Gender differences in English and Japanese "s" versus "sh"

A Senior Honors Thesis

Presented in Partial Fulfillment of the Requirements for
Graduation with Distinction in the
Department of Linguistics at
The Ohio State University

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The Ohio State University
June 2010

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0. Abstract

Men are, on average, larger than women, with longer vocal tracts and larger vocal cords. These physical differences give men lower pitched voices with deeper vowel sounds – think of men as bassoons and women as clarinets. However, there are many more differences between women's and men's speech, and not all of them can be explained by physiological differences such as these. It was revealed that some Mandarin Chinese-speaking women produce one of the "sh"-like fricatives significantly differently than men, positioning the tongue further toward the front of their mouths than expected. This altered tongue posture creates a smaller resonating cavity in front of the tongue, raising the frequency[1] of the sound and thereby making the women sound smaller, "cuter", and overall non-male-like. Evidence that this is a social, and not merely physiological, effect is that we find something similar in Mandarin-speaking children as young as ages three or four. This means that the difference in pronunciation is acquired well before puberty and cannot be attributed to sexual dimorphism.

The current study is an in-depth examination of fricatives as produced by child and adult speakers of Central Ohio English and of Tokyo Japanese. Its purpose is to explore whether there is a gender effect comparable to Mandarin's feminine accent present in the fricatives of these languages, and also at what age the effect is acquired. So far we know that there is indeed a gender effect that makes the frequencies of English-speaking women's productions of "s" very high. The increase in frequency makes the frequency gap between "s" and "sh" larger than the gap between the same two fricatives produced by men. Five-year-old girls seem to have already adopted this gendered speech

1 Note that for the purposes of this study, *frequency* refers not to how often a sound is produced by a speaker but to an acoustic measurement of oscillations per second.

behavior as well. If gender effects are indeed based solely on vocal tract size, mean frequencies should be higher overall in Japanese, whose speakers are smaller on average than English speakers, according to a theory by Heffernan in a 2004 paper.

1. Introduction

Although vowels hold much of the information that distinguishes English dialects, fricatives are full of distinguishing information as well. Fricatives are very sensitive to articulatory changes, the smallest of which can make a huge acoustic difference. They are quite well studied cross-linguistically, having been covered in Catalan (Recasens & Espinosa 2007), Glaswegian English (Stuart-Smith 2003), American English (Jongman et al 2000, Nissen & Fox 2005, Behrens & Blumstein 1998, Tomiak 1990), and several other languages. Most prior research has focused on describing fricatives in terms of their ability to differentiate words, but a few studies show that talkers can also use fricatives to identify themselves as members of social categories like dialects or genders. For example, Li (2005) examined three Mandarin Chinese fricatives, [ɕ], [s], and [ʂ], and found that Mandarin-speaking women produce the alveolopalatal [ɕ] with a constriction unusually close to the back of the teeth, creating a smaller front cavity than expected. Pulmonary air passing through this small front cavity creates a higher frequency sound, which is thought to be a sociophonetic marker of femininity. This gendered alternation has been transcribed as [s^j] and named "feminine accent". It has been found that some female children aged five and younger have developed a feminine accent as well (Li 2008). The fact that prepubescent girls are producing certain fricatives differently than boys suggests that the behavior is sociologically-conditioned, as the differences cannot be attributed to differences in vocal tract size due to changes that occur during puberty.

In the United States and Japan, men are, on average, five inches taller than women, based on U.S. data from between 1999 and 2002 (Ogden 2004) and Japanese data from 2006 (MEXT 2006), and during puberty, they go through several changes that affect the physiology of their speech, including thickening of the lips, which lengthens the oral cavity, as well as lowering of the larynx, which causes lengthening of the pharynx. The lengthening of the oral cavity combined with the lengthening of the pharynx gives most men much larger vocal tracts than most women, which can affect the quality of certain speech sounds because of the inverse relationship between vocal tract size and formant frequencies (Vorperian et al 2009). On average, men also have thicker vocal folds than women, which is a difference that can lower pitch. However, there are various other ways, unrelated to physiology, that women's speech can differ from men's.

This paper examines the sibilant fricatives /s/ and /ʃ/[2] of English- and Japanese-speaking adults and children to see whether gendered language behaviors, like the feminine accent present in the speech of some Mandarin Chinese-speaking women and girls, are present in either or both of these languages. An important reference study in determining whether the fricative gender effects are biological or social is Fuchs and Toda's 2010 study of male and female productions of /s/ in English and German. Their study used electropalatography combined with acoustic recordings to determine how speakers "act" based on palate size. They found that male and female English talkers do not have significantly different average palate sizes, but women still "actively produce a

2 The sounds /s/ and /ʃ/ are represented in this study's title by "s" and "sh", respectively.

more front place of articulation and a shorter front cavity than males (19)." They concluded that when physical size is ruled out, there are still differences between males' and females' articulations and acoustic realizations of /s/ (20). The fact that Fuchs and Toda compared English with German supports my decision to compare English with Japanese, because a cross-linguistic approach can help determine whether alternations in fricatives are biological and thus shared by all speakers, regardless of language.

It was previously found that in many English-speaking cultures, women have high frequency productions of /s/. Results of the current study could offer support for one of two explanations: a biological explanation or a sociological explanation. Finding that there is a frequency-raising trend on /s/ in Japanese parallel to the one in English, or finding that Japanese-speakers have higher overall peak frequencies than English speakers would support the biological explanation. Finding that Japanese-speaking women have high frequency productions of the alveolopalatal fricative /ʃ/ rather than the alveolar /s/ and/or finding that English-speaking young girls also show the frequency raising effect for /s/, the social explanation would be supported.

It might be the case that the results from the aforementioned experiments on Mandarin Chinese fricatives already provide some support for the social explanation in some ways, as the feminine accent in Chinese affects the alveolopalatal /ɕ/, while in English, the gendered productions occur on alveolar /s/. However, the reason to compare English with Japanese is that both languages have two sibilant fricatives, one anterior, and one more posterior.

2. Methods

2.1. Materials and Speakers: English

The English-speaking participants in this experiment were all from the Central Ohio area and were recorded in Columbus, Ohio. The raw data were recordings of words elicited in a picture-prompted word repetition task. Participants saw a picture and heard a recording of the target word, which they were asked to repeat. 334 words beginning with various consonants were organized into 6 pairs of word lists. Each word list pair contained the same set of words "shuffled" into a different order. Each participant repeated the words from one of these pairs. For the purposes of the current study, only the words beginning with fricatives /s/ and /ʃ/ were analyzed. Table 1 shows some such words. Audio recordings of 20 adult male and female speakers, 25 two-year-olds, 25 three-year-olds, 25 four-year-olds, and 25 five-year-olds were made and later analyzed using Praat signal analysis software. Some speakers' audio files could not be aligned due to excessive background noise or recording errors. Other exclusions were due to speech impediments or bilingualism. Ultimately included in the study were 19 of 20 adults[3], 18 of 25 two-year-olds, 20 of 25 three-year-olds, 21 of 25 four-year-olds, and 18 of 25 five-year-olds.

Table 1. English example words containing target fricatives

English word	Place of articulation	Code name
shape	ʃ	shep
sheep	ʃ	ship
shell	ʃ	shel
sodas	s	sdaz
soup	s	soup
sugar	ʃ	shgr
suitcase	s	stks

3 The average age for English-speaking adults was 25 years.

2.2. Materials and Speakers: Japanese

The Japanese-speaking participants were recorded in Tokyo, Japan. The same data collection methods from the English speakers were used for the Japanese speakers, and only words beginning /s/ and /ʃ/, the same fricatives as in English, were analyzed. Table 2 shows examples of some /s/-initial and /ʃ/-initial Japanese words that were used. 20 (all) adults[4], 20 of 25 five-year-olds, 24 of 25 four-year-olds, 24 of 25 three-year-olds, and 20 of 25 two-year-olds were included.

Table 2: Japanese example words containing target fricatives

Japanese word (Romaji)	English translation	Place of articulation	Code name
syawaa	shower	ʃ	shaw
syamozi	rice paddle	ʃ	shmo
sokkusu	socks	s	sokk
suika	watermelon	s	suik
siisoo	seesaw	ʃ	shii
semi	cicada	s	semi
sooseeji	sausage	s	soos

2.3. Tagging procedure

A Praat script was used to mark the locations of various important data points in the /s/- or /ʃ/-initial target words. The target words had already been marked in one tier in each Praat TextGrid file, which accompanied and corresponded to an audio file. The script automatically zoomed to one target word at a time and paused to let the user mark the beginning (Onset) and end (End) of the frication interval, as well as the end of the following vowel (vEnd). A modified script was used to mark the children's files. The modified script included a button that allowed the user to skip a token in which the child

4 The average age for Japanese-speaking adults was 22 years.

produced the wrong word, produced a word beginning with something other than a fricative or affricate, or neglected to provide a response at all.

After the first pass with the script that marked the fricatives, another script was used to mark the onset of the second formant (F2), which represents the onset of the vowel directly following the target fricative. The script zoomed to a 40 millisecond window centered at the previously marked "End" tag and asked the user to place the cursor at the onset of the second formant. It then zoomed to a 40 millisecond window centered around the user's mouse click and asked the user to doublecheck their marking. For men, the maximum Hz value was set to 5000 Hz, for women 5500 Hz, and for children, 6000 Hz. The window length was set to 0.008 seconds so that the time step between the formant markers in Praat would default to 25% of this value, or 0.002 seconds. The maximum number of formants in all cases was set to five (5).

2.4. Measures

The measure used to examine the differences between fricatives in this study is the highest spectral peak, which has been found to be reliable in distinguishing fricatives from one another (Jongman, Wayland, & Wong; Fuchs & Toda), as well as affricates (Mays). Other studies have typically used centroid as the highest spectral peak measurement but here I have chosen to use a measurement called peak ERB, calculated from an ERB-sones spectrum, instead. The ERB-sones spectrum uses rectangular band-pass filters and is modeled after a human auditory system (Zwicker 1961), as opposed to a Hz-dB spectrum, which only represents the physical parameters of a speech sound. To extract the peak ERB measurements from the spectrograms, an 8 millisecond Hamming window was extracted at 90 milliseconds before the onset of the vowel following the fricative. The Hamming window was run through a MATLAB script, which calculated an ERB-sones spectrum from which the loudest peak (peak ERB) could be pinpointed (Holliday, Beckman, & Mays 2010).

2.5. Analyses

Effects of fricative, gender, and fricative differences between genders for each of the age groups for each of the languages were evaluated in an ANOVA with fricative as a within-subjects factor and gender as a between-subjects factor. That is, there were 10 ANOVA analyses in total, which tested each of 10 different subsets of the data, defined by the five age groups and two languages. Significance level (α) was 0.05.

3. Results

3.1. English

Figures 1-5: Peak ERB average by speaker for English-speaking adults, 5-year-olds, 4-year-olds, 3-year-olds, and 2-year-olds. "S" represents /ʃ/, "s" represents /s/. Black horiz. line = /s/, gray horiz. line = /ʃ/, averaged by gender.

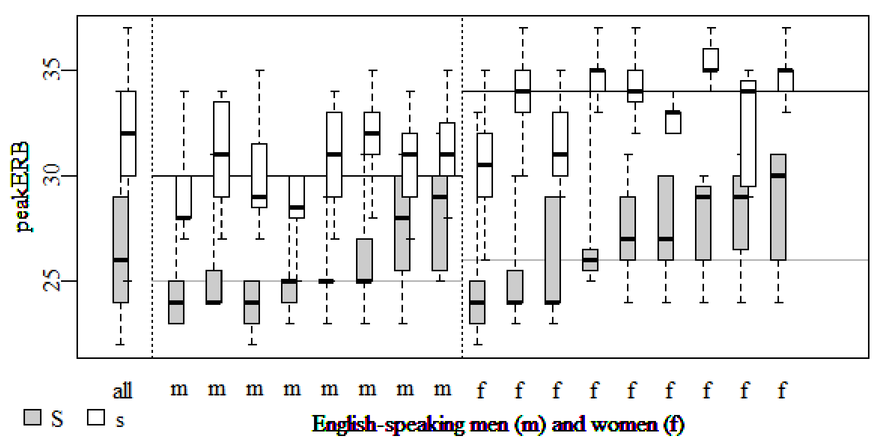


Figure 1

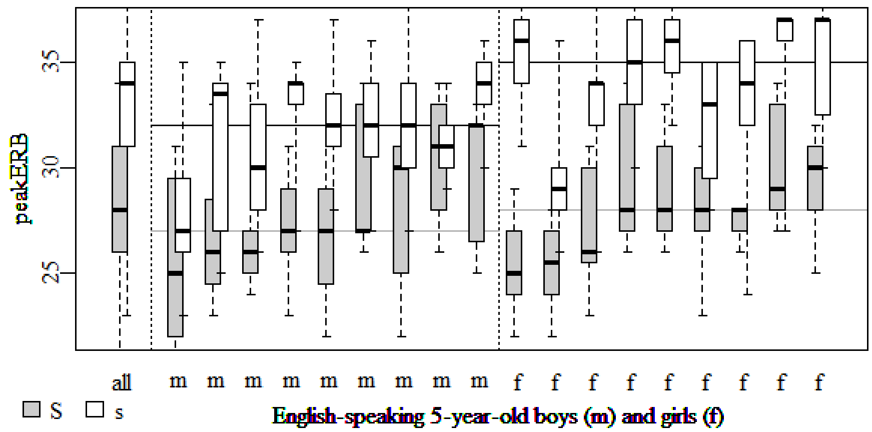
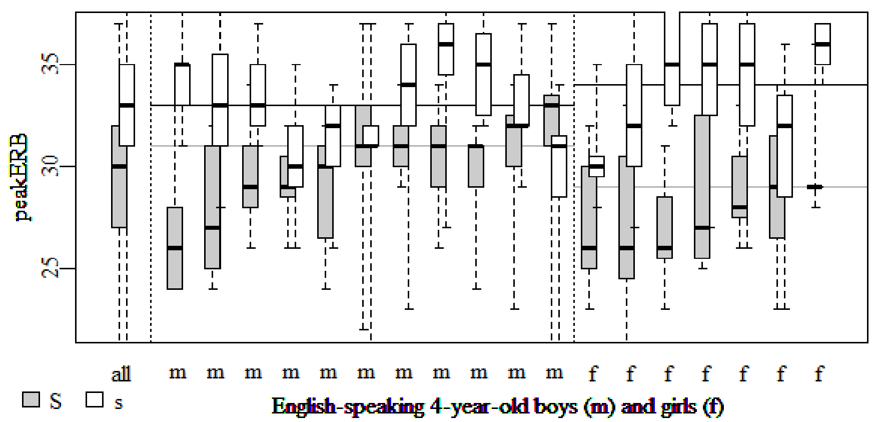


Figure 2



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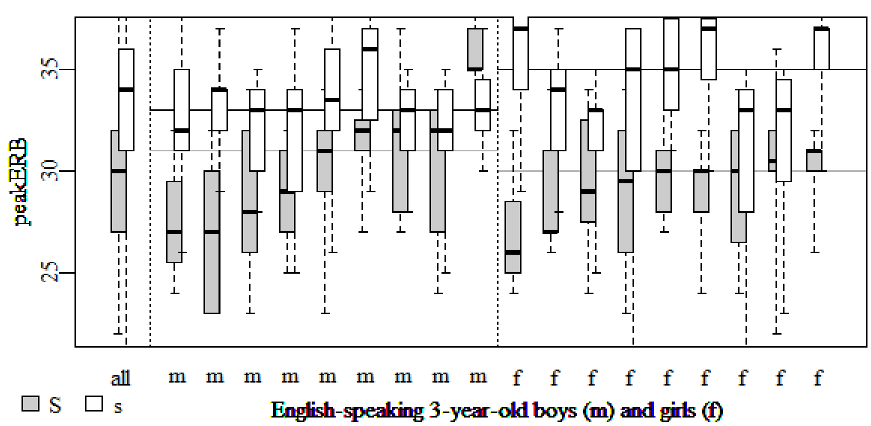

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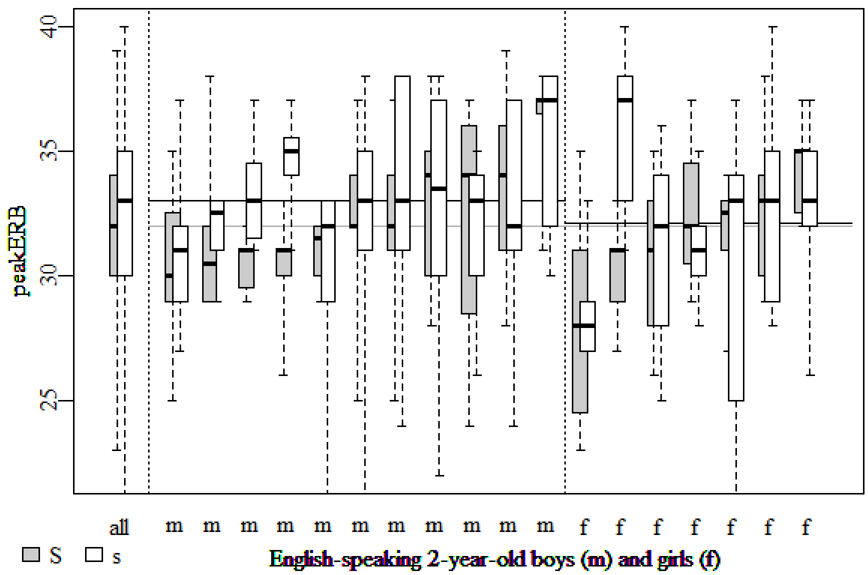

Figure 5

As expected based on previous findings which used centroid instead of peak ERB as a measurement of the frequency characteristics of the spectrum, results from English-speaking adults show that women have a very large difference between the average peaks of /s/ and /ʃ/, where the difference between the two fricatives for men is smaller. There was a significant main effect of gender ($F(1,13) = 17.7$, $p = 0.001$) and fricative ($F(1,487) = 796.7$, $p < 0.001$), and also a significant interaction of fricative and gender ($F(1,487) = 20.8$, $p < 0.001$). Furthermore, the average peak ERB for women's /s/ is about 4 ERB higher than the average peak for men's /s/.

The data for English-speaking five-year-olds are remarkably similar to adult data in that girls have a larger separation between /s/ and / ʃ/, and /s/ is higher in girls than in boys. Five-year-old girls' and boys' average peaks are all higher than adults' peaks because children have smaller vocal tracts and thus smaller resonating cavities. For five-year-olds, there was no significant main effect of gender. There was, however, a significant main effect of fricative ($F(1,541) = 403.1$, $p < 0.001$) and a significant interaction between fricative and gender ($F(1,541) = 17.5$, $p < 0.001$).

Four-year-old English-speaking children's data follow the same trends as adults and five-year-olds, with significant effects of fricative ($F(1,588) = 245.6$, $p < 0.001$) and fricative/gender interaction ($F(1,588) = 12.0$, $p < 0.001$). Boys' /s/ and /ʃ/ are very close to one another, both with averages between about 31 and 32 ERB. Averages for girls' /s/ and /ʃ/, in comparison, are about 5 ERB apart.

Three-year-old data closely resemble four-year-old data, again with significant effects of fricative ($F(1,468) = 156.3$, $p < 0.001$) and fricative/gender interaction ($F(1,468) = 11.1$, $p < 0.001$).

As with the older children, the ANOVA for the two-year-olds did not show a main effect of gender ($F(1,14) = 1.26$, $p = 0.28$). However, unlike the pattern for older children, two-year-olds also did not show a significant main effect of fricative ($F(1,442) = 1.88$, $p = 0.17$). Indeed, many two-year-olds showed no difference between the two fricatives, with averages for both fricatives and both sexes falling within 3 ERB of each other. This result, together with the results for older children, suggests that children learn to mark their fricatives appropriately for their gender at the same time that they learn how to differentiate the two lexically contrastive fricative types by achieving greater control over their articulators.

3.2. Japanese

Figures 6-10: Peak ERB average by speaker for Japanese-speaking adults, 5-year-olds, 4-year-olds, 3-year-olds, and 2-year-olds. "S" represents /ʃ/, "s" represents /s/. Black horiz. line = /s/, gray horiz. line = /ʃ/, averaged by gender.

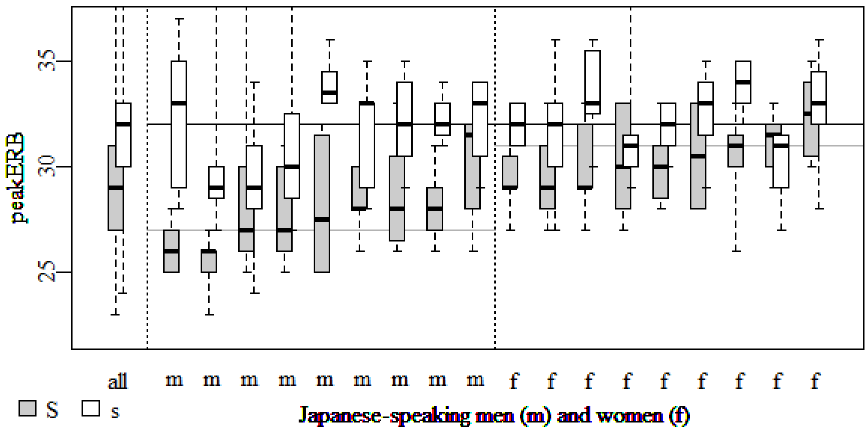

Figure 6

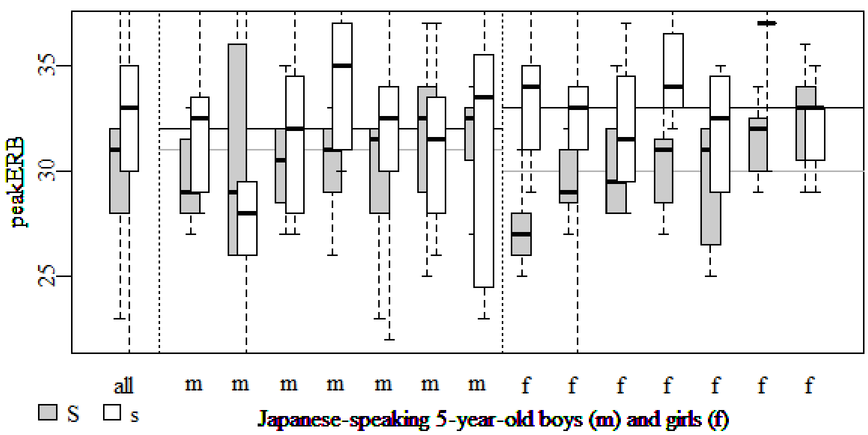

Figure 7

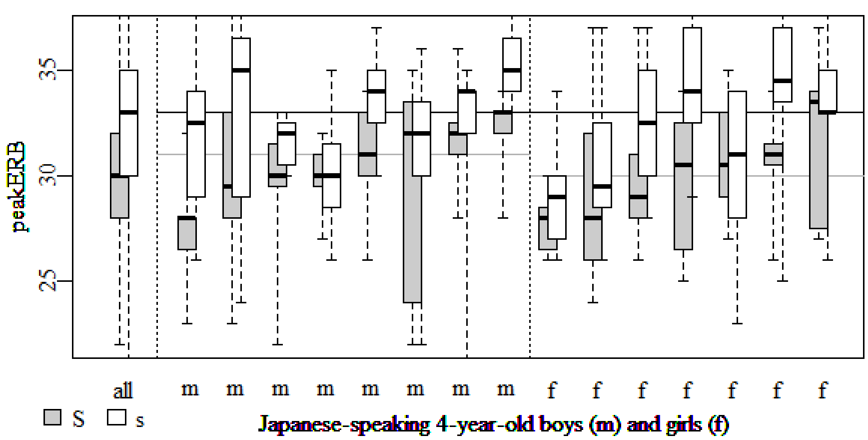

Figure 8

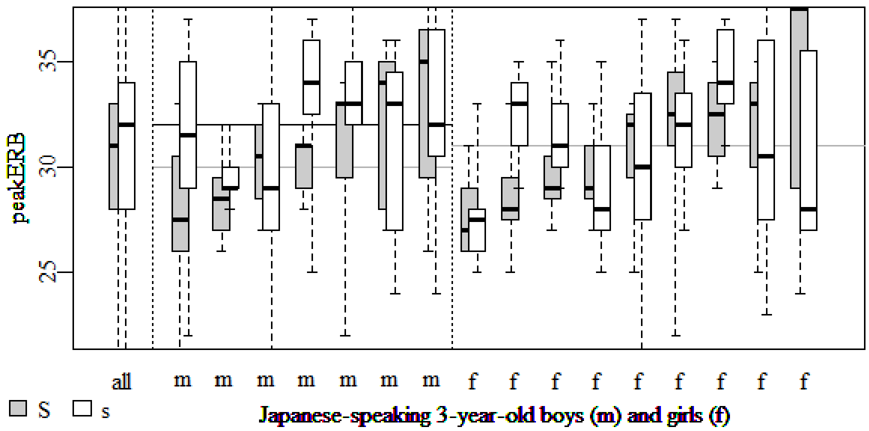

Figure 9: (Note overlapping /s/ and /ʃ/ averages for girls)

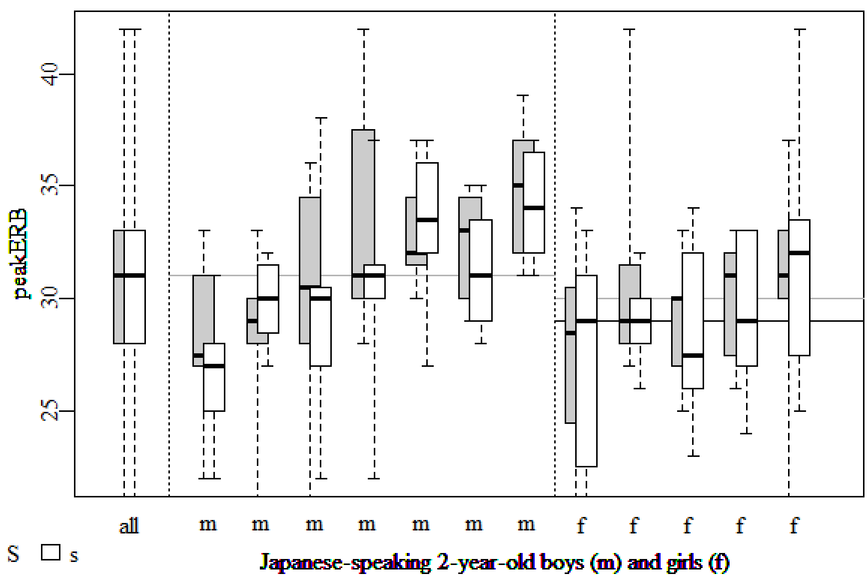

Figure 10

Average peak ERB values for Japanese-speaking women's /s/ and /ʃ/ are very close – within one or two ERB of each other – with a great deal of overlapping between the two fricatives within subjects. Women have, as expected based on sexually dimorphic vocal tract sizes, slightly higher /ʃ/ values than men. However, women's /s/ values are not higher than men's /s/ values, implying a frequency-lowering effect, contrary to the English frequency-raising effect. There were significant main effects of gender (F(1,15) =

12.3, $p = 0.003$) and fricative ($F(1,408) = 142.6$, $p < 0.001$), and also a significant interaction between gender and fricative ($F(1,408) = 14.5$, $p < 0.001$).

Five-year-old Japanese speaker data show trends quite unlike the adult data. Where women had overlapping /s/ and /ʃ/ averages and men had about a 5 ERB expanse between their /s/ and /ʃ/ averages, five-year-old girls have little overlapping while boys have a great deal. Five-year-old girls have a higher /s/ average and lower /ʃ/ average than boys. For five-year-olds, there was a significant main effect for fricative ($F(1,306) = 23.2$, $p < 0.001$) and a significant fricative/gender interaction ($F(1,306) = 7.9$, $p = 0.005$).

Four-year-old boys' and girls' averages for /s/ are similar, but girls have a lower /ʃ/ average and thus a larger difference between the two fricatives. There was a significant main effect of four-year-olds' fricatives ($F(1,320) = 33.3$, $p < 0.001$), but no fricative/gender interaction: ($F(1,320) = 0.11$, $p = 0.74$).

Three-year-old girls have such a great deal of overlapping between /s/ and /ʃ/ that the averages for the two places of articulation are the same, while boys have less overlapping and a higher /s/ and lower /ʃ/ than girls. There was a very small significant main effect of fricative ($F(1,334) = 5.66$, $p = 0.018$), and no fricative/gender interaction ($F(1,334) = 1.2$, $p = 0.27$).

Unlike the other children's results, the ANOVA for two-year-olds with fricative as a main effect showed no significant effect of fricative ($F(1,226) = 1.79$, $p = 0.18$) or fricative/gender interaction ($F(1,226) = 0.44$, $p = 0.51$), presumably because two-year-olds have not yet learned to control their articulators enough to contrast between the two fricatives.

4. Discussion

Overall, English and Japanese data did not show similar trends. It seems that as English-speaking children grow older, the relationships between the peak ERB values of their productions of /s/ and /ʃ/ become more adult-like. Females gradually learn to produce a higher-frequency /s/ with less variation from utterance to utterance, while /ʃ/ peak frequencies remain relatively constant. Males also learn to produce /s/ and /ʃ/ more differently from one another, but while females differentiate the fricatives by producing higher-frequency /s/, males do so by producing lower-frequency /ʃ/ instead.

Since Japanese speakers are, on average, smaller than English speakers, we would expect that they have higher overall peak ERB values than English speakers for both fricatives. However, this is not the case. In fact, for English-speaking women's /s/ productions, peak ERB values are two to three ERB higher than for Japanese-speaking women's /s/ productions. Both English and Japanese adults showed significant interaction effects between fricative and gender, but English women's /s/ was higher than expected while Japanese women's /s/ was lower than expected. This suggests a frequency-raising effect in English and a frequency-lowering effect in Japanese.

While the English speakers' data can be summarized easily by noting the very similar effects of gender across all age groups besides two-year-olds, the Japanese speakers' data are more complicated. The effects of gender for the 3- through 5-year-old children were like the effects of gender in the English speakers, with females having a larger difference between /s/ and /ʃ/ than the males. However, the difference between /s/ and /ʃ/ for the Japanese-speaking women is smaller than the difference for the men.

(Fittingly, as differences in peak ERB values between /s/ and /ʃ/ are generally smaller in Japanese than in English.) This suggests that peak ERB may not be the best measurement for capturing the contrast between the two fricatives in this language. This is where data from the onset of the vowel following the fricative (the aforementioned vOnset, or onset F2) would be useful to add as a secondary measure in distinguishing /s/ from /ʃ/. F2 onset indexes the back cavity (the area behind the tongue constriction). As Japanese female children grow older and their language skills increase, though, it does seem that they gradually refine their productions of /s/ until at adulthood, there is a very small ERB range within which most women's /s/ productions fall. There does not seem to be a developmental trend among Japanese-speaking males, but at adulthood, Japanese-speaking males show great robustness of contrast between the two fricatives, an observation which is also noted in the 2010 paper by Holliday et al.

5. Conclusions

There is a gender effect comparable to the "feminine accent" of Mandarin Chinese present in the fricatives of English, in which women produce the alveolar sibilant fricative /s/ with peak ERB values significantly higher than men's values for the same fricative. The effect is present in English-speaking five-year-old girls' speech as well. In other words, beginning at age five, female English speakers contrast more greatly between /s/ and /ʃ/ by producing higher frequency /s/.

As previously stated, if gender effects are indeed based solely on vocal tract size, mean peak frequencies should be higher overall in Japanese, because Japanese speakers are smaller on average than English speakers (Heffernan 2004). However, the average peak ERB value across all English-speaking women is nearly 35 ERB, while the average across all Japanese-speaking women is closer to 32 ERB. (About 9657 Hz compared to about 6930 Hz, according to the conversion formula by Glasberg and Moore.) Because both languages have a significant interaction between fricative and gender, yet the average peak ERB value for English-speaking women is higher than for Japanese-speaking women, we know that the languages both have gender effects, but the effects are different. This finding defies the expected patterns based on physiology and thus supports the sociological explanation. Based on this evidence, we can conclude that the frequency-raising gender effect on English-speaking women's /s/ is not simply due to women having smaller vocal tracts, but is somehow sociologically-conditioned by the age of five.

In sum, the cross-linguistic comparison between English and Japanese revealed that a gender effect like the frequency-raising of English females' /s/ is not found in Japanese, supporting a non-biological explanation of the effect. Comparisons across age showed that the gender effect begins at age five, before the possibility of puberty causing physical changes that might explain the male-female disparity, also supporting a non-biological explanation of the effect.

In terms of further exploring the current hypothesis that there is a frequency-lowering gender effect on /s/ as produced by Japanese-speaking women, more exploration is needed. Future plans for this project include combining peak ERB measurements with vOnset measurements in a logistic regression model to see whether prediction of the Japanese fricative based on peak ERB and vOnset measurements is possible.

6. Acknowledgements

Data collection and analysis were supported by NIDCD grant 02932 to Jan Edwards and a grant from the Arts and Sciences Undergraduate Research Office at Ohio State to the author. Thank you to Julie Johnson, Fangfang Li, Oxana Skorniakova, and Asimina Syrika for help in data preparation, and to Jeff Holliday for help with psychoacoustic measures. And a special thank you to Mary Beckman, who has been an incredible mentor and great inspiration to me in my linguistic pursuits.

Appendix

I. Table of English /s/- and /ʃ/-initial target words.

Code	Fricative	Vowel context (IPA)	English gloss
ckrt	/s/	i	secret
safe	/s/	e	safe
sail	/s/	e	sail
sakr	/s/	a	soccer
same	/s/	e	same
saus	/s/	a	sauce
sawx	/s/	a	saw
sayx	/s/	e	say
seat	/s/	i	seat
sick	/s/	ɪ	sick
soap	/s/	o	soap
sock	/s/	a	sock
soda	/s/	o	soda
sofa	/s/	o	sofa
soup	/s/	u	soup
sstr	/s/	ɪ	sister
stks	/s/	u	suitcase
supr	/s/	u	super
shel	/ʃ/	ɛ	shell
shep	/ʃ/	e	shape
shev	/ʃ/	e	shaving
shgr	/ʃ/	ʊ	sugar
ship	/ʃ/	ɪ	ship
shop	/ʃ/	a	shop
shld	/ʃ/	i	shield
shoe	/ʃ/	u	shoe
shop	/ʃ/	a	shop
shot	/ʃ/	a	shot
show	/ʃ/	o	show

shpe	/ʃ/	i	sheep
shrp	/ʃ/	aɹ	sharp
shrt	/ʃ/	oɹ	short
shut	/ʃ/	u	shoot

II. Table of Japanese /s/- and /ʃ/-initial target words.

Code	**Fricative**	**Vowel context (IPA)**	**Japanese word**	**English gloss**
saka	/s/	a	sakana	fish
saku	/s/	a	sakura	cherry
saru	/s/	a	saru	monkey
semi	/s/	e	semi	cicada
sena	/s/	e	senaka	back
sens	/s/	e	sensei	teacher
sora	/s/	o	sora	sky
sori	/s/	o	sori	sled
sose	/s/	oo	sooseji	sausage
suik	/s/	ui	suika	watermelon
suna	/s/	u	suna	sand
suzu	/s/	u	suzume	sparrow
syam	/ʃ/	a	syamoji	rice paddle
syat	/ʃ/	a	syatsu	shirt
syaw	/ʃ/	a	syawaa	shower
syoj	/ʃ/	oo	syooji	slides
syok	/ʃ/	o	syokupan	bread
syoy	/ʃ/	oo	syoju	soy sauce
syuk	/ʃ/	uu	syuukuri imu	cream puff
syum	/ʃ/	uu	syuumai	dumpling
syuz	/ʃ/	uu	syuuzu	shoes
sika	/ʃ/	i	syika	deer
sipo	/ʃ/	i	syippo	tail
siso	/ʃ/	i	syiso	seesaw

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