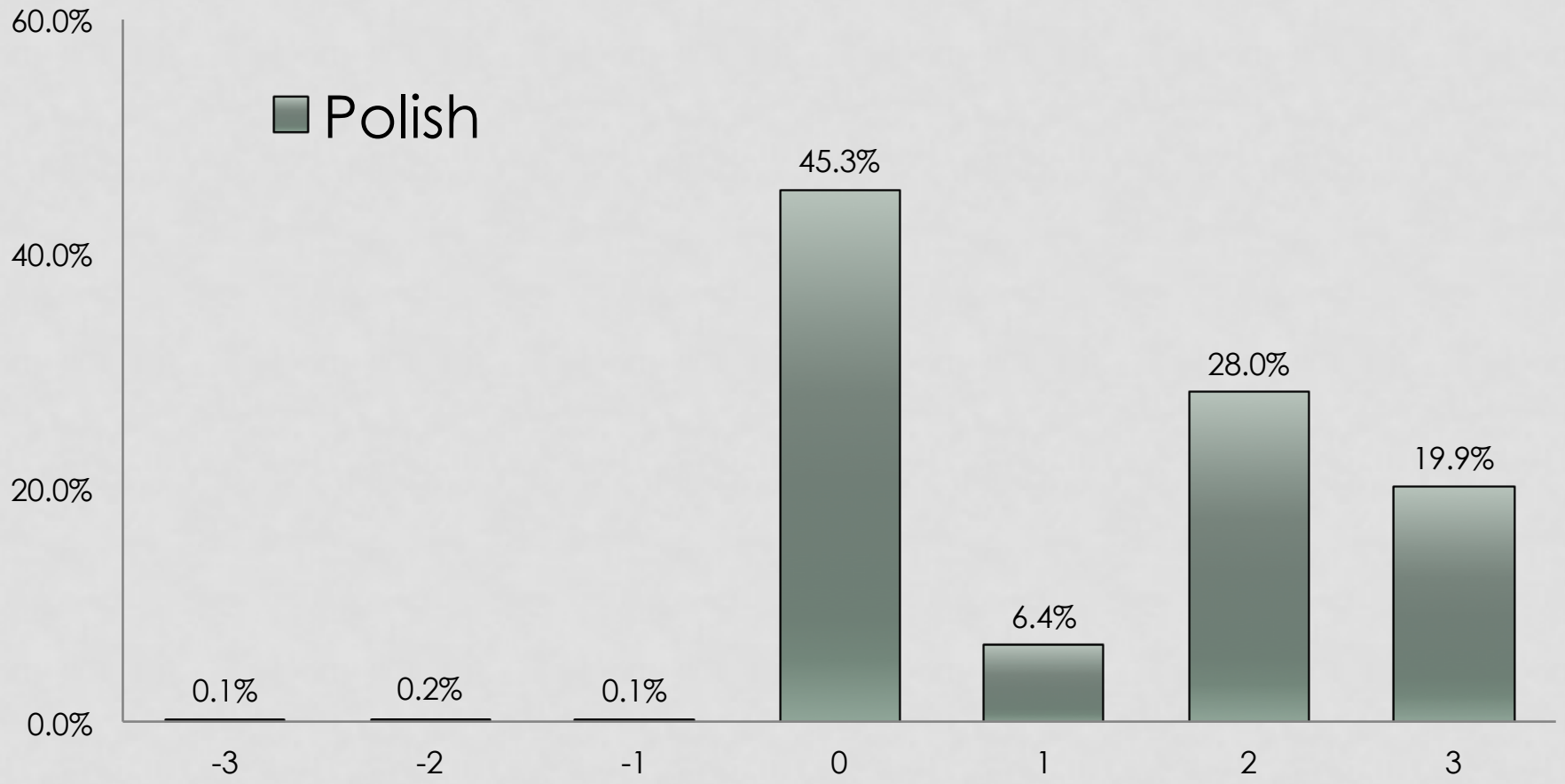
ENGLISH



THE OPPOSITE?

- At an abstract level, English mirrors SSP!
  - Not the strongest test case for lexicalist models
  - Need: language input that doesn't mirror SSP
- Polish?
  - [wb]ack < [lb]ack < [mb]ack < [bd]ack < [bn]ack < [bɹ]ack < [bj]ack
  - -3 -2 -1 0 1 2 3
  - [wza] [lvɨ] [mʂa] [ptak] [dnɔ] [klutʃ] [zwɨ]
- Polish Child Directed Speech Sample
  - From Polish CDS Frequency Dictionary (Haman 2011)
    - ~800k word tokens (~115k #CC)
    - ~44k word types (~11k #CC)

THE OPPOSITE: POLISH?

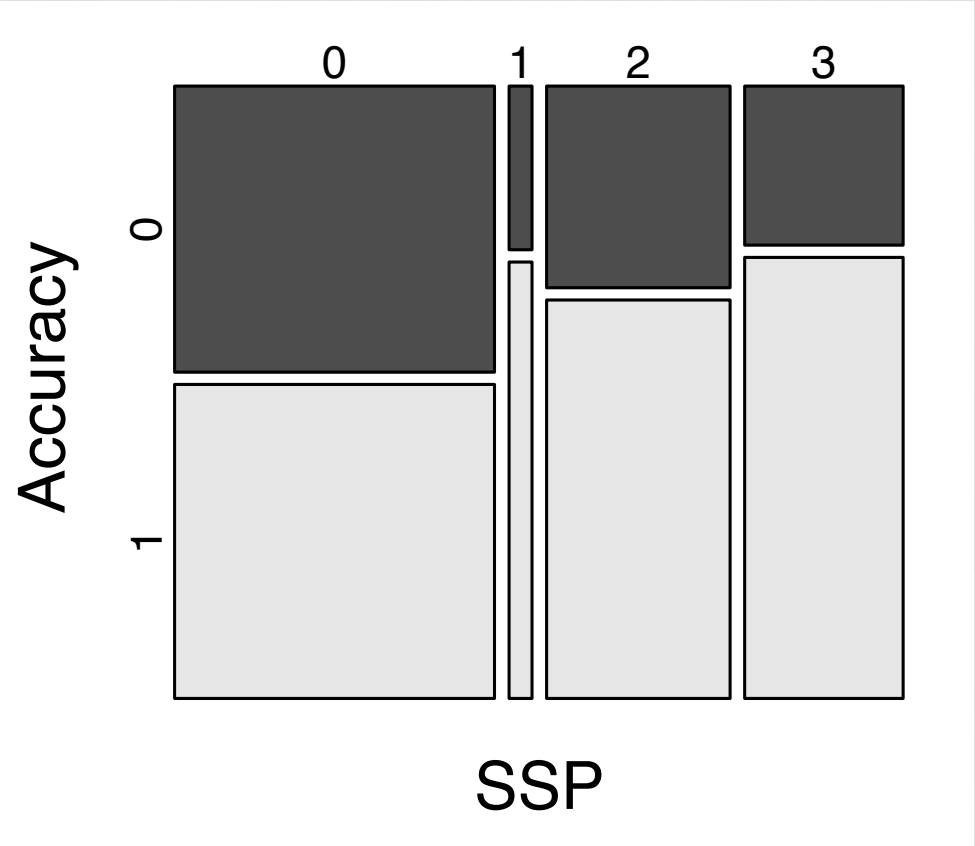


QUESTIONS AND PREDICTIONS

- What do Polish speakers know about SSP?
  - Previous Findings (Jarosz 2015 / submitted)
    - Development: Corpus study of spontaneous production
  - New Findings
    - Adult phonotactic well-formedness: judgment experiment
- Is the SSP principle derivable from the input?
  - Modeling

ACCURACY BY SSP

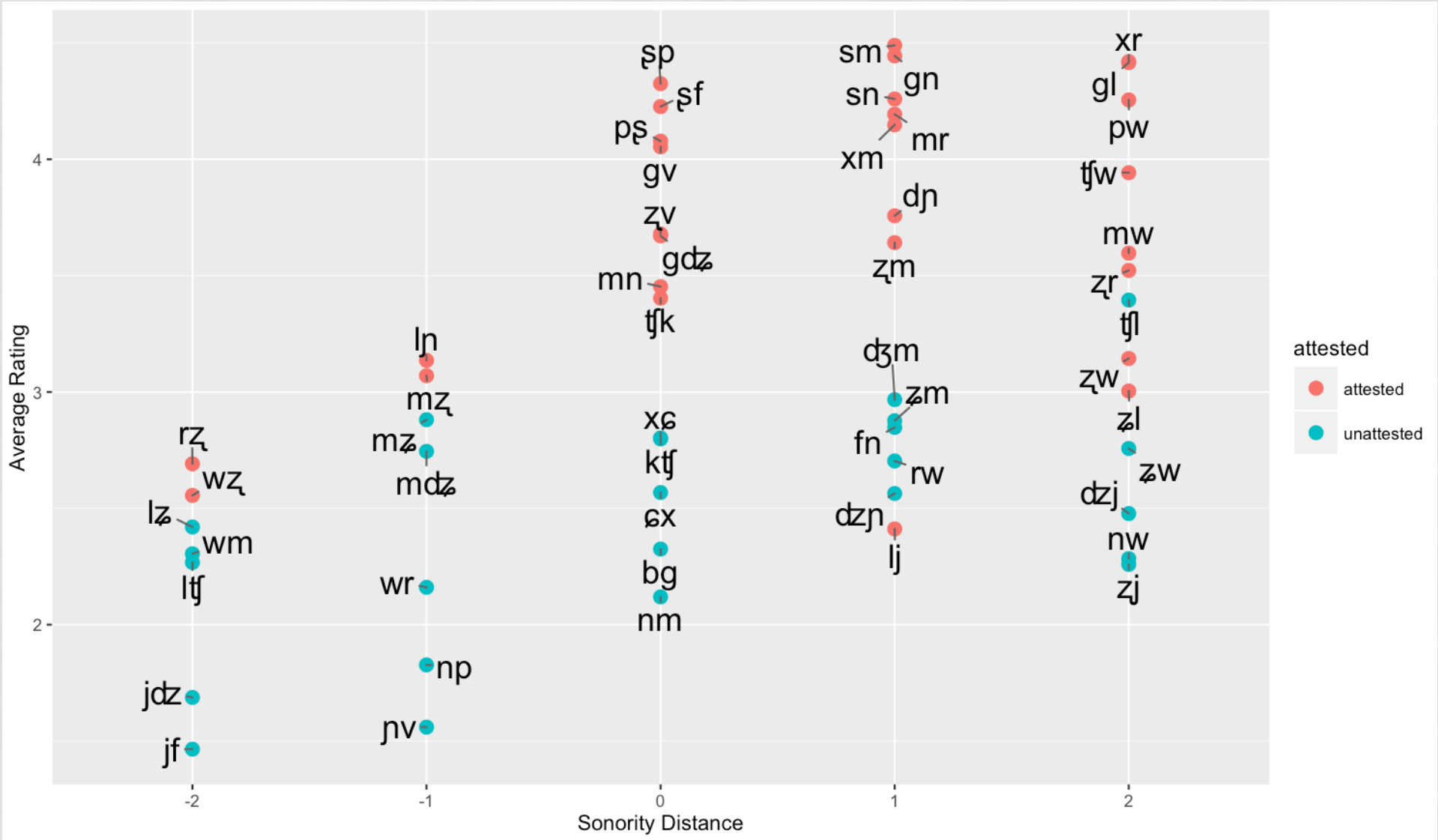
- Spontaneous Production
  - Weist-Jarosz Corpus (Weist et al., 1984; Jarosz 2010; Jarosz et al. 2015)
  - 4 Children (1:7-2;6)
- Raw data visualization
- Just Plateaus & Rises
  - Children didn't attempt falls
- Accuracy rises with SSP
  - **SSP** (***β*=0.28**, *Z*=7.16)
  - Even after controlling for
    - Age
    - Length of target word in syllables
    - Log Word Frequency
    - Primary Stress
    - Participant
    - Function word
    - Morphologically complex



JUDGMENT EXPERIMENT

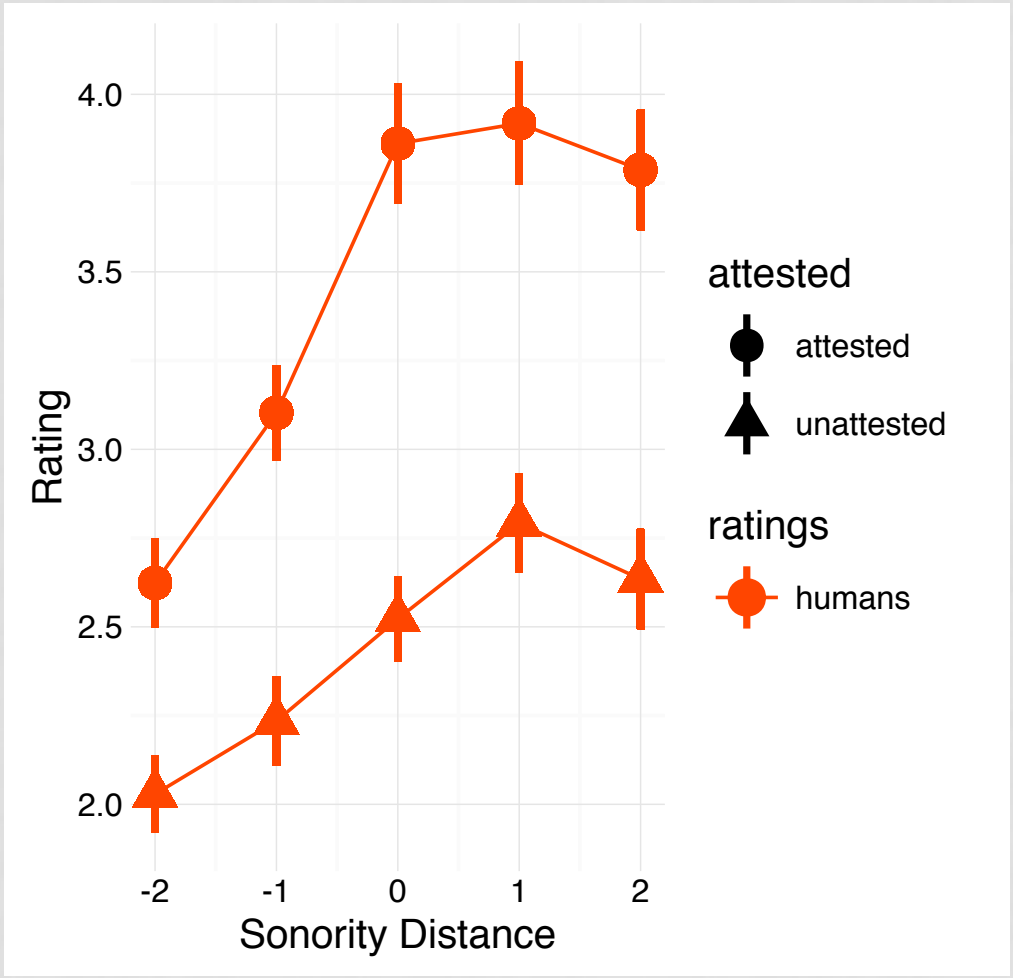
- What happens with adults? In judgments? Across the entire scale? Are attested and unattested clusters different?
  - Polish allows attestedness & SSP/grammaticality to be separated
- Stimuli
  - **28 attested heads** ranging in Sonority Rise -2/-3 thru +2/+3
  - **25 unattested heads** ranging in Sonority Rise -2/-3 thru +2/+3
  - **30 tails** ranging in morphological category
  - **10 counter-balanced presentation lists**
    - 159 test items (53 heads X 3 tails)
    - 240 fillers introducing variation in length and onset shape
- Procedure
  - Each nonce word presented orthographically
  - Pronounce the word to themselves
  - Rate on how 'natural it sounds' as a Polish word: **scale 1 to 7**
- Participants
  - **81 native Polish speakers**
  - Entirely in Polish, administered online through Polish contacts

RESULTS: AVERAGE RATINGS BY CLUSTER & ATTESTEDNESS



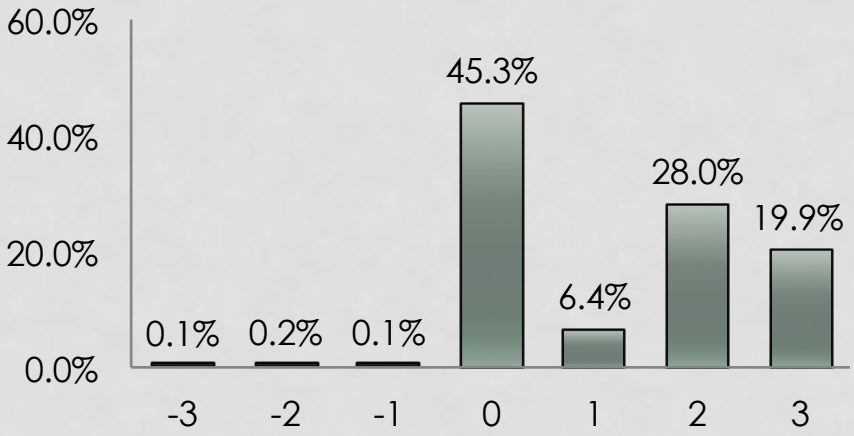
RESULTS

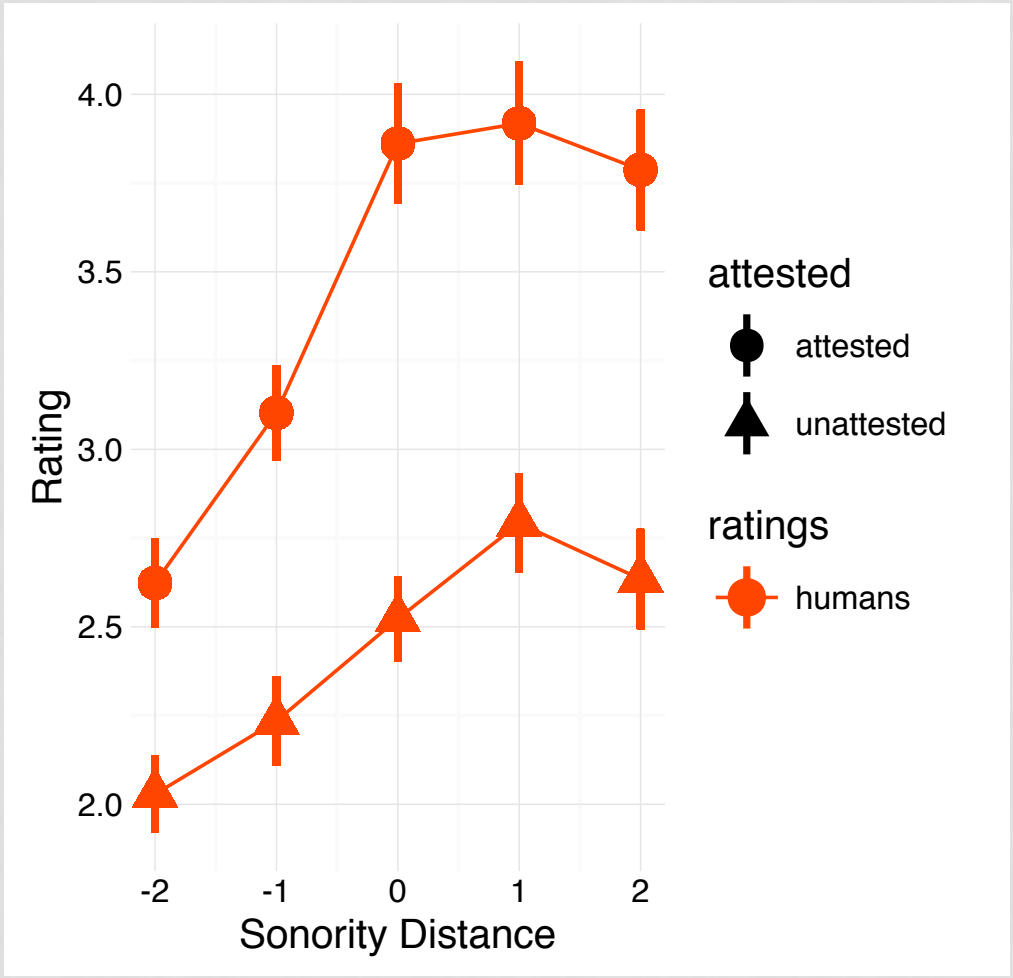
- Mixed effects model with full random effects structure
- Dependent
  - Rating
- Fixed effects
  - SSP * Attestedness
- Random slopes and intercepts, by
  - Subject
  - Tail
- Results
  - **SSP** (β=0.20, t=8.80)
  - **Attestedness** (β=0.57, t=16.18)
  - no significant interaction (β=0.02, t=1.42)



FURTHER DIRECTIONS

- Plateauing?
  - Kids rising preferences 0->3
  - Adults seem to plateau
    - No sig. SSP in 0-3 range
- Replication on 0,1,2s
  - This is really the most crucial part of the range
    - Disentangle nature & nurture
- Remember input skew:





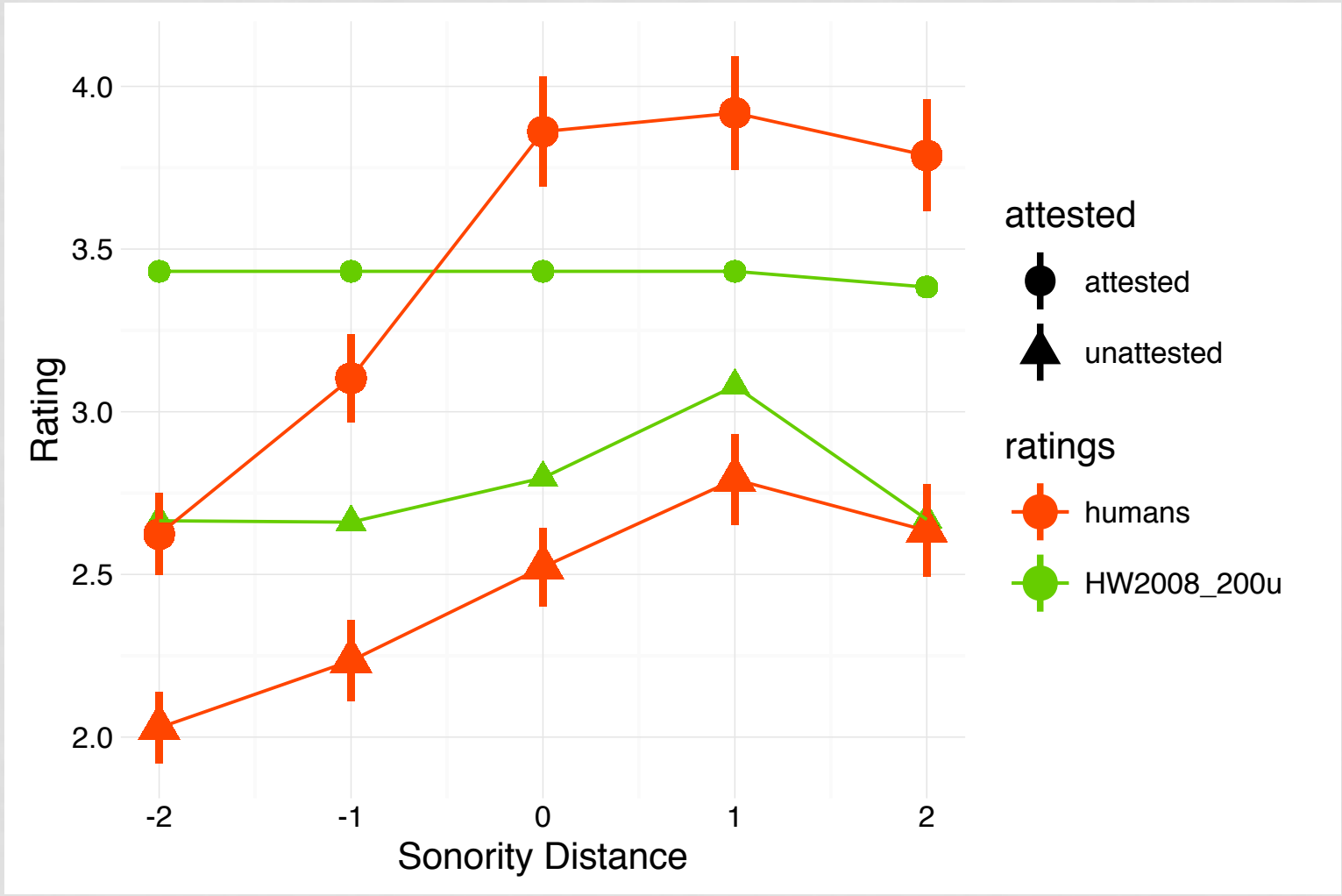
MODELING

- Models & Training
  - Trained on phonetically transcribed Polish lexicon (43,230 word types)
    - Derived from child directed speech to 1;6-3;2
  - Daland et al. (2011)
    - Word transcriptions
    - Syllabified word transcriptions
      - Maximal onset with observed word-initial clusters
      - Represented with +/- rhyme feature
    - Induce 100, 200,… constraints
  - Hayes (2011)
    - UG with 32 sonority-regulating constraints
      - *[+son][-son], *[-son][+son],…
    - No syllabification: constraints don't refer to syllable position

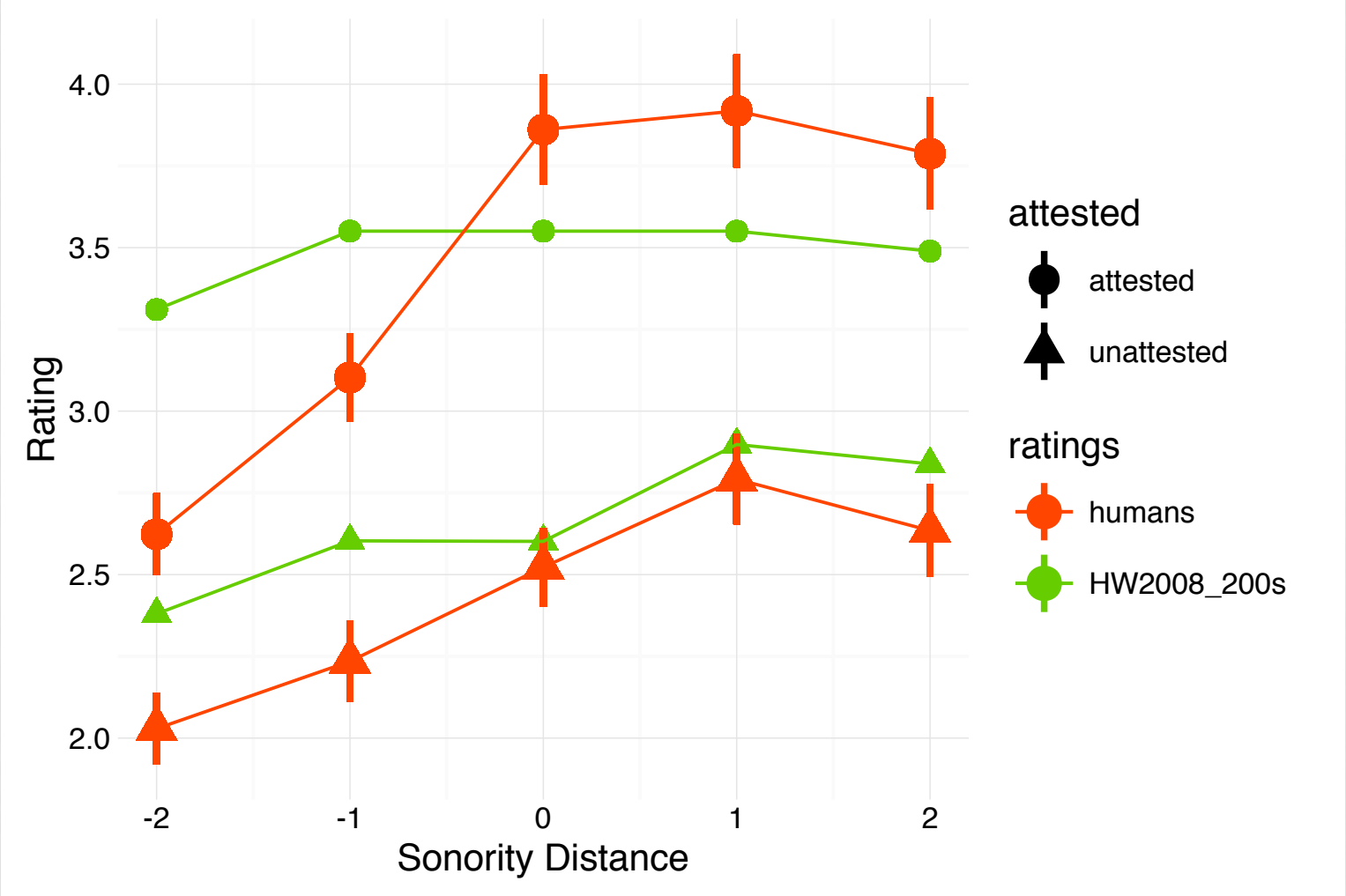
MODELING

- Evaluation & Criteria
  - Criteria
    - -2—0 range: **strong preference** (robust finding)
    - 0—2 range: **not as clear** (no effect)
    - Attestedness effect: **strong preference** (robust finding)
  - Qualitative
    - Linear regression: fit each model's predictions to ratings
    - Examine predictions by sonority rise X attestedness
  - Quantitative
    - Correlation ratings & scores (Overall, attesteds, unattesteds)

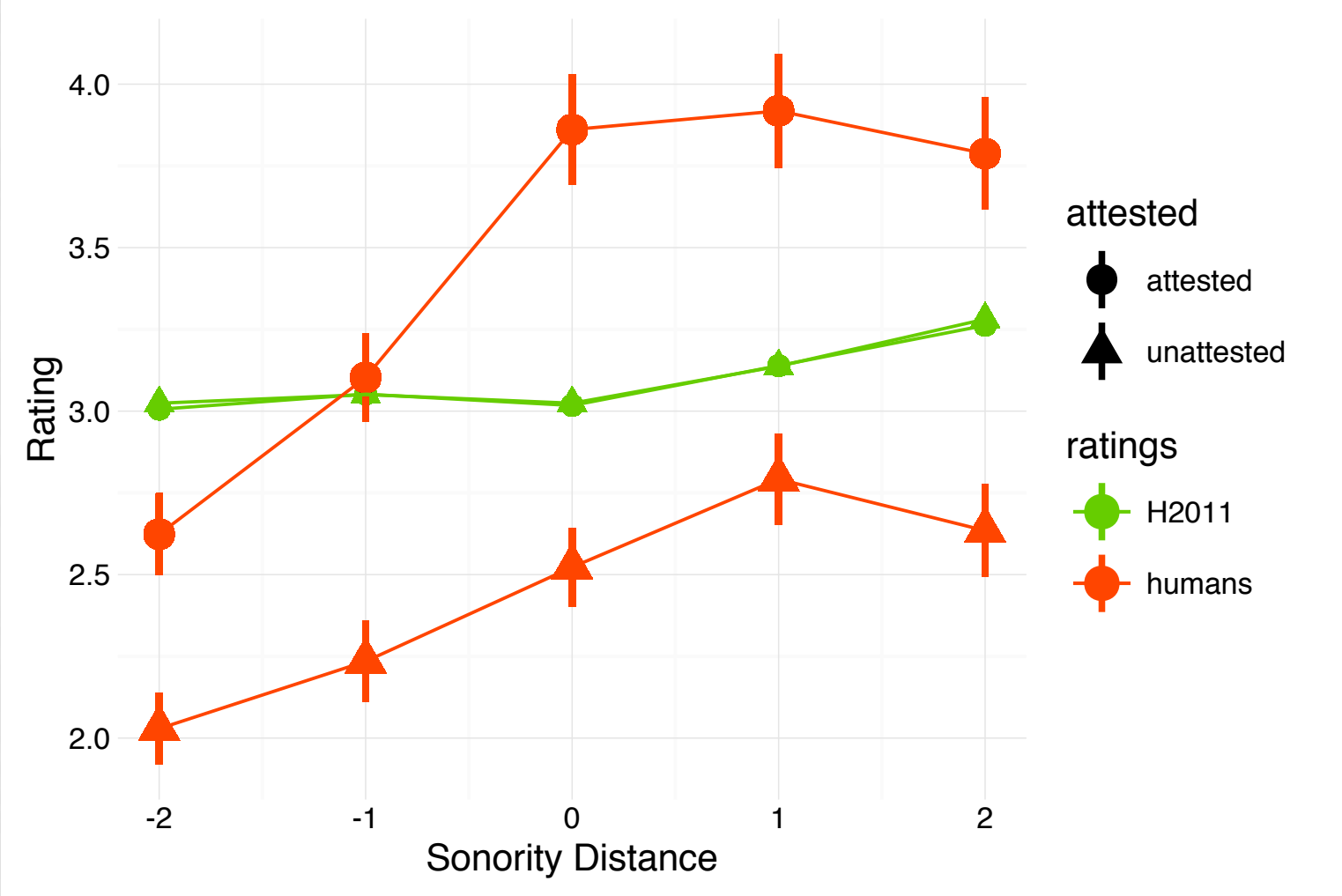
HW2008 200 UNSYLL V. HUMANS



HW2008 200 SYLL V. HUMANS



H2011 V. HUMANS



QUANTITATIVE EVALUATION

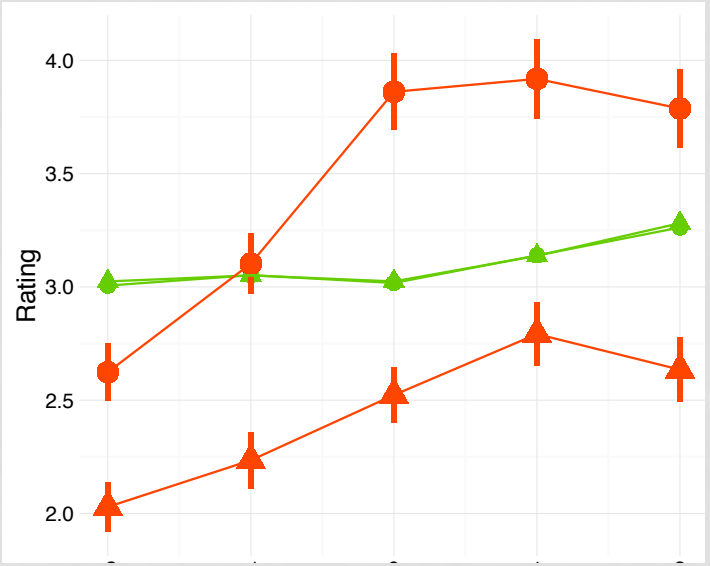
model	Overall r	Attested r	Unattested r
HW2008 100 unsyll	0.64	0.06	0.45
HW2008 200 unsyll	0.63	0.06	0.54
HW2008 100 syll	0.60	0.37	0.40
HW2008 200 syll	0.70	0.31	0.49
H2011	0.14	0.01	0.25

- These models do not capture SSP
  - HW2008 200 syllabified comes closest
    - Positive correlations with ratings don't mean SSP is captured
- Unconstrained generalization from phonetic transcriptions of Polish words does not give rise to SSP
  - Having access to syllable structure doesn't force the model to use it

UNCONSTRAINED GENERALIZATION

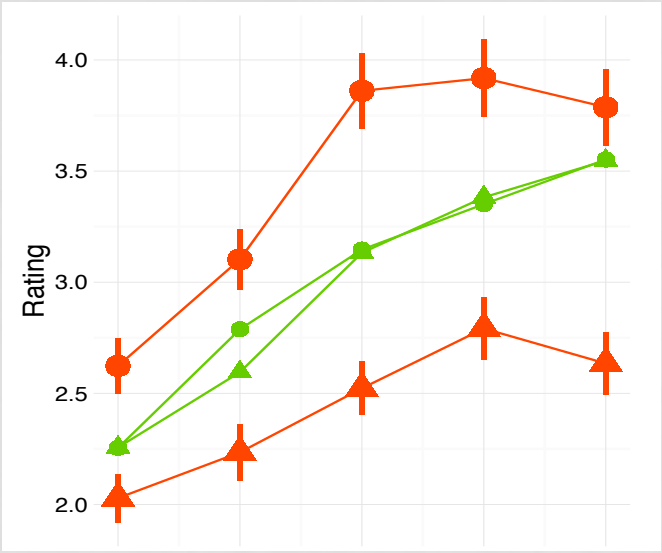
- Access to syllable structure doesn't force learner to use it
- Polish input doesn't support rises
  - Onset clusters favor plateaus
  - Input includes other transitions supporting falls
- Evidence about *[+son][-son]
  - In Rhymes: r**ok**
  - Across syllable boundaries: na**j.p**jerf
  - In codas: naj.pje**rf**

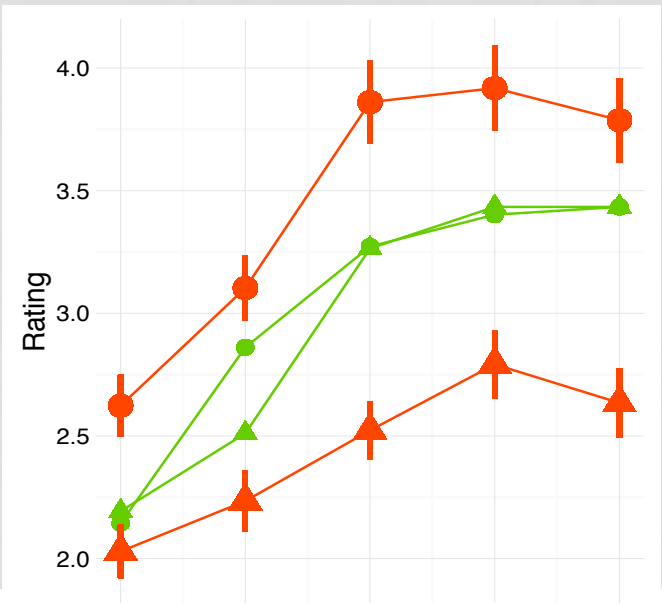
Hayes2011 Sonority Constraints



ONGOING: CONSTRAINED GENERALIZATION?

- Constrain first to onset position
  - *[+son,**-rhyme**][-son]
  - Rules out unwanted cases
  - Rules in
    - Complex onset: naj.**pj**erf
    - CV transitions: **na**j.p**je**rf
  - Note: effectively builds-in SSP
    - Nucleus defined by high sonority
- Constrain both to onset position
  - *[+son,**-rhyme**][-son,**-rhyme**]
  - Rules in only
    - Complex onset: naj.**pj**erf
    - CV transitions: **na**j.p**je**rf
  - Note: this will not work in CV-only language

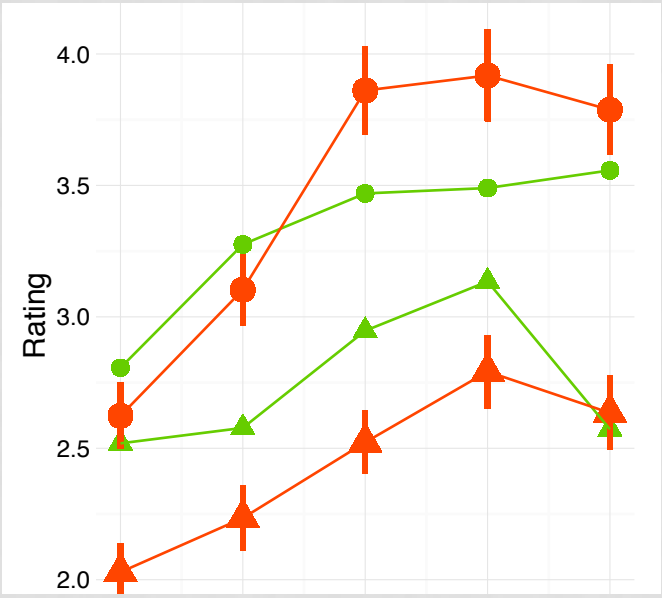




ONGOING: CONSTRAINED GENERALIZATION?

- 0-2 range is crucial!
  - Supports different conclusions
  - If trajectory is real, we need model
    - Starts with strong preference
    - Preference is distorted by experience
      - But distortion is limited
- What limits distortion?
  - Sonority sequencing is not the only aspect of phonotactics
  - These models don't capture attestedness
  - What prevents other constraints from reversing trends?
- Not trivial to build in right bias

Hayes2011 Sonority Constraints
Onset first constraint
200 additional induced



DISCUSSION

- Polish is an important test case for SSP
  - 0—3 rise range contradicts universal
- Behavioral Findings So Far
  - Development
    - Preference for higher rises 0—3 range
  - Adults
    - Preference for higher rises driven entirely by -2—0 range
- Interpretations & Further Steps
  - Need additional studies to confirm these effects
  - Some sort of bias is needed
    - Preferences do not arise with unconstrained generalization
  - Formalizing a soft and persistent bias is ongoing work

THE END

- Thank you!