CHAPTER 5

When *three* equals *tree*

Examining the nature of phonological entries in L2 lexicons of Quebec speakers of English

Pavel Trofimovich and Paul John
Concordia University, Montreal / Université du Québec à Montréal

In this study, we used auditory priming to examine the phonological content of lexical entries for adult second language speakers. In particular, we investigated whether, for native speakers of Quebec French, words like *they* and *day* as well as *three* and *tree* have identical (i.e., homophonous) phonological forms in these speakers' lexicons, which would explain these speakers' difficulty producing and perceiving words containing difficult /ð/ and /θ/ consonants. We found that our participants did not distinguish between these pairs of words in their lexicons, but were able to produce at least some of the words containing English /ð/ and /θ/ accurately. We discuss both theoretical and pedagogical implications of these findings.

Introduction

> I was seventeen years old and I was really (uh) eager to get my license so I could finally drive where I wanted to go. (um) *De* exam was pretty stressful. And after *dat* I kind of had (uh) trouble getting my license because I was like on *de* limit to get it because I made some errors. But (uh) I finally got it and finally could drive by myself… So after *dat* I got a car, which I really liked. But it actually (uh) crashed into a tree when I came back from lunch during (uh) a winter in, in two *tousand tree*.

The passage that opens our chapter is a description of a stressful experience narrated to us by one of the participants in the study reported here. This participant is an adult native speaker of Quebec French who had learned English as a second language (L2) through classroom instruction in Quebec's primary and secondary schools and reported very little exposure to and use of English in his daily life. Nevertheless, this speaker's command of English is likely well above the level of

many of his peers who have had similar experience in learning and using English. He makes relatively few morphosyntactic errors, his sentences are complex, and his speech is relatively fluent. However, one striking aspect of this speaker's English is his pervasive and very consistent substitution of English interdental fricatives /ð/ (as in *that*) and /θ/ (as in *thousand*) with /d/ and /t/, respectively. Thus, *that* ends up sounding like 'dat,' and *thousand* comes out as 'tousand.' In fact, in the space of several seconds, this speaker manages to neutralize the contrast between *tree* and *three* by pronouncing both words identically.

This particular pronunciation error – that is, one in which L2 speakers neutralize a phonological contrast in the L2 making two words sound identical – is interesting from several perspectives. One intuitive explanation for this error is that L2 speakers have difficulty producing a particular L2 vowel or consonant (English /θ/ in this case). Unable to produce English /θ/, they substitute the closest alternative, which for speakers of Quebec French appears to be /t/ (see Wenk 1979, for evidence that speakers of European French often substitute /z/ and /s/ for English /ð/ and /θ/). Another explanation, however, is that this error reflects a much more "serious" problem. It could be that L2 speakers do not distinguish between words like *tree* and *three* in their mental lexicon, which would mean that when speakers come across words like *tree* and *three* in English, they access and use identical sounding entries for these words in their mental lexicon.

Before we proceed, we should specify what is meant by the mental lexicon. The term "mental lexicon" refers to the mental dictionary language users have for words in a given language. When language users encounter words in speech or writing, they need to be able to process and understand at least two kinds of information: one related to the word's form (i.e., its phonology in the case of spoken words), the other related to the word's meaning. For example, upon hearing the word *hand*, speakers would first need to match what they hear with a phonological form stored in the mental lexicon (i.e., /hænd/), so that they can retrieve the appropriate meaning for the word (e.g., part of the upper limb consisting of a palm and fingers). Both types of information about a word's form and meaning (along with other details about its morphological and syntactic properties) are stored in the mental lexicon, and language users draw on these sources of information to understand and produce spoken words (e.g., Dell 1988; Levelt, Roelofs & Meyer 1999). In this chapter, we are concerned with the first of these two types of information – the phonological form of words.

Our goal in this chapter is therefore to examine two possible explanations for the kind of substitution error we discussed above (e.g., when a speaker of Quebec French produces English *three* as *tree*). The first possibility is that a speaker can clearly distinguish the two words in his or her mental lexicon, such that separate phonological forms for the two words (/θri:/ vs. /tri:/) can be developed, but the speaker is simply unable to produce the difficult /θ/ consonant. The other possibility, however, is that this substitution error has its origins in the speaker's mental lexicon, such that the speaker is not able to store the correct phonological form for at least one of the two words. According to this explanation, both *three* and *tree* are stored as /tri:/ in the speaker's mental lexicon, and the speaker is using this phonological form to recognize both words in listening and produce them in speaking.

From a theoretical perspective, this issue is interesting because compared to L2 learners' perception and production difficulties, which are well documented in the literature (e.g., Bohn & Munro 2007), relatively little is known about the phonological structure of L2 learners' mental lexicon. This issue is interesting from a pedagogical perspective as well. For example, teachers may wish to know if their learners' errors represent a "simple" sound substitution strategy (i.e., an articulatory simplification) or instead reflect a much deeper issue related to how learners store and use L2 words in their lexicon. As a result, teachers may choose to prioritize certain pronunciation activities in their teaching, with the goal of not only helping learners to avoid the kinds of sound substitution errors we discuss here but also helping them distinguish between words like *tree* and *three* in their mental lexicons.

This chapter is structured in the following way. We first discuss existing literature on L2 learners' mental lexicons, focusing in particular on the development and use of phonological information available in lexical entries. We then describe auditory priming as a methodology to examine the structure of learners' mental lexicons. We subsequently present evidence that, for native speakers of Quebec French, difficulties with English /ð/ and /θ/ often result in identical (i.e., homophonous) phonological entries for words such as *tree* and *three* or *day* and *they*. We also show that, despite this, at least some of these speakers learn to produce English /ð/ and /θ/ accurately. Finally, we discuss theoretical implications of our findings, with a particular focus on the relationship between the lexicon and speech production. We conclude by describing some practical suggestions which teachers may use in helping learners improve their L2 pronunciation.

Learning phonological forms of L2 words

The learning of phonological forms is a relatively easy task for adult speakers in their native language (L1). For example, in a series of word learning studies, Gaskell and his colleagues (Davis, Di Betta, Macdonald & Gaskell 2008; Dumay & Gaskell 2007; Gaskell & Dumay 2003) have shown that adults can learn the phonological forms of novel words after 12 repetitions of each word in a task

that spans about 15 minutes. In fact, following such a learning task, adults recognize newly learned word forms with about 90% accuracy (see also Storkel, Armbrüster & Hogan 2006). One reason for the ease with which L1 speakers pick up new sound sequences in their L1 is that their perceptual system is so well attuned to L1 input through years of language experience that they rarely encounter any perceptual difficulty with extracting an unknown sound sequence from the input and then committing it to memory. Put differently, L1 speakers are able to easily and accurately extract novel sound sequences and to store phonological information about these sequences in their lexicons.

In contrast, the task of learning phonological forms of words appears to be far more complicated in the L2. The chief reason for this is that the L2 learner's perceptual system is less well attuned to dealing with L2 input. In fact, it is common knowledge that L2 learners often have problems perceiving certain sound-level (segmental) and phrase-level (suprasegmental) aspects of their L2. Examples of these problems include Japanese speakers' difficulty with distinguishing English /r/ and /l/ (e.g., Hattori & Iverson 2009) or Korean speakers' difficulty with English rhythm (e.g., Trofimovich & Baker 2006). As a result of these perceptual difficulties, L2 learners may not be able to extract all the relevant detail from a novel sound sequence and may store incomplete, impoverished, or otherwise inaccurate phonological information about spoken words in their lexicons (e.g., Cutler, Weber & Otake 2006; Weber & Cutler 2004). For instance, Hayes-Harb and Masuda (2008) showed that, at least early in the learning process, native English speakers could not store the distinction between Japanese singleton and geminate consonants (e.g., [oto] 'sound' vs. [otto] 'husband') in their lexicons, presumably because English does not have a similar contrast.

Researching mental lexicon

How do researchers find out what kind of information is available in L2 learners' lexicons? To answer this question, researchers rely on tasks that require speakers to access the content of word entries in the lexicon. A task commonly used for this purpose is a lexical decision task (see McDonough & Trofimovich 2008 for review, and Altarriba & Knickerbocker; and Williams & Cheung, this volume, for examples of studies using this task). In this task, participants see or hear a sequence of letters or sounds (e.g., *krost*) and decide whether this sequence constitutes a real word in a language. This task is well suited for the study of the lexicon because participants need to access their lexicons in order to decide whether a spoken or written sequence has a corresponding entry there. Thus, for example, if participants hear *stork*, they would search their lexicon for an entry that matches this sound sequence. Once the entry is found and accessed, they would respond that this sequence is indeed a real word.

The study by Pallier, Colomé, and Sebastián-Gallés (2001) provides an example of how a lexical decision task can be adapted to examine the nature of phonological information stored in a lexical entry (see also Cutler & Otake 2004). These researchers used auditory repetition priming in combination with a lexical decision task. In this task, participants made lexical decisions in response to sound sequences twice, with several filler items interspersed between the two repetitions of each target sequence. The logic here was that the first presentation of a sequence would influence (prime) its second presentation, such that participants should respond faster on the second than on the first presentation of the same sequence. This expected improvement in response speed is referred to as an auditory priming effect. As a methodology, auditory priming is particularly well suited for the study of phonological content of lexical entries. This is because auditory priming is sensitive to form-based aspects of speech, such that maximally identical repetitions of sound sequences give rise to the largest priming effect (see McDonough & Trofimovich 2008 for more detail on auditory priming, and Trofimovich 2008 for a sample auditory priming study).

In their study, Pallier et al. (2001) examined what phonological information highly proficient Spanish-Catalan bilinguals use in order to recognize spoken words. They studied two groups of bilinguals: a group dominant in Spanish and a group dominant in Catalan. The target materials were composed of two critical sets of Catalan words. The first set included two identical repetitions of the same word (e.g., /nɛtə/ "clean"), the second set involved two distinct, phonologically contrasting Catalan words (e.g., /nɛtə/ "clean" – /netə/ "granddaughter"). The words in the second set differed by one sound only (/ɛ/-/e/ in this case). However, what is crucial here is that both /e/ and /ɛ/ exist in Catalan but Spanish has only /e/. Pallier et al. predicted that Catalan-dominant bilinguals would demonstrate an auditory priming effect for two repetitions of the same word, but would show no such effect for two repetitions of phonologically contrasting words. This is because the contrasting words have two distinct phonological forms for these bilinguals. A different pattern of findings was predicted for Spanish-dominant bilinguals. They, similar to Catalan-dominant bilinguals, should show an auditory priming effect for two repetitions of the same word. However, these bilinguals might *also* show an auditory priming effect for two repetitions of phonologically contrasting words. This would happen, Pallier et al. argued, if these bilinguals failed to store the distinction between /ɛ/ and /e/ in their lexicons. In this case, for Spanish-dominant bilinguals, the two contrasting words would effectively "behave" as one and the same word, since they would be homophonous.

Table 1. Summary of the priming effects reported by Pallier et al. (2001)

	Identical Catalan word repeated (/nɛtə/-/nɛtə/)	Contrasting Catalan word repeated (/nɛtə/-/netə/)
Catalan-Spanish bilinguals	Yes	No
Spanish-Catalan bilinguals	Yes	Yes

Note. "Yes" and "No" refer to the presence and absence of a significant priming effect.

Table 1 summarizes the findings reported by Pallier et al. (2001). As predicted, these researchers found that both groups of bilinguals demonstrated an auditory priming effect for two identical repetitions of the same Catalan words. However, only Spanish-dominant bilinguals, unlike Catalan-dominant bilinguals, showed an auditory priming effect for two repetitions of phonologically contrasting Catalan words (like /nɛtə/ and /netə/). Put differently, for the Spanish-dominant bilinguals, responses to /nɛtə/ were facilitated by their previous exposure to /netə/ and vice versa. Because Catalan has both /e/ and /ɛ/ but Spanish has only /e/, Pallier et al. concluded that the phonological information stored by Spanish-dominant bilinguals in their lexicons was not sufficiently detailed to help them distinguish two similarly sounding, yet different Catalan words. Thus, even for early bilinguals (exposed to their L2 by age 6), lexical entries for some phonologically contrasting words may lack certain details that appear in L1 lexical entries. Such words may be stored similarly in the mental lexicon, with the result that different L2 words (e.g., /netə/ and /nɛtə/ in Catalan) may in fact have identical (homophonous) phonological content.

To summarize, Pallier et al. (2001) found that Catalan-Spanish bilinguals (for whom Catalan was the L1) behaved predictably like native speakers of Catalan: they showed priming for identical repetitions of Catalan words, but not for repetitions of phonologically contrasting (i.e., phonologically distinct) words. However, Spanish-Catalan bilinguals (for whom Catalan was an L2 learned by the age of 6) behaved differently from native speakers of Catalan: they showed priming for both identical and phonologically contrasting repetitions of Catalan words. This suggested that Spanish-Catalan bilinguals, taken as a group, had failed to store distinct forms for phonologically contrasting L2 words like /nɛtə/ and /netə/ in their mental lexicons.

The current study

For the current study, we adapted the auditory priming methodology used by Pallier et al. (2001) with early bilinguals to examine the phonological content of lexical entries for adult L2 speakers. Our focus was the contrast between English /ð/ and /d/ (as in *they-day*) as well as between English /θ/ and /t/ (as in *three-tree*) for Quebec French speakers of English. Both these contrasts exist in English, whereas only /d/ and /t/ exist in Quebec French. We wished to determine if L2 speakers have identical phonological forms for words like *they* and *day* as well as *three* and *tree* in their lexicons, which would explain L2 speakers' difficulty distinguishing these words. We also wished to determine if L2 speakers would nonetheless at times be able to produce these words accurately. By studying the relationship between the phonological content of lexical entries and speech production, we intended to examine how closely speech production is guided by the lexicon, and whether learners could actually produce phonological contrasts that are difficult for them without having precise phonological information available in their lexicons. As stated earlier, our pedagogical motivations behind this study were to explain to teachers the precise nature of difficulties learners may have with words like *three* and *tree* and to suggest possible learning activities that would help remedy these difficulties.

To address these objectives, we tested a group of L2 speakers of English (all native speakers of Quebec French) and a group of native English controls in an auditory priming task and a production task. Our auditory priming task was modeled after Pallier et al. (2001), with participants sometimes exposed to identical repetitions of words (e.g., *three-three* or *day-day*) and sometimes to phonologically contrasting words (e.g., *three-tree* or *they-day*). In addition, we used the /p/-/t/ contrast (as in *cap-cat*), present in both English and French, as a control condition to examine how both groups of participants would perform on these non-problematic items. For our production task, participants were recorded saying individual words containing English /ð/ and /θ/, and these productions were subsequently evaluated for accuracy by 10 judges.

Both tasks were used to evaluate the two theoretical possibilities we discussed previously. The first possibility was that our participants would be able to distinguish words like *three* and *tree* or *they* and *day* in their mental lexicons but would simply have difficulty producing the difficult /θ/ and /ð/ consonants. In this case, our participants should show no priming effect for repetitions of phonologically contrasting words in the priming task (since these words are two distinct words and therefore should not prime each other), but should simply have trouble articulating the difficult /ð/ and /θ/words in the production task. The second possibility was that our participants would *not* be able to distinguish words like *three* and *tree* or *they* and *day* in their mental lexicons. In this case, our participants should show priming for repetitions of phonologically contrasting words in the priming task. This finding would indicate that these words are not distinguished at the level of the lexicon, and would also suggest that our participants would not

have accurate phonological forms available in their mental lexicon to guide their production of /ð/ and /θ/ words.

Method

Participants

The participants were 16 native English speakers (12 female, 4 male) and 30 L2 speakers (12 female, 18 male). The native English speakers (age: 34.6; range: 19–63) were born to English-speaking parents in Canada (10), the United States (3), and the United Kingdom (3). Although all English speakers reported knowledge of another language (French, Spanish, Danish), they reported being dominant in English and using English at home. All native speakers self-rated their English speaking and listening abilities at a mean of 8.6 (1 = *extremely poor*, 9 = *extremely fluent*). They also reported using English on average 89% in speaking and 86% in listening daily (0 = *not at all*, 100 = *all the time*).

The L2 speakers (age: 32.5; range: 20–60) were born to French-speaking parents in Quebec and had been exposed to Quebec French since birth. All had received primary and secondary education in French and had started learning English at a mean age of 9.7 years as part of formal classroom instruction. The L2 speakers self-rated their French speaking ability at a mean of 8.7 and their French listening ability at a mean of 8.8 (1 = *extremely poor*, 9 = *extremely fluent*). They rated their English speaking and listening ability much lower, at a mean of 5.3 and 6.1, respectively. They also reported relatively little use of English on a daily basis at the time of the study: on average 7.5% of time in speaking and 18.7% in listening.

Materials and procedure

The testing, which lasted about 45 minutes per participant, was conducted individually in a quiet room. The experimental procedure was controlled by E-Prime (Schneider, Eschman & Zuccolotto 2002), and auditory stimuli were presented via Sony (MDR-XD200) stereo headsets. As part of the testing session, participants performed several other tasks (including a perception task and a sentence production task); however, results of these tasks will not be discussed here. For all participants, the order of tasks was the same: they first filled out a background questionnaire, then performed an auditory priming task followed by a word production task. For the L2 participants, all instructions in the auditory priming task were given in French.

Auditory priming task

The target materials for the auditory priming task consisted of 16 pairs of phonologically contrasting /ð/-/d/ and /θ/-/t/ words (e.g., *they-day*, *three-tree*), 16 pairs of phonologically contrasting /t/-/p/ words (e.g., *tool-pool*, *tan-pan*), and 80 nonwords used as fillers (see Appendix for a list of target materials). Our original materials for /ð/-/d/ and /θ/-/t/ words included separate sets for these two contrasts. However, we had to eliminate many of these words because they were of relatively low frequency and thus would have been unknown to our participants (e.g., *bayed-bathe* or *fates-faiths*). Therefore, in order to maintain a list that would be sufficiently large for the priming task, we had to combine the phonologically contrasting /ð/-/d/ and /θ/-/t/ words under one category. The 16 phonologically contrasting /t/-/p/ words were included as control materials to ensure that L2 speakers could perform the auditory priming task as intended with materials that should pose little difficulty for them. The idea here was that L2 speakers would have no trouble with /t/-/p/ words because these sounds exist in English and French, even though they may be realized differently across the two languages at the phonetic level.

All target materials were recorded by a male native speaker of English (age: 45) directly onto a computer using a Plantronics (DSP-300) head-mounted microphone, then saved as digital files and normalized for perceived loudness. The two sets of target words were organized into four counterbalanced study-test list pairs. Each pair contained a 40-word study list and a 40-word test list. An additional 40 unique nonwords were added to each list to make lexical decision judgments possible. Thus, each list contained a total of 80 items. The 40 critical items in each list were composed of 16 /ð/-/d/ and /θ/-/t/ words, 16 /t/-/p/ words, and 8 "baseline" words that were not phonologically contrasting. Of the 16 /ð/-/d/ and /θ/-/t/ words from each study list (e.g., *worthy*, *tie*), 8 were repeated in the test list (e.g., *worthy*); the remaining 8 words were replaced in the test list by minimally contrasting words (e.g., *thigh*). Of the 16 /t/-/p/ words from each study list (e.g., *tale*, *pea*), 8 were repeated in the test list (e.g., *tale*); the remaining 8 words were replaced in the test list by minimally contrasting words (e.g., *tea*). The 8 "baseline" words were unique to each list. Across all lists, each word appeared equally often as a repetition and as a phonologically contrasting word, and each word occurred equally often in study and test lists. Sample materials for study and test lists appear in Table 2.

The auditory priming task consisted of a study and a test phase. In the study phase, participants heard 80 items presented with a 5-second inter-stimulus interval. Participants were told that they would hear some words that were real words in English and some words that were nonsense words. On each trial, participants first saw a written reminder (*Is it a real English word?*) in the middle of the screen,

Table 2. Sample materials for study and test lists in the priming task

	/ð/-/d/ & /θ/-/t/ words	/t/-/p/ words	"baseline" words
Study list	day	taste	sister
	thigh	cup	today
	their	pea	water
	taught	tale	dirty
Test list	(a) day	(b) taste	pencil
	(a) thigh	(b) cup	supper
	(c) dare	(d) tea	many
	(c) thought	(d) pale	country

Note. (a) through (d) refer to the four critical sets of words analyzed in this task: (a) /ð/-/d/ and /θ/-/t/ words repeated verbatim, (b) /t/-/p/ words repeated verbatim, (c) /ð/-/d/ and /θ/-/t/ words repeated as phonologically contrasting words, (d) /t/-/p/ words repeated as phonologically contrasting words.

with the *N* = *No* and *Y* = *Yes* labels displayed below to indicate the location of the response buttons. The reminder stayed on the screen for 2 seconds and was followed by an auditory presentation of a word (or a nonword). Participants were told to press, as rapidly as possible, the 'm' key on the keyboard (marked Y) with their right index finger for a real word or the 'c' key (marked N) with their left index finger for a nonword. Participants were allowed 5 seconds to make a response; otherwise a new trial was initiated automatically. The 80-trial sequence was preceded by a 5-trial practice session. The test phase started immediately after the study phase. Here, participants were told that they would make the same judgments for another set of words, and they proceeded in the same manner as in the study phase. For both the study and the test phase, all trials were randomized for each participant, and participants were assigned equally frequently to the four study-test list pairs.

Word production task

The target materials for the word production task included seven words containing English /ð/ and eight words containing English /θ/ (see Appendix). None of these words appeared in the auditory priming task. The 15 target words and 36 distractor words were organized into two randomized lists. Participants read aloud both lists, recording each word directly onto a computer using a Plantronics (DSP-300) head-mounted microphone. This task was self-paced, such that the next word was shown after the participant recorded the previous one. In order to allow participants an initial practice attempt at producing each word, only the recordings from the second list were analyzed further.

Data analysis

For the auditory priming task, the dependent measure was a repetition priming effect, which was defined for each participant as the mean response latency for repeated words subtracted from the mean response latency for unrepeated, baseline words. Repetition priming effects were calculated for each participant separately for (a) /ð/-/d/ and /θ/-/t/ words repeated verbatim (e.g., *three-three*, *day-day*), (b) /t/-/p/ words repeated verbatim (e.g., *tea-tea*, *tale-tale*), (c) /ð/-/d/ and /θ/-/t/ words repeated as phonologically contrasting words (e.g., *three-tree*, *day-they*), and (d) /t/-/p/ words repeated as phonologically contrasting words (e.g., *tea-pea*, *pale-tale*). These four critical sets of words are illustrated in Table 2. Following standard procedure in priming research, only data for correct responses were included. Also, as commonly done in priming research, exceedingly long responses (above 2 s), which likely reflect slow, effortful, and strategic processing, were considered outliers and were removed. Incorrect responses and outlier response latencies account altogether for about 12% of the data.

For the word production task, the dependent measures were production accuracy scores for /ð/ and /θ/. These measures were derived from the judgments of 10 native English listeners (6 female, 4 male; age: 26–55) who rated English /ð/ or /θ/ in each word for accuracy. The listeners, who were tested individually, were asked to make a binary decision about these sounds in each word ("sounds like a good English /ð/ or /θ/" or "does not sound like an English /ð/ or /θ/"), without distinguishing various degrees of accuracy. The listening session was self-paced, and the listeners were allowed to listen to each word, re-play it, and change their responses as many times as they wished. With rare exceptions, all maintained an efficient scoring pace, making accuracy decisions without frequent re-playing of recordings and changing of the ratings given. The listeners were consistent in their ratings (Cronbach α = .82–.98). Therefore, production accuracy scores for /ð/ and /θ/ were computed for each participant by averaging the correct ratings given by the 10 judges across the seven /ð/ and the eight /θ/ words produced.

Results

Auditory priming task

We first compared the performance of both groups of participants on exact repetitions of words. The goal of this analysis was to confirm the expected finding in the priming literature, namely, that language users respond faster to a word that has been experienced previously. In this case, we did not expect any differences

between the two groups of participants. We predicted that both groups would show an auditory priming effect for exact repetitions of both /ð/-/d/ and /θ/-/t/ words (e.g., *they-they*, *three-three*) as well as /t/-/p/ words (e.g., *tan-tan*, *pan-pan*). Thus, for all speakers, accessing a lexical entry for a word on one occasion should help speakers access the entry for the same word on another occasion. For this analysis, we submitted the priming effects for exact repetitions of words to a two-way repeated-measures analysis of variance (ANOVA), with group (native speakers, L2 speakers) as a between-subjects factor and word type (/ð/-/d/ and /θ/-/t/ vs. /t/-/p/) as a within-subjects factor. This analysis yielded no significant effects or interactions, $F < 2.78$, $p > .10$. Figure 1[1] displays these findings graphically (the higher the bar, the larger the priming effect). Therefore, the finding of this analysis was that both groups of participants showed statistically comparable priming effects for exact repetitions of words from phonologically difficult contrasts (ð/-/d/ and /θ/-/t/) and from a phonologically easy one (/t/-/p/).

In our next analysis, we compared the performance of both participant groups on repetitions of phonologically contrasting words. This analysis was critical for testing between the two alternative possibilities we discussed earlier. Our goal

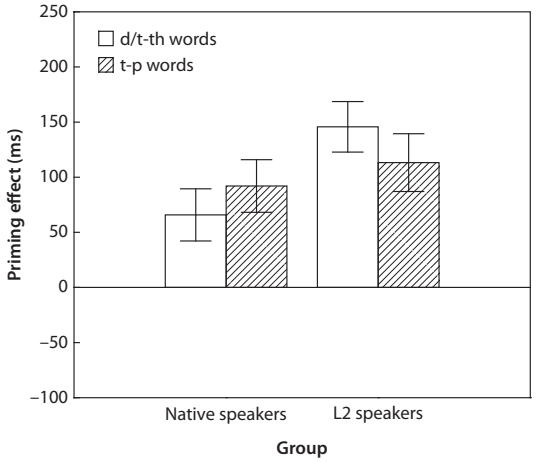

Figure 1. Mean priming effects for exact repetitions of words: (a) /ð/-/d/ and /θ/-/t/ words repeated verbatim and (b) /t/-/p/ words repeated verbatim. Brackets enclose ± 1 standard error.

1. For Figures 1 and 2, the descriptions of part labels are discussed in captions (a and b in Figure 1, c and d in Figure 2) but part labels (a, b, c, d) are not indicated in figures.

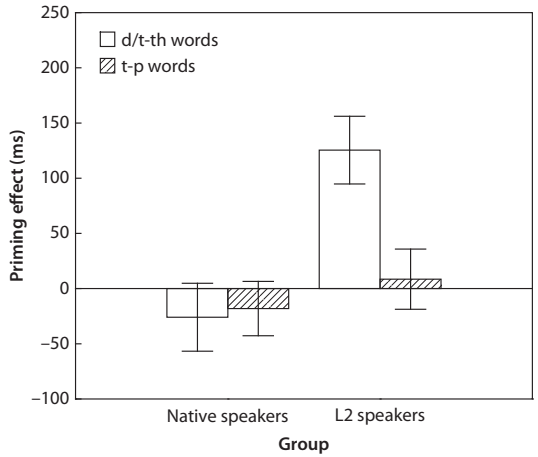

Figure 2. Mean priming effects for repetitions of phonologically contrasting words: (c) /ð/-/d/ and /θ/-/t/ words repeated as phonologically contrasting words and (d) /t/-/p/ words repeated as phonologically contrasting words. Brackets enclose ± 1 standard error.

was to determine if both groups of participants treat phonologically contrasting words (i.e., words with distinct phonological forms) as truly distinct at the level of the lexicon. We predicted that the native speakers would show no auditory priming effect for repetitions of these words because native speakers treat these words as distinct and, as a result, have distinct entries for them in their lexicons. However, we predicted that the L2 speakers would show an auditory priming effect for repetitions of phonologically contrasting /ð/-/d/ and /θ/-/t/ words (e.g., *they-day*, *three-tree*), but not for repetitions of /t/-/p/ words (e.g., *tan-pan*). Our expectation was that the L2 speakers would have difficulty distinguishing /ð/-/d/ and /θ/-/t/ contrasts in their lexicons, but would have little trouble with the /t/-/p/ contrast.

We submitted the priming effects for repetitions of phonologically contrasting words to a similar ANOVA as before. This analysis yielded a significant main effect for group, $F(1, 44) = 7.09$, $p = .011$, and a significant group × word type interaction, $F(1, 44) = 4.37$, $p = .042$, but no significant main effect for word type, $F(1, 44) = 3.35$, $p > .05$. Figure 2 depicts these results in a graphical format. As predicted, the native speakers showed similar priming effects for both sets of phonologically contrasting words, $t(15) = .18$, $p = .86$. These effects were negligible in magnitude and were not different from zero. However, the L2 speakers showed a much larger priming effect for /ð/-/d/ and /θ/-/t/ words than for /t/-/p/ words, $t(29) = 3.15$, $p = .004$. The priming effect for /ð/-/d/ and /θ/-/t/ words was on

Table 3. Summary of the priming effects in the priming task

	Identical word repeated		Contrasting word repeated	
	/ð/, /d/ & /θ/, /t/	/t/, /p/	/ð/-/d/ & /θ/-/t/	/t/-/p/
Native speakers	Yes	Yes	No	No
L2 speakers	Yes	Yes	Yes	No

Note. "Yes" and "No" refer to the presence and absence of a significant priming effect.

average +125 ms while the priming effect for /t/-/p/ words was not different from zero. Therefore, the finding of this analysis was that only the L2 speakers demonstrated an auditory priming effect for repetitions of phonologically contrasting words, and only when these words contained phonologically difficult contrasts /ð/-/d/ and /θ/-/t/.

The results of the auditory priming task are summarized in Table 3. Overall, we found that for identical repetitions of spoken words, both native and L2 speakers demonstrated significant priming effects. This finding is consistent with previous research showing that prior experience with a phonological form of a spoken word on one occasion facilitates subsequent processing of the same phonological form on another occasion (for review, see McDonough & Trofimovich 2008). However, for repetitions of distinct, phonologically contrasting words, only the L2 speakers showed a significant priming effect and only in one case: when these words contained the phonologically difficult contrasts /ð/-/d/ and /θ/-/t/ (i.e., not when the words contained the /t/-/p/ contrast). This finding suggested that the L2 speakers did not distinguish words like *three* and *tree* or *they* and *day* at the level of the lexicon.

Word production task

Thus far, our findings have been consistent with the second possibility we discussed earlier. We found that the L2 speakers in this study did not seem to be able to distinguish phonologically contrasting words containing English /ð/-/d/ and /θ/-/t/ at the level of the lexicon. In other words, what on the surface seems to be a "straightforward" sound substitution error may in fact have "deeper" psycholinguistic origins. As we argued earlier, this finding could explain why L2 speakers often fail to produce English /ð/ and /θ/ words accurately. However, this interpretation invites a further question: is it the case that not being able to distinguish some L2 words from other lexical items necessarily leads to inaccurate production of these words? The goal of the next analysis was therefore to examine whether L2 speakers could produce words containing English /ð/ and /θ/ accurately. Through

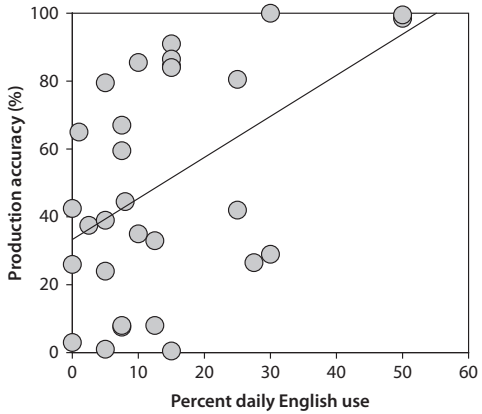

Figure 3. The relationship between L2 speakers' daily English use (0–100% scale) and their production accuracy for English /ð/ and /θ/, with a regression line showing the best fit to the data.

this analysis, we wished to determine the extent to which L2 speech production is guided by the lexicon.

Overall, the native speakers were much more accurate than the L2 speakers in their production of words containing English /ð/ (93% vs. 50% correct) and English /θ/ (97% vs. 48% correct). These differences between the two groups were also highly significant statistically, $t(44) > 5.02$, $p < .0001$. However, the L2 speakers showed a lot of variability in their production scores. Figure 3 shows the L2 speakers' combined accuracy for English /ð/ and /θ/ words plotted as a function of these speakers' amount of self-reported daily English use. As can be seen from this graph, the L2 speakers' production scores ranged from 0% to 100%, and there was a statistically significant positive relationship between these speakers' production accuracy and their daily English use, $r(29) = .46$, $p = .004$. Even though the L2 speakers overall reported relatively little use of English daily (0–50%), those who tended to use English more often on a daily basis also tended to produce English /ð/ and /θ/ more accurately.

When we plotted a similar relationship between the L2 speakers' priming effects for phonologically contrasting /ð/-/d/ and /θ/-/t/ words and their amount of self-reported daily English use, we failed to find a similar positive relationship. In fact, this relationship was close to zero, $r(29) = .03$, p = n.s., as shown in Figure 4. This suggested that those who tended to use English more often on a daily basis were not necessarily those who showed smaller (i.e., more nativelike) priming effects for repetitions of phonologically contrasting /ð/-/d/ and /θ/-/t/ words. In

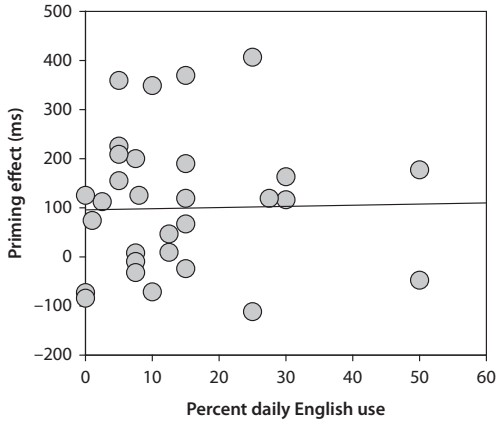

Figure 4. The relationship between L2 speakers' daily English use (0–100% scale) and their auditory priming scores (in milliseconds) for phonologically contrasting /ð/-/d/ and /θ/-/t/ words, with a regression line showing the best fit to the data.

fact, the L2 speakers' production scores for /ð/ and /θ/ were not associated with the magnitude of their auditory priming effects for repetitions of phonologically contrasting /ð/-/d/ and /θ/-/t/ words, $r(29) < .22$, $p > .13$. Therefore, the main result of the production task was that at least some L2 speakers were able to produce words containing English /ð/ and /θ/ accurately, but that their accuracy was unrelated to their ability to distinguish difficult /ð/-/d/ and /θ/-/t/ contrasts in the lexicon.

Discussion

Our goal for this study was to examine whether a seemingly "simple" sound substitution error has its origins in the L2 lexicon. We found that our L2 speakers as a group appeared not to be able to distinguish words like *they* and *day* as well as *three* and *tree* in their lexicons. However, these speakers, particularly those who tended to use their L2 more often on a daily basis, were able to produce at least some words containing difficult /ð/ and /θ/ consonants accurately. Taken together, our findings suggest that speech production was not strictly limited by the lexicon, at least for these L2 speakers. Put differently, the speakers could at times produce phonological contrasts even without having precise phonological information available to them in their lexicons.

Of course, this conclusion needs to be treated with caution for at least two reasons. One reason is that the words used in our word production task were not the same as those included in the auditory priming task (i.e., the task we used to examine the phonological content of lexical entries). An overlap in task materials would have created an unnecessary confound by giving our participants practice with the same materials across the two tasks. However, this methodological issue opens up the (albeit unlikely) possibility that our L2 speakers may have had precise phonological information stored in their lexicons for the very words they were asked to produce. Another reason to interpret our conclusions cautiously is that the words targeted in our word production task could have been somewhat more familiar to our participants than the words included in the auditory priming task. If the words from the word production task were indeed more familiar to our participants, then they could have been more likely to create nativelike lexical entries for these words, which would in turn enable them to produce the words more accurately. Despite these possible alternative interpretations, our results do imply that seemingly simple sound substitution pronunciation errors have deeper psycholinguistic origins and that L2 speakers' lexicons may not necessarily closely reflect what L2 speakers can produce. In the remainder of this chapter, we discuss two questions raised by our findings.

Speech production and L2 lexicon

The first question is theoretical in nature: How do L2 speakers manage to produce difficult L2 contrasts, such as /ð/-/d/ and /θ/-/t/, if they do not distinguish these contrasts in their mental lexicons? This issue is reminiscent of a relatively common observation from L2 speech research, namely, that some L2 speakers are able to produce L2 contrasts that they are not able to distinguish perceptually (e.g., Sheldon & Strange 1982; see also Baker & Trofimovich 2006). At least one possibility here is that explicit pronunciation instruction, particularly audiovisual training and teaching emphasis on articulatory (motor) properties of speech production, could help learners produce L2 words accurately without having precise phonological information available to guide their articulation. For example, Hazan, Sennema, Iba, and Faulkner (2005) showed that audiovisual training – a procedure whereby learners are able to both see and hear a speaker produce words with difficult L2 contrasts – was beneficial in helping Japanese learners improve not only in their perception but also in their production of two English contrasts (see also Hardison 2003). Most strikingly, the effect of this training was most pronounced for a contrast in which articulatory gestures are distinctive (as in /b/-/v/ where the difference between bilabial /b/ and labiodental /v/ is visually apparent)

as opposed to a contrast with less distinctive articulatory gestures (as in /r/-/l/). Given that English /ð/ and /θ/, as interdental fricatives, are quite distinctive in their articulatory gestures, it is not surprising that at least some L2 speakers could pick up, either through explicit instruction or through observing the speech of others, how these two consonants are produced and could use this information to guide their production.

Another possibility that could explain how L2 speakers can produce English /ð/ and /θ/ without being able to distinguish them from /d/ and /t/ in their mental lexicons is that L2 speakers make use of orthographic information in their speech perception and production. For instance, Escudero, Hayes-Harb and Mitterer (2008) found that the presence of orthographic information during novel word learning had a powerful influence on what information L2 learners actually stored in their lexical entries for these words. These researchers showed that L2 learners are often not able to learn difficult phonological contrasts (similar to English /ð/-/d/ and /θ/-/t/) without having orthographic information available to them at the time of learning. Because English /ð/ and /θ/ are spelled consistently in English as 'th', this information might therefore be effectively used by learners to accurately produce words containing /ð/ and /θ/.

Yet another possibility that would increase the likelihood that L2 speakers produce English /ð/ and /θ/ without being able to distinguish them from /d/ and /t/ in their mental lexicons might be related to a sociolinguistically motivated tendency. One such tendency is hypercorrection, which refers to the overproduction of a speech element from one speech variety in another speech variety (see Janda & Auger 1992). The crucial point here is that the overproduced element is valued by the speakers according to some criterion. A well-known example of hypercorrection comes from Labov's study of the use of post-vocalic /r/ (as in *car*) in the speech of New Yorkers of different social classes (e.g., Labov 1972). Labov documented that post-vocalic /r/ is variably deleted in the speech of all New Yorkers, but generally less so for people from the upper levels of society. As a consequence, post-vocalic /r/ has developed into a prestige marker associated with the distinguished speech of the educated and the upper classes. Interestingly, however, Labov found greater frequency of post-vocalic /r/ by lower-middle-class speakers than by upper-class speakers in more formal styles of speech. Such overproduction of the prestige marker in the speech of those who do not normally speak the prestige variety is what is termed hypercorrection.

It is possible that the production of English /ð/ and /θ/ in the speech of at least some native French speakers of English may be a form of hypercorrection (see John & Cardoso 2009 for another example of hypercorrection in L2 speech). The substitution of English /ð/ and /θ/ by /d/ and /t/ in the speech of Quebec francophones is well documented and represents an important marker of ethnolinguistic identity for Quebec francophones (e.g., Gatbonton 1975; Gatbonton & Trofimovich 2008; Gatbonton, Trofimovich & Segalowitz, in press). Because these substitution errors clearly mark L2 speakers as belonging to the francophone group, at least some members of this group may continue producing English /ð/ and /θ/ as /d/ and /t/ as a way of maintaining their L1 identity. Others, however, may prize authentic production of English /ð/ and /θ/ because of the prestige associated with speaking English like a native speaker. These speakers would probably prefer to minimize /ð/ and /θ/ substitution errors as one of the most salient features of their L2 accent.

Building an L2 lexicon

The second question raised by our results is pedagogical: How can L2 teachers help their learners to not only perceive and produce L2 sounds and words accurately but also to build more nativelike L2 lexicons? The main issue here is to help learners distinguish English /ð/ from /d/ and English /θ/ from /t/ in perception and production, which can be done by using a variety of listening and speaking activities widely available in published pronunciation textbooks (e.g., Celce-Murcia, Brinton & Goodwin 1996). Central to this issue, however, is the challenge for learners to notice, extract, and store the relevant phonological information about English /ð/ or /θ/ with the lexical entry for a given word containing an interdental fricative. Put differently, learners must be able to associate the phonological differences between words like *three* and *tree* or *they* and *day* with the relevant lexical entries in their mental lexicons, such that, for example, /θ/ (as opposed to /t/) would be associated with *three* while /ð/ (but not /d/) would be linked with *they*.

One pedagogical possibility that comes to mind in order to help learners build more nativelike L2 lexicons is to rely more on the use of pictures in pronunciation training. The argument here is that pictures can be used to encourage learners to develop distinct rather than homophonous phonological forms for certain "tricky" lexical items, partly by providing learners with clear access to the meanings of the words depicted. Therefore, by looking at pictures of objects and hearing the pronunciation of object names, learners will be better able to associate accurate pronunciations with word entries in the mental lexicon. Figure 5 shows a sample listening activity of this kind, with response options given as pictures. In this case, learners are not simply asked to respond "same" or "different," identify the sound being targeted, circle the spelling of a word, or indicate which word contains the target sound. Rather, learners are required to select the image that

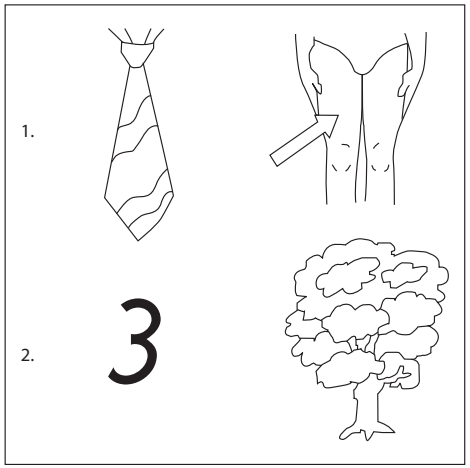

Figure 5. An example of a listening identification activity using pictures.

best represents the word they just heard. For example, if they hear *thigh*, they should circle the image of a thigh; if they hear *tree*, they should choose the image of a tree. It is likely that by engaging in activities of this kind, learners will be able not only to perceive the difference between two confusable sounds but also to associate the correct pronunciation of a sound with the relevant word meaning. Although English /ð/ and /θ/ distinguish relatively few word pairs in English (Munro & Derwing 2006) and the words they distinguish may not be easily picturable (e.g., *doze-those*, *true-threw*), picture-based activities, such as picture stories and pronunciation bingo with pictures, may be useful in helping learners create nativelike lexical entries for words containing other difficult L2 contrasts, especially those whose mispronunciation clearly impedes communication (Levis & Cortes 2008).

Another pedagogical possibility that could help learners build nativelike L2 lexicons is to rely on orthography in L2 pronunciation teaching (Altarriba & Knickerbocker, this volume, provide further evidence on the important role of orthographic information in learning novel L2 words). An explicit emphasis on the use of spelling regularities to predict L2 pronunciation has been advocated extensively by Dickerson (1978, 1987, 1990). The idea here is that spelling regularities in a language often provide learners with enough cues to enable them to determine the correct pronunciation of an unknown word without recourse to native speaker pronunciation models or extensive knowledge of phonetics and

phonology. An explicit instructional focus on the link between spelling regularities and pronunciation may be beneficial in helping learners build nativelike L2 lexicons because learners will be better able to predict accurate pronunciations from spelled word forms, thus linking the correct pronunciation of a sound with a word's spelled form and its meaning. Dickerson (1987), for instance, shows that the spelling 'th' followed by a vowel in English function words is always pronounced as /ð/ (e.g., *them, although, either, than, nevertheless*). He also points out that the spelling 'ther' followed by an 'n' or a "weak ending" (such as -ed, -ing, or -y) predicts the /ð/ pronunciation (e.g., *northern*, *brotherly*, *withering*, *blithering*, *father*), and that most other cases of 'th' spelling uniformly predict the /θ/ pronunciation (*northwest*, *tooth*, *athletic*, *isotherm*, *therapy, thin*). Of course, to benefit from such spelling regularities, learners first need to be aware of precise articulatory gestures associated with English /ð/ or /θ/. Once the articulation of English /ð/ or /θ/ poses little difficulty, learners (particularly those at intermediate or advanced levels) can then successfully use spelling-based rules to perceive and produce these words accurately. This should eventually help them distinguish phonologically contrasting words like *three* and *tree* as well as *they* and *day* in their lexicons.

Concluding remarks

We began our chapter by citing an English narrative spoken by a native speaker of Quebec French. This speaker, like many francophone speakers of English from Quebec, consistently substitutes English /ð/ or /θ/ (as in *they* and *three*) with /t/ and /d/, so that these words come out sounding like *day* and *tree*. Although L2 learner mispronunciations of English /ð/ and /θ/ may not greatly impede learner interaction with either native speakers or other learners (Jenkins 2000; Levis & Cortes 2008), such substitutions are a particularly salient feature of the L2 accent, so a better understanding of their dynamics is invaluable. Our results show that L2 speakers are often unable to extract and store precise phonological information about spoken words in their L2 lexicons.

This conclusion raises an important issue, namely, why should it matter if L2 learners extract and store precise phonological information about spoken words in their lexicons? Indeed, we have shown that at least with respect to producing speech, L2 speakers may rely on several strategies to cope with their difficulties in building nativelike L2 lexicons. As we have speculated earlier, these strategies may include using articulatory (visual) information about how sounds are

produced, attending to L2 orthographic regularities, or engaging in a sociolinguistically-motivated strategy in order to produce L2 words authentically. Nevertheless, there are at least two reasons why building a nativelike L2 lexicon seems to be an appropriate goal for L2 learning and teaching. One reason for this is that not all L2 learners may be able to successfully use alternative strategies to produce L2 words accurately. As shown in Figure 3, less than half of the L2 participants tested in this study were able to produce English /ð/ or /θ/ at or above 50% accuracy. Similarly, even though some participants were able to produce English /ð/ or /θ/ in the apparent absence of an accurate phonological form, their production was considerably more variable than that of the native speakers. Hence, any compensatory strategies the L2 speakers may have used were less reliable in ensuring accurate production than the L1 strategy of storing contrasts in the lexicon. What could help these speakers improve their production of L2 words and, ultimately, build their L2 lexicons are pedagogical interventions of the kind we discussed in this chapter, coupled with massive amounts of L2 exposure and experience (see Williams & Cheung, this volume, for discussion of experience in word learning).

Another reason for helping learners build nativelike L2 lexicons is that imprecise, non-target phonological information stored as part of lexical entries for L2 words may have negative consequences for speech comprehension. As Pallier et al. (2001) argued, if L2 speakers are unable to store precise phonological information about L2 words in their lexicons, speakers would have to cope with much more uncertainty because the input they hear may map less readily onto the contents of their lexical entries (see also Broersma & Cutler 2009). For instance, because L2 speakers may be unable to distinguish /θ/ from /t/, a spoken word like *three* not only will be congruent for many speakers with lexical entries for words like *three* and *tree* but also will "compete" (early in the word recognition process) with a lot of other words sharing similar phonology (e.g., *thrive*, *throb*, *trust*, *trim*, *treason*). At least some of these other words (e.g., *trust*, *trim*, *treason*) could be eliminated from lexical competition if speakers are able to extract and store precise phonological information about spoken words in their L2 lexicons, thus making the word recognition process faster and more efficient. All in all, our results, first, demonstrate the value of researching seemingly "simple" pronunciation errors from a psycholinguistic perspective, particularly using priming methods to probe the phonological forms that learners store in the mental lexicons and that may underlie mispronunciations, and, second, they point to possible pedagogical solutions that teachers may use in helping learners improve their L2 pronunciation.

Acknowledgements

This project was supported by Social Sciences and Humanities Research Council of Canada (SSHRC) and Fonds québécois de la recherche sur la société et la culture grants to Pavel Trofimovich. The authors would like to thank Yvette Relkoff and Randall Halter for their help with all aspects of this study and Sarita Kennedy for her helpful comments on an earlier version of this paper.

References

Baker, W., & Trofimovich, P. (2006). Perceptual paths to accurate production of L2 vowels: The role of individual differences. *International Review of Applied Linguistics in Language Teaching (IRAL)*, *44*, 231–250.

Bohn, O.-S., & Munro, M. J. (Eds.). (2007). *Language experience in second language speech learning: In honor of James Emil Flege*. Amsterdam: John Benjamins.

Broersma, M., & Cutler, A. (2009). Phantom word activation in L2. *System*, *36*, 22–34.

Celce-Murcia, M., Brinton, D., & Goodwin, J. (1996). *Teaching pronunciation: A reference for teachers of English to speakers of other languages*. Cambridge: Cambridge University Press.

Cutler, A., & Otake, T. (2004). Pseudo-homophony in non-native listening. *Journal of Acoustical Society of America, 115,* 2392.

Cutler, A., Weber, A., & Otake, T. (2006). Asymmetric mapping from phonetic to lexical representations in second-language listening. *Journal of Phonetics*, *34*, 269–284.

Davis, M. H., Di Betta, A. M., Macdonald, M. J. E., & Gaskell, M. G. (2008). Learning and consolidation of novel spoken words. *Journal of Cognitive Neuroscience*, *21*, 803–820.

Dell, G. S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of Memory and Language*, *27*, 124–142.

Dickerson, W. B. (1978). English orthography: A guide to word stress and vowel quality. *International Review of Applied Linguistics in Language Teaching (IRAL)*, *16*, 127–147.

Dickerson, W. B. (1987). Orthography as a pronunciation resource. *World Englishes*, *6*, 11–20.

Dickerson, W. B. (1990). Morphology via orthography: A visual approach to oral decisions. *Applied Linguistics*, *11*, 238–252.

Dumay, N., & Gaskell, M. G. (2007). Sleep-associated changes in the mental representation of spoken words. *Psychological Science*, *18*, 35–39.

Escudero, P., Hayes-Harb, R., & Mitterer, H. (2008). Novel second-language words and asymmetric lexical access. *Journal of Phonetics*, *36*, 345–360.

Gaskell, M. G., & Dumay, N. (2003). Lexical competition and the acquisition of novel words. *Cognition*, *89*, 105–132.

Gatbonton, E. (1975). *Systematic variations in second language speech: A sociolinguistic study.* Unpublished doctoral dissertation, McGill University, Montreal, Canada.

Gatbonton, E., & Trofimovich, P. (2008). The ethnic group affiliation and L2 proficiency link: Empirical evidence. *Language Awareness*, *17*, 229–248.

Gatbonton, E., Trofimovich, P., & Segalowitz, N. (in press). Ethnic group affiliation and pattern of development of a phonological variable. *Modern Language Journal*.

Hardison, D. (2003). Acquisition of second-language speech: Effects of visual cues, context and talker variability. *Applied Psycholinguistics*, *24*, 495–522.

Hattori, K., & Iverson, P. (2009). English /r/-/l/ category assimilation by Japanese adults: Individual differences and the link to identification accuracy. *Journal of the Acoustical Society of America*, *125*, 469–479.

Hayes-Harb, R., & Masuda, K. (2008). Development of the ability to lexically encode novel second language phonemic contrasts. *Second Language Research*, *24*, 5–33.

Hazan, V., Sennema, A., Iba, M., & Faulkner, A. (2005). Effect of audiovisual perceptual training on the perception and production of consonants by Japanese learners of English. *Speech Communication*, *47*, 360–378.

Janda, R. D., & Auger, J. (1992). Quantitative evidence, qualitative hypercorrection, sociolinguistic variables – and French speakers' 'eadhaches with English h/Ø. *Language & Communication*, *12*, 195–236.

Jenkins, J. (2000). *The phonology of English as an international language*. Oxford: Oxford University Press.

John, P., & Cardoso, W. (2009). Francophone ESL learners' difficulties with English /h/. In B. Baptista, A. Rauber, & M. Watkins (Eds.), *Recent research in second language phonetics/phonology: Perception and production* (pp. 118–140). Newcastle Upon Tyne: Cambridge Scholars.

Labov, W. (1972). *Sociolinguistic patterns*. Philadelphia, PA: University of Pennsylvania Press.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*, 1–38.

Levis, J., & Cortes, V. (2008). Minimal pairs in spoken corpora: Implications for pronunciation assessment and teaching. In C. A. Chapelle, Y. R. Chung, & J. Xu (Eds.), *Towards adaptive CALL: Natural language processing for diagnostic language assessment* (pp. 197–208). Ames, IA: Iowa State University.

McDonough, K., & Trofimovich, P. (2008). *Using priming methods in second language research*. New York, NY: Routledge.

Munro, M. J., & Derwing, T. M. (2006). The functional load principle in ESL pronunciation instruction: An exploratory study. *System*, *34*, 520–531.

Pallier, C., Colomé, A., & Sebastián-Gallés, N. (2001). The influence of native-language phonology on lexical access: Exemplar-based vs. abstract lexical entries. *Psychological Science*, *12*, 445–449.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh, PA: Psychology Software Tools, Inc.

Sheldon, A., & Strange, W. (1982). The acquisition of /r/ and /l/ by Japanese learners of English: Evidence that speech production can precede speech perception. *Applied Psycholinguistics*, *3*, 243–261.

Storkel, H. L., Armbrüster, J., & Hogan, T. P. (2006). Differentiating phonotactic probability and neighborhood density in adult word learning. *Journal of Speech, Language, and Hearing Research*, *49*, 1175–1192.

Trofimovich, P. (2008). What do second language listeners know about spoken words? Effects of experience and attention in spoken word processing. *Journal of Psycholinguistic Research*, *37*, 309–329.

Trofimovich, P., & Baker, W. (2006). Learning second-language suprasegmentals: Effect of L2 experience on prosody and fluency characteristics of L2 speech. *Studies in Second Language Acquisition*, *28*, 1–30.

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language*, *50*, 1–25.

Wenk, B. J. (1979). Articulatory setting and de-fossilization. *Interlanguage Studies Bulletin*, *4*, 202–220.

Appendix

Target words used in the auditory priming task

/ð/-/d/ and /θ/-/t/ word pairs		/t/-/p/ word pairs	
Dan	than	tail	pale
dare	their	tan	pan
day	they	taste	paste
den	then	till	pill
doze	those	tool	pool
dough	though	cat	cap
breeding	breathing	sheet	sheep
wordy	worthy	coat	cope
tank	thank	shot	shop
team	theme	tray	pray
tree	three	tour	poor
tie	thigh	teach	peach
true	threw	toast	post
taught	thought	tea	pea
boat	both	type	pipe
mat	math	cut	cup

Target words used in the word production task

/ð/ words	/θ/ words
brother	author
either	bath
leather	healthy
northern	nothing
rather	think
that	thirty
them	thousand
	tooth