Contrast and covert contrast in the acquisition of /s/ and /ʃ/ in English and Japanese

Fangfang Li (cathy@ling.ohio-state.edu) and **Jan Edwards** (jedwards2@wisc.edu)
Department of Linguistics, the Ohio State University; Department of Communicative Disorders, the University of Wisconsin-Madison

INTRODUCTION

[Acquisition of voiceless sibilant fricatives]

- Late acquisition across languages (Jacobson 1968, Templin 1957, and Stoel-Gammon & Dunn 1985)
- Opposite error patterns in English and Japanese
  English: /ʃ/ → [s] (Prather et al, 1975; Ingram 1981)
  Japanese: /s/ → [ʃ] (Nakanishi et al., 1972)

[Covert Contrast]

- Covert contrast: perceptually indistinguishable, but statistically significant acoustic difference (e.g., Macken & Barton 1979; Scobbie et al.,1996, among others)
- *Baum & McNutt (1990)*: covert contrast in both amplitudinal and spectral manifestations between frontal /s/ and target /θ/ in the productions of misarticulating children.
- *Tsurutani (2004)*: covert contrast was found between target /ʃ/ and error [ʃ] in 5 Japanese-acquiring children.

[Objectives]

- To verify the error patterns in both languages using both native speaker transcription and acoustic analysis.
- To look for possible covert contrast in both languages, and describe patterns of covert contrast.
- To distinguish between language-specific and language-universal aspects in the course of first language acquisition for both languages.
- To offer possible accounts for the opposite error patterns of the two languages.

METHODS

[Participants and Task]

- 50 participants in all, including 5 adults for each language and 10 two-year olds and 10 three-year olds per language
- Word-repetition task
  - For children: both pictures and audio prompts were provided
  - For adults: audio prompts only

[Materials]

- Words beginning with target consonant- vowel sequences
- Consonant: /s/ and /ʃ/
- Vowel:
  -- /a/, /i/, /o/, /e/ and /u/
  -- 3 word types for each target CV

/s/	Sample words	/ʃ/	Sample words
sa	soccer	ʃa	shot
se	same	ʃe	shell
si	seat	ʃi	sheep
so	soap	ʃo	shoulder
su	soup	ʃu	shoe

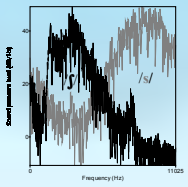
ANALYSES

[Native Speaker transcription]

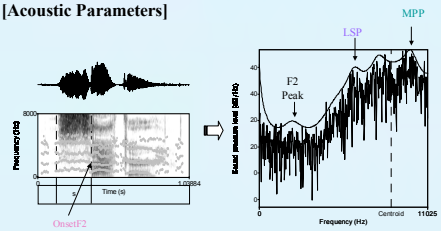
- Native speaker transcription done by one native speaker
- Second native speaker independently transcribed 10% of the utterances, with 90% inter-transcriber reliability

[Parameterization]

- Articulation:
  /s/ -> shorter front cavity
  /ʃ/ -> longer front cavity
- Acoustics: energy distribution
  /s/ -> more energy in high-frequency
  /ʃ/ -> more energy in low-frequency



[Acoustic Parameters]



Type	Acoustic Parameter	Definition	Articulatory Interpretation
Fricative spectrum	Most Prominent Peak (MPP)	The frequency of the highest amplitude peak	Negative correlation with the length of front cavity
	Lowest Spectral Peak (LSP)	The frequency of the left edge of the energy prominence	
	Centroid (Cent)	1st spectral moment (the weighted mean frequency)	
	Skewness (Skew)	3rd spectral moment (frequency band above centroid minus frequency band below)	
Amplitude	Amplitude Ratio (ampRatio)	The log ratio of the F2 peak amplitude to that of the high-frequency maximum	A measure of constriction degree
CV transition	Onset F2 Frequency (onsetF2)	The F2 frequency at the onset of the following vowel	Negative correlation with the length of back cavity

[Statistical test of the difference]

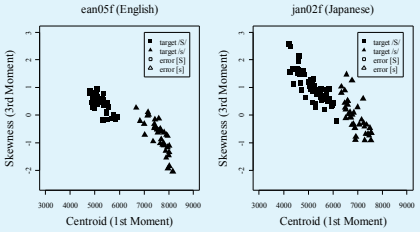
Used regression analyses to test whether these acoustic parameters are significantly different for the two fricative categories for each adult group and for each individual child.

RESULTS

[Adults]

	English		Japanese	
	p-value	*r-square*	*p-value*	*r-square*
Cent	0.001	90.05%	0.001	78.97%
MPP	0.001	89.59%	0.001	78.74%
LSP	0.001	82.18%	0.001	61.58%
Skew	0.001	55.23%	0.001	57.22%
AmpRatio	0.001	59.31%	0.001	51.50%
OnsetF2	0.001	72.76%	0.001	43.55%

The /s/:/ʃ/ contrast account for more of the variability in all acoustic parameters for the English speakers, perhaps because …



- /s- ʃ/ in English
  - contrast in tongue *position*
  - /ʃ/ is rounded
- /s- ʃ/ in Japanese
  - contrast in tongue *posture*
  - are in complementary distribution before the two front vowels

[Children]

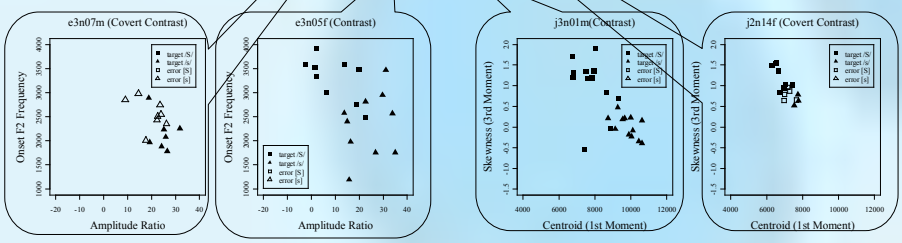
	English children	Cent	MPP	Skew	LSP	Amp Ratio	Onset F2
Contrast	e2n10m	82.82%	82.77%	61.79%	67.67%	48.26%	65.78%
	e2n11f	91.73%	91.50%	85.39%	61.39%	9.04%	18.95%
	e3n00f	77.14%	76.92%	59.28%	68.40%	41.60%	70.71%
	e3n01m	69.27%	69.07%	26.34%	60.24%	74.28%	51.09%
	e3n03f	87.54%	88.00%	58.59%	56.90%	27.75%	65.51%
	e3n05f	84.89%	84.78%	60.64%	55.02%	54.93%	60.17%
	e3n09m	52.95%	52.62%	39.41%	21.55%	32.16%	66.31%
	e3n11f	82.82%	75.48%	26.40%	61.06%	37.72%	37.98%
	e3n14f	91.73%	59.96%	29.72%	44.96%	63.78%	58.72%
Covert Contrast	e2n00f	41.52%	41.79%	43.33%	16.74%	28.21%	54.25%
	e2n01m	40.61%	40.73%	59.58%	87.81%	48.52%	69.62%
	e2n02f	26.02%	26.77%	38.60%	24.27%	11.39%	5.41%
	e2n03m	24.07%	23.84%	19.80%	31.02%	17.09%	16.04%
	e3n07m	45.82%	44.56%	30.95%	63.26%	27.75%	37.83%

	Japanese Children	Cent	MPP	Skew	LSP	Amp Ratio	Onset F2
Contrast	j3n01m	58.01%	73.82%	55.04%	38.21%	52.59%	66.60%
	j3n09m	83.55%	83.38%	56.87%	77.32%	43.87%	23.34%
	j3n12f	49.93%	49.62%	53.59%	38.67%	48.57%	29.35%
Covert Contrast	j3n05m	24.94%	25.77%	31.57%	22.17%	7.06%	67.95%
	j3n06f	32.57%	39.19%	35.34%	9.77%	45.27%	52.87%
	j2n14f	82.95%	77.64%	68.32%	20.86%	58.86%	76.47%
	j3n11f	31.98%	30.94%	6.81%	63.33%	12.96%	81.77%
	j3n13f	23.75%	25.29%	54.75%	57.17%	23.48%	64.08%

(in red: $p < 0.05$)

[Phonetic Development of 2-3 year olds of English and Japanese]

	Mapping from the categorical representation to the parametric space…	English n = 20	Japanese n = 20	Realization in… Transcription	Realization in… Acoustic Analyses
	Realizes contrast with irrelevant parameters	3	2	Consistently substitutes different sounds for both of the two target fricatives	
Covert Contrast	Realizes contrast with relevant but non-primary parameters	5	3	Substitution using one fricative for the other	Reliable difference, but in a non-primary parameter
Covert Contrast	Realizes contrast with primary parameter but not in a robust way	0	3	Substitution using one fricative for the other	Small but reliable difference in the primary parameters, but the difference is too small in magnitude to be perceptible
Contrast	Realizes contrast with primary parameters robustly	7	3	contrast	Large and reliable difference in the primary parameters



CONCLUSION & DISCUSSION

- For adults' productions, all six parameters clearly differentiate the two fricatives for both languages, but the English contrast is more robust than the Japanese one.
- For children's productions, the opposite error pattern ([s] for /ʃ/ in English and [ʃ] for /s/ in Japanese) was confirmed by transcription analysis for both languages.
- The covert contrast patterns in native speaker transcriptions suggest that Cent and MPP are the primary acoustic parameters for discriminating the contrastive fricative pairs.
- Four levels of phonetic development were identified, as evidenced by results of both the transcription and acoustic analyses, with covert contrast being either the manifestation of incorrect mapping to non-primary parameters or less robust mapping to the primary parameters.
- Japanese-acquiring children develop the /s-ʃ/ contrast relatively later than English-acquiring children. This may be due, at least in part, to the greater overlap of the two lingual sibilant fricatives in Japanese.

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