Ontogeny recapitulates phylogeny:
Child speech development as a microcosm of sound change

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I. Introduction

(1) *Ontogeny recapitulates phylogeny*: There are striking parallels between child phonological processes and the typology of sound change in adult grammars. (Schleicher, 1861; de Saussure, 1915; see excellent summary in Foulkes & Vihman, 2013).

- Patterns such as stopping, cluster reduction, final devoicing, and final consonant deletion are well-attested in both child speech and sound change (Greenlee & Ohala 1980, Locke 1983, Vihman 1980).

(2) *Children as agents of sound change?* It has been proposed that children's imperfect learning of the adult grammar could provide the driving force for language change (e.g. Paul 1886; Sweet 1888; Grammont 1933; Andersen 1973, Kiparsky 1965).

- "the processes of learning language are of supreme importance for the explanation of changes… they represent the most important cause of these changes" (Paul 1886: 34)

(3) Arguments against this hypothesis:

- Lack of systematicity across children (Saussure 1915, Kiparsky 1988)
- Lack of evidence that adults adopt variants innovated by children (Aitchison 2003).
- Differences between child speech patterns and adult sound change (Vihman, 1980, Kiparsky 1988:390); see example of a child-specific pattern in Table 1.
- Transience of children's speech patterns: Innovated patterns do not persist in the speech of individual children.

Positional velar fronting (Inkelas & Rose, 2007). Preceded by accurate velar production. Persisted for around a year before being abruptly eliminated			
a.	Fronting of velars in prosodically strong positions		
	cup	[ˈtʰʌp]	1;09.23
	again	[əˈdɪn]	1;10.25
	conductor	[tʌnˈdʌktə]	2;01.21
	hexagon	[ˈhɛksəˌdɔn]	2;02.22
b.	Absence of velar fronting in prosodically weak positions		
	bagel	[ˈbejgu]	1;09.23
	back	[ˈbæk]	1;10.02
	octopus	[ˈɑktəpʊs]	2;04.09

Table 1: A child-specific transient pattern: Positional velar fronting

(4) Our goal: Explain how and why children show systematic, transient, non-adult-like speech patterns en route to the acquisition of a mature L1 phonology.

- Many child speech patterns have striking parallels with children's performance limitations.
  - e.g. Velar fronting is related to large size and anterior position of child's tongue.
- But children's errors are systematic and sensitive to phonological structures—inconsistent with a performance-only account à la Hale & Reiss (1998, 2008).

(5) We propose that child-specific speech patterns reflect phonologization of child-specific performance limitations (e.g. Inkelas & Rose, 2007; McAllister Byun, 2012).

- An actuation problem in child phonology: Phonetic pressures that give rise to (e.g.) velar fronting are shared across many children, but not all children exhibit a systematic pattern of velar fronting.

(2) In this talk, we present a model which covers:

- The actuation of child-specific phonological patterns
- The trajectory (usually, stability then elimination) of these patterns
- …with implications for sound change

II. The A-map model (McAllister Byun, Inkelas & Rose 2012; Inkelas, McAllister Byun & Rose 2012; McAllister Byun & Inkelas 2012)

(7) Proposal: The A(RTICULATORY)-MAP MODEL.

- Candidates have an associated motor-acoustic mapping whose properties play a role in the comparison of candidates by the production grammar.
- Selection is influenced by two competing pressures: **Accuracy** (matching adult acoustic target) and **precision** (mapping to predictable, replicable acoustic outcomes)
- ACCURATE and PRECISE are the corresponding grammatical constraints.

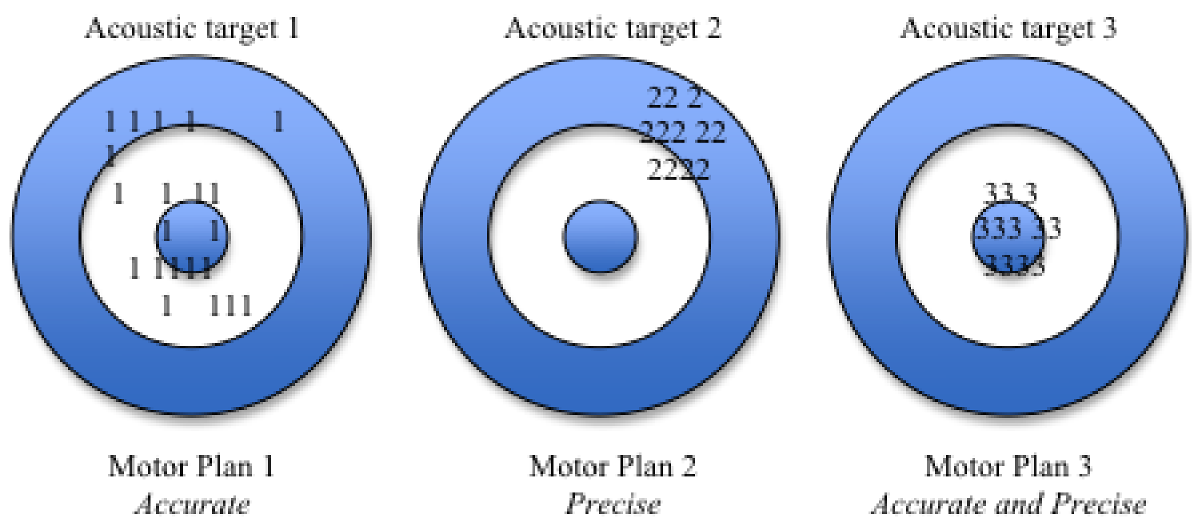


Figure 2: Schematization of accuracy versus precision

(8) Assessment of ACCURATE/PRECISE is determined with reference to the A-map, a dynamically updated distillation of information from the child's experience in producing and perceiving speech.

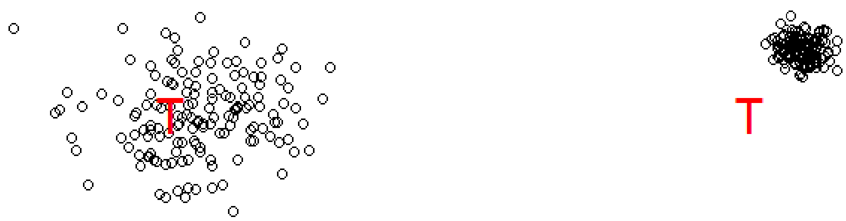
- We assume an exemplar space populated by episodic traces of motor plans executed and acoustic outcomes, with links between them.
- Exemplar space also encodes acoustic traces produced by other speakers.
- Traces decay over time.

(9) An A-map entry is a vector with three components: <MP_{mean}, A_{mean}, A_{SD}>.

- MP_{mean} = stored motor plan, as averaged over cloud of previous executions of closely related motor plans.
- A_{mean} = center, in multidimensional acoustic space, of the cloud of acoustic outcomes associated with past executions of motor plan *MP*.
- A_{SD} = standard deviation of the entire distribution of acoustic outcomes associated with past executions of *MP*.

(10) Relation of A-map to constraint violation

- Magnitude of ACCURATE violation is determined by the distance between *MP* and the center of *T*, the cloud of traces representing adult productions of the target.
- Magnitude of PRECISE violation is determined by A_{SD}. A broader, more scattered cloud (large A_{SD}) incurs a greater penalty than a compact cloud.
- In Figure 2, ACCURATE prefers (A) over (B), while PRECISE favors (B) over (A).



Candidate A
A_{mean} close to *T*
Large A_{SD}

Candidate B
A_{mean} further from *T*
Small A_{SD}

Figure 2. Accuracy versus precision in the A-map

(11) When motor targets are complex, frequent performance breakdowns create considerable scatter in actual acoustic outcomes around the intended target. Sources of error:

- Random noise (trial-to-trial variability) in execution of a selected motor plan
- Motor plan referral: One motor plan is targeted for production, but interference from a similar, highly activated plan results in execution of the non-target plan.
  - Compare slip-of-the-tongue errors in spreading activation models of adult speech.
  - Acoustic outcome has links to both intended plan and plan that was actually executed.

III. Case study: Consonant-vowel interactions in a child acquiring English

(12) Some children acquiring English show pattern in which major consonant place is conditioned by vowel context (Bates, Watson & Scobbie 2002, citing Fudge 1969)

- Alveolar place before a front vowel

drink	[ti]
again	[dɛn]

- Velar place before a back unrounded vowel

truck	[kʌk]
garden	[gʌŋ]
doggie	[gʌgɯ]

(13) Motor pressures underlying consonant-vowel interactions:

- In early stages of development, children produce gross speech gestures in which multiple structures (e.g. jaw and tongue, jaw and lips) move together as a single unit.
- Lingual control is especially difficult, so tongue may borrow its movements from the active jaw articulator (Green, Moore & Reilly 2002; MacNeilage & Davis 1990).
- "Frame-dominance" (MacNeilage & Davis 1990): Young child's optimal speech pattern features open-close jaw oscillations with no change in position of tongue relative to jaw.
    - Since tongue does not move independently, identity of consonant is highly constrained by vocalic context.

(14) Frame dominance in the A-map:

- Syllable with front vowel + coronal consonant or back vowel + velar consonant is more stable than a syllable in which consonant and vowel have conflicting place specifications.
- When non-homorganic syllable is attempted, frequent performance errors yield high A_{SD}.
- Subset of possible A-map vectors for target *again* (<MP_{mean}, A_{mean}, A_{SD}>):

  </gɛn/, [gɛn], 2>
  </dɛn/, [dɛn], 1>
  </gʌŋ/, [gʌŋ], 1>

(15) We implement the A-map model in the Harmonic Grammar framework (Legendre, Miyata & Smolensky, 1990); ACCURATE and PRECISE are weighted constraints whose violation magnitude is calculated with reference to the A-map.

(16) Comparison of candidates for target *again*

	Adult target: [gɛn]	PRECISE	ACCURATE	*H*
		w = 2	*w* = 1	
a.	</gɛn/, [gɛn], 2>	-2		-4
☞b.	</dɛn/, [dɛn], 1>	-1	-1	-3
c.	</gʌŋ/, [gʌŋ], 1>	-1	-2	-4

(17) Bias against heterorganic syllables originates in a phonetic performance limitation, but it is expressed in grammatical computations through influence of PRECISE.

IV. Analogies between sound change and child phonology in the A-map model

(18) Garrett & Johnson (2013) (also Blevins 2004): Three key elements of phonologization

a. Existence of *structured variation*
b. *Constraints on selection*, i.e. "linguistic factors influence the choice of variants"
c. *Innovation*, i.e. individual-level behaviors that initiate and transmit change

(19) Structured variation:

- Child speech is more variable than adult speech; children are more susceptible to the type of articulatory and perceptual pressures that yield variation in adult speech communities.
- Some aerodynamic and articulatory biases are shared across children and adults.
- Other phonetic biases are specific to child speakers (e.g. poor tongue-jaw dissociation).
- Output of a single child is a microcosm of the structured variation found in an adult speech community. Areas of dissociation derive from child-specific phonetic pressures.

(20) Constraints on selection

- Variation originates by random chance, shaped by shared and unshared phonetic biases.
- A-map keeps track of variation in the child's input and output.
- Systematic patterns emerge from interplay between PRECISE and ACCURATE (along with other constraints).

(21) Innovation:

- Children produce a range of forms due to errors in motor planning or execution, as well as vocal play/experimentation.
- All of these motor-acoustic mappings are tracked in the A-map.
- An innovative form will gain traction when PRECISE and ACCURATE repeatedly judge it to be optimal.
- Children whose grammar assigns a high weight to PRECISE will deviate from the adult target (i.e. innovate) more than children with high-weighted ACCURATE.
  - Previous accounts (e.g. Vihman & Greenlee, 1987) have characterized these individual differences as a reflection of personality traits such as tolerance for risk-taking; compare Yu (2010).

(22) Extreme innovation in child speech: English-acquiring child C (Bedore et al., 1994).

- C produced a dental click [ǀ] for target coronal sibilants /s, z, ʃ, ʒ, ʧ, ʤ/ (a-c), but produced other fricatives correctly (d-e):

a. Target /s, z/:	saw	[ǀɔ]	d. Target /θ, ð/:	teeth	[tiθ]
	this	[ðɪǀ]		that	[ðæt]
	preschool	[pwiǀu]		thing	[θɪŋ]
	sometimes	[ǀəmtaɪmǀ]			
b. Target /ʃ, ʒ/:	shark	[ǀark]	e. Target /f, v/:	feet	[fit]
	treasure	[twɛǀɚ]		before	[bəfoʊ]
	fish	[fɪǀ]		have	[hæv]
c. Target /tʃ, dʒ/:	match	[mæǀ]		even	[ivən]
	jelly	[ǀɛwi]			
	orange	[owənǀ]			

(23) Motor and acoustic factors underlying C's speech pattern:

- Dental click is neither featurally nor articulatorily a good match for sibilant targets.
- But acoustically, the high-frequency spectral energy of sibilants is similar to the noise produced at the release of [ǀ] (Bedore et al., 1994).
- Clicks tend to be early-emerging in languages that have them (e.g. Mowrer & Burger, 1991); may be motorically simpler than sibilants.

(24) A-map account:

- C's initial attempts to produce sibilant fricatives led to frequent performance errors, yielding a high A_{SD}/large-magnitude PRECISE violation.
- Through experimentation, C had at some point produced dental clicks. Due to relatively low motor demands, dental clicks had a low A_{SD} in C's A-map.
- Acoustic similarity between [ǀ] and sibilants produced a sufficiently low ACCURATE violation to allow [ǀ] to beat out competitors like [t].

(25) Why don't the same phonetic pressures give rise to click substitution in more children?

- We assume it is unusual for a child to have experimented with clicks recently enough for the A-map to register them as suitable MP candidates for sibilant output targets.
- A-map model: Individual children differ in their speech output histories, so the determination of the most stable form will necessarily vary across individuals.
- The role of chance and individual experience in determining a child's phonological patterns can be compared to the complex, non-deterministic relationship between phonetic precursors and phonologized patterns in sound change actuation.

V. A persisting influence of the A-map in sound change?

(26) Could the same mechanism used to capture child speech patterns also play a role in modeling sound change?

(27) Capturing maturation in the A-map model

- PRECISE and ACCURATE change in weight over time, but they remain part of the grammar as the child matures. No assumption of child-specific constraints.
- However, the effects of PRECISE are attenuated as the A-map changes over the course of normal neuromuscular maturation.
- *Example*: Motor control stabilizes earlier for jaw than for tongue. Once lingual control stabilizes, though, both jaw and tongue gestures are trivially easy to execute.
    - Targets previously associated with different-sized violations of PRECISE now converge on similar values.
- As A-map flattens, ACCURATE plays more decisive role, privileging adult-like forms.

(28) However, the A-map is never *completely* flat.

- Some pressures that produce systematic errors in children remain present at a low level in adults.
- May drive gradient phonetic tendencies or sporadic speech errors.
- If there are meaningful differences in the stability of motor-acoustic mappings within a pool of phonetic variants, PRECISE will favor more stable variants.

(29) Example: Consonant harmony

- Systematic patterns of CH can be found in children, where assimilation involves major place of articulation, and in adults, where only minor place is involved.
- Both types of harmony bear a striking resemblance to patterns of assimilation in adult speech errors (Hansson 2001, Garrett & Johnson 2013).
    - e.g. *popcorn* → [kɑpkɔrn], *sunshine* → [ʃʌnʃaɪn]
- Young children, still mastering the motor skill of producing a sequence of similar but non-identical consonants, produce these errors with particularly high frequency.
- This, via PRECISE, can produce a systematic pattern of consonant harmony (McAllister Byun & Inkelas, 2012).
- Children quickly overcome the motor difficulty associated with alternating between major places of articulation, and major place harmony is typically suppressed by 3;0.

(30) Lingering effects of PRECISE in adult consonant harmony?

- Some errors persist in the more challenging context of alternating between similar segments that differ only in minor place.
- Error rates vary across adult speakers.
- Perceptual mismatch created by minor place error is small (low ACCURATE violation).
- Possible that assimilated form could emerge as most harmonic in the grammar of an adult who experiences particular difficulty with consonant place sequencing.
    - Phonologization: Consonant harmony has taken on phonological status in the grammar of the individual in question.
- Transmission of the sound change depends on other factors such as social status of speaker who phonologizes the change (Baker, Archangeli, & Mielke, 2011).
- Probability that pattern will be adopted at the community level is low but non-zero.

VI. Conclusion

- The same processes of variation, competition, and selection operate in sound change and in many child-specific phonological patterns.
- The changes occurring in childhood are typically greater in magnitude than any changes exhibited over the adult lifespan.
- Child speech development can thus offer an improved lens through which to view the actuation of a sound change: the changes are more dramatic and unfold quickly enough that they can be observed in real time within individuals.
- Cross-fertilization between children's phonological development and adult sound change should be encouraged (Ferguson and Farwell 1975).

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