On the differential substitution of English [θ]
A phonetic approach

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A phonetic approach to the differential substitution of English [θ] successfully predicts that speakers of languages with a dental [s̪], or a slit-type [s], will substitute it for the English fricative, while speakers of languages with a more retracted [s] will not. Data from native speakers of Quebec French, European French, Russian, and Japanese is employed in the study.

0 Introduction

The pronunciation of English [θ] and [ð] (henceforth [θ]) is known to be problematic for the second language (L2) learner whose native language (L1) does not have these sounds in its inventory. To deal with this sound, the learner resorts to L1 segment transfer, transferring either /t/ or /s/ depending on the L1. This phenomenon is commonly referred to as differential substitution and is known to be a challenge to L2 research. Several phonological accounts have been proposed and the idea of a phonetic-based approach has been discarded (Weinberger 1990). The study presented in this paper is a response to this rejection of a possible phonetic explanation of the phenomenon. I investigate whether the spectral characteristics of the fricative [s] of the L1 can serve as the predictor of which segment will be used as a substitution for the English interdental fricative [θ]. Quebec French (QF), European French (EF), Russian, and Japanese are the four languages considered.[1]

1 Previous Accounts

The differential substitution of English [θ] phenomenon has, so far, been treated as a phonological problem. The very existence of differential substitution appears to be enough grounds for phonologists to reject a phonetic-based hypothesis for the phenomenon. Wilson (ms) notes that Altenberg and Vago allow that the problem is phonetic in nature but that phonetics cannot predict the substituted form. Three phonological studies are briefly described below:

Hancin-Bhatt (1994) proposes the Feature Competition Model, which assumes that features in a given language's inventory have values of greater or lesser prominence.[2] This model predicts, for example, that since the feature [continuant]

1 Though QF and EF are both dialects of the French language, they will simply be referred to as *languages* for purposes of simplicity. EF investigated in this paper is spoken in France.

2 Hancin-Bhatt explains that "prominence" is calculated by relating the number of phonemic distinctions a particular feature makes in a UR to the total number of phonemes in the language's inventory" (252).

is of high prominence in German, speakers of this language will tend to notice it in the perception of the English interdental fricative, [θ], making them likely to map it with their fricative [s]. Given that QF and EF have the same underlying inventory, Hancin-Bhatt's model still cannot explain why they substitute a different segment for [θ].

Wilson (ms) accounts for the QF - EF problem by claiming that the low-level phonological rule of assibilation of alveolar stops preceding high front vowels in QF versus the non-occurence of this allophonic process in EF forms the basis of the differential substitution. This difference between the two languages allegedly causes their speakers to effect different phonological transfers. He argues that the QF substitution /t/ is due to QF constraints on phonological representations and that the EF /s/ substitution is due to the transfer of a postlexical (redundancy) rule. This approach finds one (allophonic) difference between QF and EF and from it builds a multi-layered and highly complex analysis of the phenomenon.

Weinberger (1990) attempts to account for the differential substitution of English [θ] by Russian /t/ and by Japanese /s/ using Underspecification Theory. A major problem with this study is that Weinberger starts off with the wrong claim that Russian speakers substitute /t/ for [θ].[3] This fact undermines his phonological claims. Weinberger claims that phonetics can have no say in the matter of differential substitution. He notes that Russian and Japanese speakers substitute different segments for [θ] — /t/ and /s/ respectively (but see the criticism above) — even though these segments are identical in both languages, namely that /s/ and /t/ are alveolar. Based on the research I report in this paper, it appears that he based his judgment on the labels provided by his source(s). We shall see that an acoustic analysis of /s/ in both these languages shows that they are *not* identical. This analysis will be extended to QF and EF to see whether their different substitution pattern can be explained.

2 The substitution patterns

The substitution patterns for the four languages in question are indicated in (1).[4]

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3 The Russian speakers who participated in the study informed me that speakers of their language substitute /s/. If Weinberger's /t/ substitution claim is correct for some speakers, then we may be dealing with dialect-based substitutions. I return to this in section 8.3.1.

4 At this point, the *phonetic* brackets do not include precise phonetic information about the sound produced. Recall that [s] in Japanese and Russian are acoustically different; in these two cases then, the [s] substituted is different; hence the use "Japanese [s]," "Russian [s]", etc.

(1) • QF → [t]
• EF → [s]
• Russian → [s]
• Japanese → [s]

These patterns reflect what the L2 speakers substitute *most* of the time. Two subjects—a EF and a Russian speaker—were found to fluctuate in their substitutions. This fluctuation is not considered in the study but will be briefly discussed in section 9.2.[5]

3 The hypothesis

I will assume that the L1 segment substituted for English [θ] reflects the L2 learner's judgment of what the best perceptual and articulatory match in his/her native language is. The phonetic nature of the relevant L1 segments—[t] and [s]—determines whether they are considered a good match or not. The study specifically proposes that the spectral characteristics of [s] in the L1 can predict which L1 segment will be substituted for English [θ].[6] The proposed hypothesis follows.

(2) Hypothesis

A speaker of a language with a fronted/dental [s̪] in its inventory will substitute it for the English target [θ] while a speaker of a language with a more retracted, e. g. alveolar, [s] and a dental [t̪] in its inventory will substitute the [t̪] for [θ].[7]

This hypothesis implies that place of articulation is considered a more important cue than manner of articulation in selecting a match for [θ]. While [s] matches [θ] in manner of articulation it does not adequately approximate it in place of articulation and is therefore not considered a good match; [t̪] though a stop, approximates the place of articulation of the target and is used as the substitute.

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5 The fluctuation appears to be environmentally determined. This should be considered in a larger scale study.

6 The possibility that an "L2 dialect" is part of the explanation for the segment substituted was ruled out after working with one of the EF speakers. His only contact with English has been in Calgary without any contact with other EF speakers. "On line" language-specific differences are considered the cause and are investigated in this study.

7 The pattern "alveolar [s] - alveolar [t]" (allegedly found in German) is not included in this study.

We expect then, that [s] substituting languages have a dental [s̪] in their inventory, while the [t] substituting languages have an alveolar [s] (and a dental [t̪]). The next section describes how place of articulation can be read in the noise filtering cue.

4 Spectral characteristics of fricatives and their relation to articulation

In the literature, fricatives are described and referred to in classes of shared articulatory and spectral characteristics. The fricatives [f / θ] and [s / ʃ] form two separate groups.

4.1 Group [f / θ]

Both these fricatives—the so-called non-sibilant fricatives— are produced by the approximation of a lower articulator to the upper incisors—the lower lip and the tongue tip respectively.[8] The sound produced is "the result of turbulence generated at the constriction itself" (Ladefoged and Maddieson 1996: 138). In the production of [θ], the tongue is quite flat, forcing the airstream through a wide thin slit; [θ] is traditionally referred to as a slit fricative. This type of constriction produces a low energy sound which is reflected in the faintness of its spectrographic frequency band. The breadth of the band for the fricatives of this group is not agreed on for the reason given by Ladefoged and Maddieson (1996: 173), who state that "it seems that in the case of the pairs **f**, **θ** and **v**, **ð** in English, the inconsistencies between speakers are . . . great . . ." Borden and Harris (1980: 122) and Strevens (1960) agree on a broad band; Strevens specifies that it extends from approximately 1.4 KHz to 8 KHz. Fry (1979: 122), on the other hand, notes that the band extends from 6 to 8 KHz. As for the place of articulation of [f] and [θ], F2 transitions are the main indicators (Borden and Harris: 185; Fry: 141).

4.2 Group [s / ʃ]

The so-called sibilant fricatives are produced by a high velocity jet of air that is formed at a narrow constriction—in the dental or alveolar region for [s] and in the post-alveolar region for [ʃ]—that goes on to strike the edge of some obstruction such as the teeth (Ladefoged and Maddieson, 1996: 138, 145, 148). In the production of [s], the tongue is grooved, resulting in a narrow constriction, while in the production of [ʃ], it is flatter, forming a wider constriction. The great intensity of these two sounds is seen in the darkness of their frequency bands. Their place of articulation is indicated by a relatively sharp cut-off of their noise filtering cue. Fry (1979: 140) states that ". . . the noise filtering cue indicates place of articulation by progressively higher cut-off of the noise as the point of articulation moves forward in the tract; the sounds are in other words progressively higher pitched". [s] is noted to have most of its energy above 4 KHz and extending to 8 KHz while [ʃ] has its energy above 2.5 KHz and extending to 6 KHz (Borden

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8 Variations are recognized in the articulation of [θ]. MacKay (1987: 95) notes that it can be interdental or articulated with the tip of the tongue behind the upper front teeth.

and Harris: 122). Only resonances in the front cavity— the ones formed in front of the constriction—are heard.[9] Thus, the [ʃ] place of constriction produces a long effective resonator and consequently, a lower pitched sound, while the [s] place of articulation, being further front, shortens the effective resonator producing a higher pitched sound (Borden and Harris: 122). The noise filtering cues are therefore sufficient in determining the places of articulation of [s] and [ʃ].

5 Expectations and other considerations

The above discussion suggests that in testing my hypothesis I should expect that a more fronted (or dental) [s̪] will be indicated by a higher cut-off of the noise energy than for an alveolar [s]. However, Mann and Repp (1980) and Soli (1981) claim that the noise spectra of fricatives are affected by vowel coarticulation effects. Mann and Repp discuss the effect of a round vowel on a fricative, as in [su]. They note that the rounding of the lips will have the effect of lowering the cut-off of the fricative. This is explained by the fact that lip rounding in the production of a back vowel results in an "extended" type of rounding; the effective resonator is thus extended and a lower frequency sound is produced (Rogers, 1991:179). Soli claims that the place of articulation of a fricative assimilates to high vowels—30 to 60 ms before the onset of the vowel—and that this results in an increase of 100 to 300 Hz of the peak frequencies. It is not clear in this latter claim whether cut-offs are also affected. In any case, they seem to suggest that the onset of the fricative is unaffected by the following vowel. However, we shall see in section 7 that this cannot be relied on. This suggests that a careful selection of tokens is crucial. The tokens of the four languages in question shall allow for comparison of the fricative in identical or, at least, similar environments.[10]

6 The corpus and recording procedures

6.1 Choice of tokens

The tokens chosen were all real words in the languages investigated. To control for consistency across the four languages, care was taken to select tokens that had the fricative /s/ word-initially before a stressed vowel to ensure clarity of articulation; for this reason, monosyllabic words were chosen whenever possible. Also, to account for the fricative-vowel coarticulation effect, the tokens contained the sequence /s/ + the vowels [i], [e] or [ɛ], and [a].[11] An acoustic analysis of the

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9 Borden and Harris (1980: 122) explain that this is due to the narrowness of the constriction.

10 We can only approximate the degree of equality in the vowel quality cross-linguistically: an [i] in QF could be slightly different from a Russian [i]. We will not worry about these slight differences here.

11 Tokens [su..] and [so..] or [sɔ..] were initially also part of the token bank. However, it was found—as claimed by Mann and Repp (1980)— that they did lower the cut-off of the noise.

target, English [θ], (produced by native speakers of English) was also performed. In these tokens, [θ] appears in the same environments as the above [s] tokens. The tokens are listed in Appendix I.

6.2 Recording of tokens

Three native speakers of each of the four languages and of the target language were recorded reading down the list of their respective tokens, repeating each one three times to allow for the choice of repetition to be analyzed (to control for a falling intonation in all cases). The recording was performed with a Sony Professional Walkman WM-D6C and a Realistic Electret 33-1063 tie-pin microphone at a consistent recording level. For speaker information, see Appendix II.

7 Corpus analysis

7.1 Transfer to Soundscope 16.1

The selected repetition of each token was transferred to Soundscope 16.1 at a sampling rate of 22 000 samples per second and at a constant sound level input. All tokens were normalized.

Though testing the hypothesis only involves the analysis of the noise cut-offs, a more full acoustic profile for each token was gathered, as presented in section 7.2.

7.2 Measures taken

Noise Cut-off: In KHz. 25 dB is considered to be the lowest point of perceivable noise.[12]

Peak intensity: The peak intensity of the fricative was noted in decibels and the location of the peak intensity, in KHz.

High intensity area: Location/range (in KHz) of the high intensity area—35 dB and above.

Average intensity: Averages were calculated by taking 25 dB to be the lowest point of perceivable noise and the peak intensity figure to be the highest.

A spectrogram and an Average Spectrum (AS) of the fricative portion was printed out for every wave. The AS is a plotting of average intensities at all (relevant) frequencies in the time period selected—in this study, the entire duration of the fricative. The cut-offs of some fricatives were clearly seen to be affected by vowel coarticulation. Most often, the vowel coarticulation effect only began in the

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They were rejected because the lowering effect was too great: approximately of 1.5 KHz; this would have had a undesirable effect on the averages.

12 On the instrument used, a complete lack of spectrographic trace began at 25dB.

mid portion of the fricative, as suggested by Soli (1981) and reported in section 5 above. In these cases, the cut-off frequency at the onset of the fricative was easily readable. In other cases, however, the spectrographic evidence was ambiguous. The cut-off remained at the same frequency level throughout the entire fricative portion. This made it impossible to tell whether the fricative was produced without any vowel coarticulation or with vowel coarticulation that was already present at the onset of the noise. But since the cut-off levels in these cases corresponded roughly to those found in the initial portion of the fricatives that showed no coarticulation effects until halfway through, it was assumed that there was (surprisingly) no vowel effect on the fricative.

8 Data analysis

8.1 Results

Averaged results of the noise cut-offs and average intensities are shown in Table 1. A spectrogram of a typical [s] production is shown for each language in Figures 1 to 4. Figures 5 and 6 show spectrograms of a [θ] token production by two different speakers.

Measures	English [θ]	QF [s]	EF [s̪]	Jpn [s]	Russian palat. [sʲ]	non-pa. [s]
Cut-off (KHz)	2 / 6	4.3	5.6	6.5	2.6	4.3
Peak intensity (dB)	29	41	44	30	37	37.6
Location of peak (KHz)	7.5	7.4	7.25	09	5.5	5.75
High intensity range (KHz)	spread	6.6 - 9	6.1 - 9	spread	spread	spread 5.6-7
Avg. intensity (dB)	27	33	34.5	27.5	31	31

Table 1 Averaged spectral measurements for the target fricative [θ] in English, and for the native fricative [s] in Quebec French, European French, Japanese, and Russian[13]

13 The results for both English subjects are noted for cut-off frequency. An average would have been misleading due to the large discrepency between the measurements for each speaker (see footnote 8).

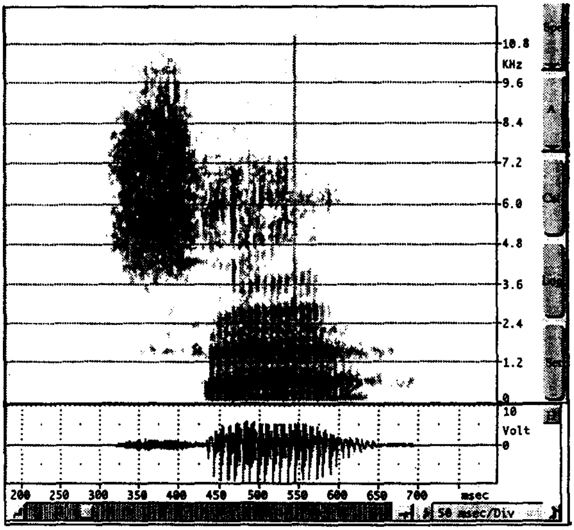

Figure 1 QF [sa] produced by speaker pa

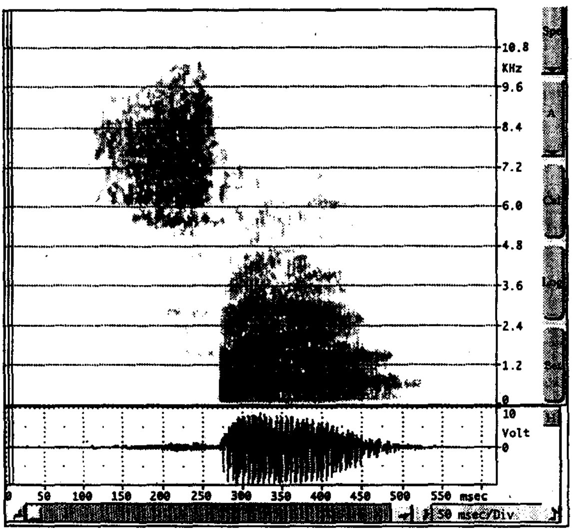

Figure 2 EF [sa] produced by speaker al

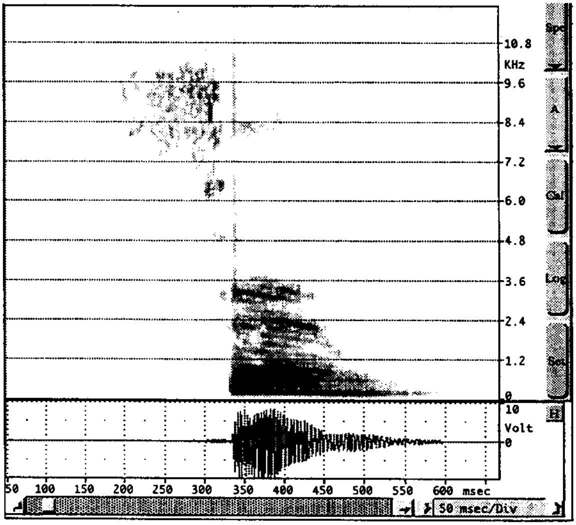

Figure 3 Japanese [sɛŋ] produced by speaker na

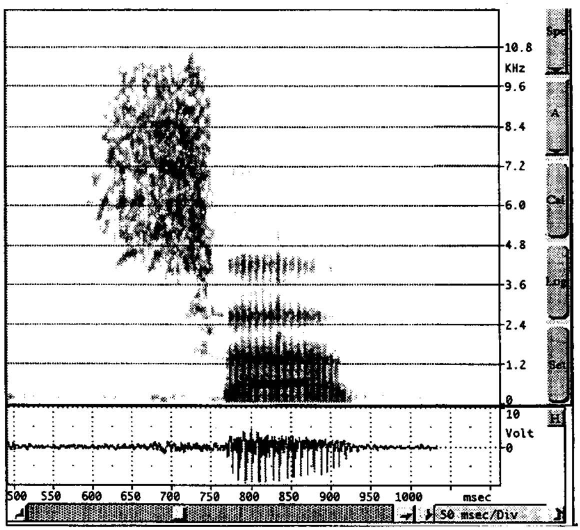

Figure 4 Russian [sat] produced by speaker vic

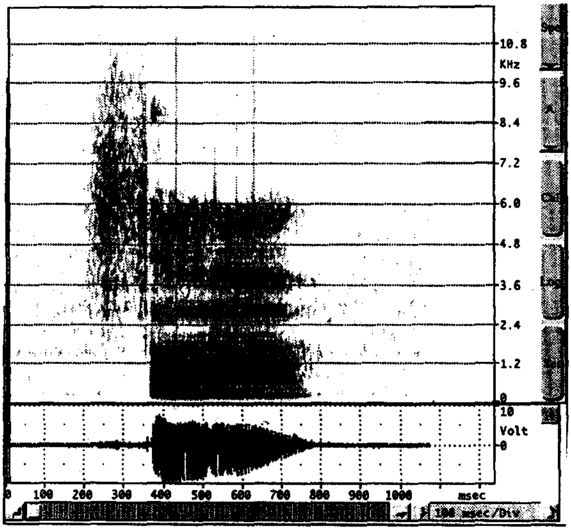

Figure 5 English [θa] produced by speaker vl

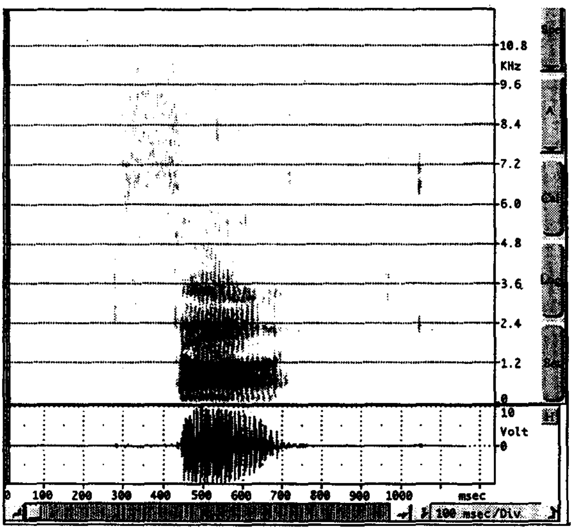

Figure 6 English [θa] produced by speaker er

8.2 General observations

The hypothesis will be upheld if the fricative [s] in the [s̪] substituting languages—EF, Japanese, and Russian—has a higher cut-off than the [s] in the [t̪] substituting language (QF). This is indeed supported by the fairly high cut-offs in Japanese and EF. Russian, however, appears to pose a problem with its low cut-offs.

8.3 Language-specific cases

8.3.1 The [t̪] substituting language

QF: With a 4.3 KHz cut-off point, it seems reasonable to consider the QF [s] as an alveolar [s] (compared to 4 KHz for alveolar [s], as suggested in section 4.2).

8.3.2 The [s̪] substituting languages

EF: This language's [s] can definitely be considered dental with a cut-off of 5.6 KHz.

Japanese: This language has the highest cut-off, appearing to suggest that it is even more dental than EF. However, the low intensity characteristic of Japanese [s] suggests that it is probably also produced with a flattened tongue, making it a slit-type fricative just as English [θ] is (they have very similar levels of energy—29dB for English [θ] compared to 30 dB for Japanese [s]). This means that the cut-off of the noise energy is not necessarily an indication of place of articulation here. Recall that in the case of [θ], F2 transitions are claimed to be the indicators of place of articulation. It is not clear then whether Japanese [s] is dental or not. F2 transitions need to be taken into consideration in further study.

Russian: The Russian [s] cut-offs seem to suggest that the hypothesis is not upheld. But unfortunately, the Russian data is inconclusive. One speaker (from St. Petersburg) substituted [s]; the other speakers' (from Tyumen) substitutions are unknown since they had successfully acquired [θ]. The non-palatalized [s]'s low cut-off of 4.1 KHz suggests that they would have substituted [t]. Until further data is acquired, I will withhold judgment. It is clear however that some speakers substitute [s].

9 Discussion

9.1 Is the hypothesis upheld?

The hypothesis tested is repeated in (3).

(3) Hypothesis

A speaker of a language with a fronted/dental [s̪] in its inventory will substitute it for the English target [θ] while a speaker of a language with a more retracted, e. g., alveolar [s] and a dental [t̪] in its inventory will substitute the [t̪] for [θ].

QF and EF uphold the hypothesis. These languages respect the claim that the place of articulation of the fricative [s] of a language—indicated by the cut-off of the noise filtering cue—determines which L1 segment will be substituted. QF was found to have an average cut-off of 4.3 KHz, a reasonable figure for an alveolar classification and thus not a good match for [θ]. In this case the [t̪] will be substituted—the correct prediction for QF. EF [s̪] showed a high cut-off, at 5.6 KHz. It can therefore be identified as a dental [s̪] and thus, as predicted, the substitute for [θ]—which is correct. The results of the spectral analyses of Japanese [s], however, shows that the hypothesis stated is not applicable in all cases. As discussed in section 8.3.2, [s] in this language is low in intensity and thus similar to English [θ] in that respect; their intensity peaks are of 30 and 29 dBs respectively. Similar levels of peak intensity appears to entail similar types of constriction—a slit or nearly slit-type constriction. We saw that with this type of fricative, place of articulation is not seen in the noise filtering cue and was thus not determined in this study.[14] For Japanese, the type of constriction of its [s] determines the substituted segment. A low intensity slit-type [s] is automatically considered a good match with the target. For Russian, the results are inconclusive.

9.2 A proposed revision

The hypothesis was on the right track with its statement of place of articulation of [s] as the substitution determiner, but only for cases of languages with *sibilant* [s]—as found in QF and EF. *Slit / non-sibilant* [s] involve a separate case calling for intensity as a determining factor. This leads to a revised version of the hypothesis.

(4) Revised hypothesis

- If a language has a sibilant [s], its place of articulation will be the determining factor in the substitution pattern:

A speaker of a language with a fronted/dental [s̪] in its inventory will substitute it for the English target [θ] while a speaker of a language with a more retracted, e. g., alveolar [s] and a dental [t̪] in its inventory will substitute the [t̪] for [θ].

- If a language has a slit / "weak-sibilant" [s], it will be substituted for [θ].

The revised hypothesis suggests that the type of constriction as well as the place of articulation involved in the production of [s] is an important factor in the

14 F2 transitions cues should be considered in further study in order to determine these slit-[s]s' exact place of articulation.

judgment of goodness of match. Not any [s] fricative is considered a good match with the fricative [θ]. A three way substitution criterion is suggested:

① Slit -[s] "weak-sibilant" fricatives are clearly *good* matches (as in Japanese).
② A sibilant dental [s̪] fricative, though louder than the slit [θ] (thus not agreeing with its type of constriction) is considered an *acceptable* match if it agrees in place of articulation (as in EF).
③ A sibilant [s] that doesn't agree in place of articulation with the target is considered a double *bad* match and will not substituted; L1 [t̪] is substituted in this case (as in QF).

Perhaps it is possible that, in the third case, alveolar [t] is substituted regardless of its place of articulation—a "quiet" alveolar [t] is perhaps considered a better match for [θ] than a "loud" alveolar [s]. This, however, remains to be determined (see footnote 7). If this was shown to be the case, then the restriction to [s - t̪] patterns could be eliminated from the hypothesis.

This three-way criterion could perhaps explain why fluctuations sometimes occur, as briefly discussed in section 2. It was mentioned there that a EF and a Russian speaker were found to (sometimes) fluctuate. Speculatively, for EF this fluctuation could be explained by the fact that [s̪] substitution is an *acceptable* match; this segment agrees in place of articulation but is not a good match in its type of fricativeness. QF and Japanese speakers were never found to fluctuate. For QF this could be because its alveolar [s] is a *bad* match and will therefore *never* be substituted for [θ]. Japanese [s] showed to be quite similar to [θ] in intensity and would therefore always be considered a *good* match.

10 Conclusion

The results obtained in this pilot study are promising. They seem to suggest that phonetics indeed has a say in the matter of the differential substitution of the English interdental fricative [θ]. We saw that the results of an acoustic analysis of the fricative [s] in the L1 can sucessfully predict which L1 segment will be substituted for the target [θ].

The next step is, of course, to test our revised hypothesis against a larger body of data from more languages. A larger scale acoustic analysis of [s]—one that includes more tokens produced by more speakers—would allow the obtainment of more reliable averages and also to see whether any threshold dividing [t] - [s] substitutions can be established. In the sibilant [s] cases, a cut-off threshold is to be determined, while in the slit-type [s] cases, we would be looking for a peak intensity threshold. The place of articulation of the slit [s] fricatives should also be included in the measurements of further study—this involves analyzing the F2 transition cues.

A study of the type presented in this paper could be extended to cases that involve context-dependent substitutions, as in the alleged phenomena in Dutch and Mandarin:

- Dutch speakers substitute [t̪] for [θ] syllable-initially but [s̪] syllable-finally (Hancin-Bhatt, 1994: 244).
- Mandarin speakers substitute [t̪] for [θ] word-initially, but [f] word-finally (Weinberger, 1990: 142).

It would also be interesting to see what kind of L1 [s] fricatives lead to [f] fricative transfer.

This phonetic account shows that speakers are sharply attuned to acoustic details in fricatives. We saw that not any type of fricative is considered a good match with the English fricative [θ]. A working hypothesis has been established for further research based on a hierarchy of preferred substitutions: [ŝ] > [s̪] > [t̪] > [t] >>>*[s] (where [ŝ] represents a slit-type "weak sibilant"). I believe that the phonetic basis of differential substitution hypothesis remains a viable avenue of research.

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Appendix I
Tokens

♣	s + [i]	s + [e / ɛ]	s + [a / aj /ɑ]	s + [ɯ]
QF	[si] 'if'	[se] or [sɛ] 'his / her (plur.)'	[sa] 'his / her (fem.)'	____
EF	[si] 'if'	[se] or [sɛ] 'his'	[sa] 'his / her (fem.)'	____
Japanese	____ [2]	[sɛŋ] 'a thousand'	[sajgen] 'limits'	____
Russian Palatalized [sʲ] [6]	[sʲila] 'strength'	[sʲetʲ] 'net'	[sʲak] 'that' [4]	____ [5]
Russian Non-palatalized [s]	____ [3]	[sɛɾ] 'sir'	[sat] 'garden'	[sɯn] 'son'
English	[θijf] 'thief'	[θɛft] 'theft'	[θɑ] 'thaw'	____

Notes:

1 Tokens with the rounded vowels [u] and [o] or [ɔ] were also recorded but were not included in the calculation of averages (because of their strong frequency-lowering effect on the fricative).
2 In Japanese, [s] preceding [i] is pronounced [ʃ].
3 The non palatalized counterpart tends to (allophonically) appear with the back vowel [ɯ], as in [sɯn] 'son'.
4 This is from the Russian expression [itakisʲak] 'in this way and that way'.
5 See note 3
6 Token [sʲɔk] was added for two of the subjects.

Appendix II
Speaker Information

Speakers	City of origin	Gender	Age	Occupation
QF				
al	Drummondville	F	Mid 20's	student
pa	Trois-Rivières	M	Mid 20's	accountant
au	St-Jean d'Iberville	F	50	librarian
EF				
od	Britanny	F	Early 40's	teacher
gi	Lyon	M	40	teacher
ac	Paris	M	Mid 30's	waiter
Japanese				
yu	?	F	Early 20's	student
na	?	F	Early 20's	student
mi	Fukuoka	F	Early 20's	student
Russian				
el	St. Petersburg	F	Mid 30's	PhD student
vic	Tyumen	M	Early 20's	student
vad	Tyumen	M	Early 20's	student

Appendix III
Results: raw data

Quebec French

Measures	Speaker al			Speaker pa			Speaker au		
	[si]	[se]	[sa]	[si]	[se]	[sa]	[si]	[se]	[sa]
Cut-off (KHz)	4.4	6[1]	6	4	4	4	4.8	4.6	4.6
Peak intensity (dB)	45	38	38	42	41	41	39	42	43
Location of peak (KHz)	7.5	7.5	7.5	6.6	6.6	5.5	8.8	8.6	8
High intensity range (KHz)	7.1-9.9	7.2-9.6	7.5-9	6-8.6	6.2-8.2	4.8-8.2	7.2-9.5	6.6-9.2	7-8.8
Avg intensity (dB)	35	31.5	31.5	33.5	33	33	32	33.5	34

Note: 1 These two figures (6 KHz) were excluded from the average calculations: they are strangely much higher than the other figures; this would have an enormous effect on the average due to the small number of subjects.

European French

Measures	Speaker od			Speaker[2] g			Speaker ac		
	[si]	[se]	[sa]	[si]	[se]	[sa]	[si]	[se]	[sa]
Cut-off (KHz)	5.2	5.6	5.5	3	3.2	3.8	5.8	5.5	6
Peak intensity (dB)	43	45	42	49	43	48	45	49	40
Location of peak (KHz)	7.2	7.5	8.5	4.8	4.5	7.5	6.5	6.6	7.2
High intensity range (KHz)	5.5-9.5	6.2-8.6	6.4-9.5	3.5-3.8	3.8-8.2	3.7-8.3	6-9	6.2-8.8	6.5-8.5
Avg intensity (dB)	34	35	33.5	34	34	36.5	35	37	32.5

Note: 2 This speaker's measurements were not included in the calculation of the averages due to the great discrepencies with the results of the other two speakers. This would have affected the averages greatly.

Japanese

Measures	Speaker yu		Speaker na		Speaker mi	
	[sɛŋ]	[sajgɛn]	[sɛŋ]	[sajgɛn]	[sɛŋ]	[sajgɛn]
Cut-off (KHz)	7.2	4.4	7.2	7.2	6.2	6.5
Peak intensity (dB)	25	35	25	28	32	35
Location of peak (KHz)	9.2 - 9.5	7.2 - 8	9.5	9.5	8.8	9.5
High intensity range (KHz)	spread	6.6 - 8.8	spread	spread	spread	7 - 9.9
Avg intensity (dB)	25	30	25	26.5	28.5	30

Russian: palatalized [s^j]

Measures	Speaker[3] el			Speaker vic			Speaker[4] cad		
	[s^{j}ila]	[s^{j}et^j]	[s^{j}ak]	[s^{j}ila]	[s^{j}et^j]	[s^{j}ak]	[s^{j}ila]	[s^{j}et^j]	[s^{j}ak]
Cutoff (Khz)	4.8	4.8	4.8	2.6	2.6	2.6		------	
Peak intensity (dB)	50	44	46	49	34	31		------	
Location of peak (KHz)	6.2	7.2	7.7	5	5	5		------	
High intensity range (Khz)	5-8.4	5.5-8.4	5.5-8.2	2.6-9	spread	spread		------	
Avg intensity (dB)	42.5	34.5	35.5	37	29.5	28		------	

Notes:

3 This speaker's measurements were not included in the calculation of the averages due to the great discrepencies with the results for the other two speakers. These results would have affected the averages greatly because of the small number of speakers. Note that the speaker is from a different location than the other two.

4 Unfortunately, these tokens were not obtained for this speaker.

Russian: token [sʲɔk]
Token [sʲɔk] was excluded from the study because of the recognized rounding effect of the vowels on the fricatives. However, since we did not have many tokens from speaker vad, this token was used (especially to test the level of intensity).

Measures	Speaker vic	Speaker vad
	[sʲɔk]	[sʲɔk]
Cut-off (Hz)	2.6	2.6
Peak intensity (dB)	36	35
Location of peak (KHz)	4.4	8.2
High intensity range (KHz)	spread	spread
Avg Intensity (dB)	30.5	30

Russian: non-palatalized [s]

Measures	Speaker d			Speaker vic			Speaker vad		
	[sɛɾ]	[sat]	[sɯn]	[sɛɾ]	[sat]	[sɯn]	[sɛɾ]	[sat]	[sɯn]
Cutoff (Khz)	4.8	4.8	--	4.4	4.4	4.4	--	--	4
Peak intensity (dB)	42	45	--	37	35	39	--	--	37
Location of peak (KHz)	6.6	6.6-7	--	6	6	6.2	--	--	4.8
High intensity range (Khz)	6-8.6	5-5.8	--	5.5-6.2	spread	5-7.7	--	--	spread
Avg intensity (dB)	33.5	35	--	31	30	32	--	--	31

English: The interdental fricative [θ]

Measures	Speaker vl			Speaker er		
	[θijʃ]	[θɛft]	[θɑ]	[θijʃ]	[θɛft]	[θɑ]
Cut-off (Hz)	3.5	3	2.8	6.2	! [5]	7.2
Peak intensity (dB)	32	31	33	28	27	23
Location of peak (KHz)	8	7.5	7	7.2	7.8	7.2
High intensity range (KHz)	spread	spread	spread	spread	spread	spread
Avg Intensity (dB)	25	28	29	26.5	26	24

Note: 5 Since the cut-off levels are noted at 25 dB, it is not possible to note one here. This token's peak intensity is below this level (23 dB).