Cross-language perception of final stops in Thai and English: A comparison of native and non-native listeners

Kimiko Tsukada

MARCS Auditory Laboratories
University of Western Sydney, Australia
k.tsukada@uws.edu.au

Abstract

This study examined Australian English speakers' and Thai-English bilingual speakers' ability to perceive word-final stops in English and Thai. Thai bilinguals lived in Sydney, Australia, for 5.5 years on average (*range* = 0.2 – 30.3). In Experiment 1 (categorial discrimination test), Thai bilinguals were able to discriminate stop contrasts differing in place of articulation in their two languages with equally high degree of accuracy, but English-speaking listeners' discrimination was good only for English. In Experiment 2 (identification test), English stops produced by native Thai speakers were perceived most accurately by both English and Thai listeners. English listeners' performance deteriorated when they heard stops in unfamiliar languages. There appeared to be a positive cross-language transfer effect when Thai listeners heard Korean stimuli, as word-final stops in both Thai and Korean are phonetically realized as unreleased stops. Despite a large variation in length of residence in English-speaking countries, Thai bilinguals were a homogeneous group with respect to their patterns of stop perception. This suggests robustness of the L1 perception system in adult bilinguals.

1. Introduction

It is generally agreed that previous linguistic experience in first language (L1) has a profound influence on subsequent second language (L2) learning (Flege 2003). There is, however, limited research on the effect of L2 learning on L1 (Guion, Flege, and Loftin 2000; Guion 2003). In other words, our current knowledge of if and how one's L1 might change after an extensive exposure to L2 seems rather limited. However, there is a suggestion that L2 learning might result in a change in feature weighting (Gottfried and Beddor 1988). This implies that it is at least theoretically possible that an L1 sound system might change as a result of L2 learning. Recently, Guion (2003) provided vowel production data which suggest that Quichua-Spanish bilinguals' two vowel systems show plasticity and influence each other. As for L2 effect on the production/perception of L1 consonants, researchers examined, among other things, how variation in voice onset time (VOT) is processed by bilinguals (Flege and Hillenbrand 1984; Williams 1979).

This study examines the perception of final English and Thai stops by two groups of listeners: Thai-English bilinguals and Australian English (AE) speakers living in Sydney, Australia. Some cross-language studies investigated English speakers' perception of Thai stops varying in VOT (Beach, Burnham, and Kitamura 2001; Pater 2003). In general, English listeners were better at perceiving Thai stimuli differing in the presence or absence of aspiration (i.e., /p/ vs. /p^h/) than the stimuli differing in the voicing status (i.e., /b/ vs. /p/). The present study departs from previous research and examines the perception of native and non-native stop place contrasts which are functional (i.e., phonemic) in both Thai and English, but are phonetically realized differently as described below.

Word-final stops are *invariably unreleased* in Thai and *variably released* in English. Previous research identified several factors that influence the frequency of occurrence of final release bursts in English. These include the identity of the preceding vowel (Lisker 1999; Parker and Walsh 1981), gender of the talker (Byrd 1992; Byrd 1993; Byrd 1994), place of articulation (Byrd 1993; Crystal and House 1988), dialect (Byrd 1992), speaking style (Bond and Moore 1994; Picheny, Durlach, and Braida 1985; Picheny, Durlach, and Braida 1986) and the position of the stop within the utterance (Halle, Hughes, and Radley 1957). Although the presence or absence of release does not signal a change in meaning in English, released stops are known to be more intelligible than unreleased stops (Householder 1956; Malécot 1958; Wang 1959). Word-final stops in Thai, on the other hand, are always unreleased (Tingsabadh and Abramson 1993) as in some other Asian languages such as Cantonese, Korean and Vietnamese. However, there is some evidence that the lack of release bursts does not impair intelligibility at least for native speakers of those languages (Abramson and Tingsabadh 1999).

The aim of this study was to compare the perception of Thai bilinguals and Australian English speakers when they process final stops contrasting in place of articulation (i.e., /p t k/) in their native and non-native languages.

2. Experiment 1: Discrimination

The purpose of this experiment was to assess the discrimination of English and Thai stop place contrasts by AE listeners and Thai bilinguals.

2.1. Method

2.1.1. Stimuli

English and Thai monosyllabic (/CVC/) words ending with /p t k/ were used as stimuli. The AE and Thai speakers were recorded in a studio in MARCS Auditory Laboratories at University of Western Sydney, Australia. Test words

Proceedings of the 10th Australian International Conference on Speech Science & Technology
Macquarie University, Sydney, December 8 to 10, 2004.

Accepted after full paper review

(all real words in English or Thai) were presented to each speaker in randomized orders. Thai words were transcribed using Thai scripts and had either high or low tones. The recorded speech materials were digitized at 44.1 kHz using CoolEdit and test words were segmented and stored in separate files. Tokens from three female speakers were used for English stimuli and tokens from three male speakers were used for Thai stimuli. All English final stops were produced with an audible release burst.

2.1.2. Listeners

Two groups of listeners participated: A group of 23 native Thai speakers (5 male, 18 female) with a mean age of 30.6 years (*sd* = 11.0, *range* = 17 – 57) and a group of 10 AE listeners (1 male, 9 female) with a mean age of 23.4 years (*sd* = 9.3, *range* = 18 – 48). All of them reported normal hearing and had no history of language problems.

Thai bilinguals' mean length of residence (LOR) in Australia was 5.5 years (*sd* = 6.2, *range* = 0.2 – 30.3). Their mean age of arrival (AOA) in Australia was 24.9 years (*sd* = 7.1, *range* = 14 – 41). They were paid for their participation. Ten English-speaking listeners were enrolled in first-year Psychology course at University of Western Sydney. They received credit points for their participation. None of them had any knowledge of Thai. All participants were tested individually in MARCS Auditory Laboratories in a single session lasting about 45 to 60 minutes.

2.1.3. Task

A categorial discrimination test (CDT) employed in previous L2 speech research (Flege, MacKay, and Meador 1999; Guion, Flege, Akahane-Yamada, and Pruitt 2000; Flege 2002; Flege and MacKay 2004) was used. The stimuli were presented in triads via headphones at a self-selected comfortable level using a notebook computer. Each contrast was tested by change and no-change trials. The three stop tokens in all change and no-change trials were spoken by different talkers, and so were always physically, if not phonetically, different. Listeners were asked to choose a word that was different from the other two, if there was any.

The change trials contained an odd item out. For example, a change trial testing the /p/-/t/ contrast might consist of /p/$_2$ /t/$_1$ /p/$_3$ (where the subscripts indicate different talkers). The correct response for change trials was the button ("1", "2", or "3") indicating the position of the odd item out, which occurred with near-equal frequency in all three possible serial positions. The change trials tested the participants' ability to respond appropriately to relevant phonetic differences between tokens and distinguish stops drawn from two different categories.

The correct response to no-change trials, which contained three different instances of a single category (e.g., /p/$_1$ /p/$_3$ /p/$_2$ or /t/$_3$ /t/$_1$ /t/$_2$), was a fourth button marked "NO". The no-change trials tested the participants' ability to ignore audible but phonetically irrelevant within-category variation (e.g., in voice quality). The participants were required to respond to each trial, and were told to guess if uncertain. A trial could be replayed, but responses could not be changed once given. The inter-stimulus interval in all trials was 0.5 s. The first ten tokens were for practice and were not analyzed. The listeners heard stop contrasts in their own language first and then in the other language.

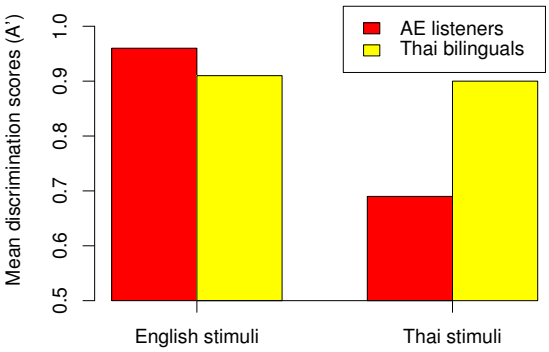

Figure 1: *Mean discrimination scores for Australian English and Thai stimuli.*

Responses to the change and no-change trials were used to calculate A' scores (Snodgrass, Levy-Berger, and Haydon 1985), an index of discrimination accuracy. A score of 1.0 indicated perfect sensitivity, whereas a score of 0.5 or lower indicated a lack of phonetic sensitivity.

2.2. Results

Fig. 1 shows mean discrimination scores for two sets of stimuli by the AE and Thai listeners. The Thai bilinguals' mean discrimination scores for Thai and English hardly differed: 0.90 (*sd* = 0.06, *range* = 0.78 – 0.97) for Thai and 0.91 (*sd* = 0.08, *range* = 0.71 – 0.99) for English, respectively. Most AE listeners found it very difficult to discriminate Thai stop contrasts. Only two out of ten listeners obtained scores that fell within (but at the lower end of) the native Thai range (0.79 and 0.81). However, most AE listeners were very good at discriminating English stop contrasts. Only one out of ten listeners obtained scores lower than 0.90. Their mean discrimination scores for Thai and English were 0.69 (*sd* = 0.08, *range* = 0.58 – 0.81) and 0.97 (*sd* = 0.04, *range* = 0.85 – 0.99), respectively. As a group, both Thai and AE listeners were very consistent in discriminating stop contrasts as reflected in small standard deviations.

A two-way ANOVA with listeners' L1 (Thai, AE) as a between-subjects factor and Stimulus language (Thai, AE) as a within-subjects factor was carried out. Both main effects and a two-way interaction were significant [L1: $F(1, 31) = 11.9, p < 0.01$, Stimuli: $F(1, 31) = 116.2, p < 0.001$, L1 x Stimuli: $F(1, 31) = 102.5, p < 0.001$]. The significant two-way interaction was explored by simple effects tests. The simple effect of stimuli was significant only for the AE listeners [$F(1, 9) = 168.0$, $p < 0.001$]. Their discrimination scores were substantially lower in Thai than in English (0.69 vs. 0.97). The Thai bilinguals' scores, on the other hand, did not differ significantly according to the language

they heard (0.90 in Thai vs. 0.91 in English) [$F(1, 22) = 0.34$, *ns*].

The simple effect of L1 was significant for both Thai and English stimuli, but in the opposite direction. The Thai bilinguals were significantly better at discriminating their L1 final stop contrasts than AE listeners were [$F(1, 31) = 70.0, p < 0.001$], but when discriminating the English stimuli, their scores were poorer than the AE listeners' [$F(1, 31) = 4.5, p < 0.05$]. The between-group difference for the English stimuli was not very big (0.91 for Thai vs. 0.97 for AE), but the difference reached statistical significance, possibly due to a very small inter-subject variability in the AE group.

2.3. Discussion

The Thai bilinguals were capable of discriminating final stops in both English and Thai whereas the AE listeners showed accurate discrimination only in their own language. Given that English final stops are sometimes unreleased and the AE listeners are expected to have experience listening to unreleased stops in their own language, it is somewhat surprising that they did not discriminate unreleased Thai stops more accurately. It may be the case that the AE listeners were disadvantaged, because they had no knowledge of Thai.

However, it is possible that, even when naturally unreleased, place contrasts in English stops are perceptually more salient and discriminable than Thai stop contrasts for any listener. To confirm or disconfirm this hypothesis, it would be necessary to test native Thai listeners who have minimal exposure to English. If such monolingual Thai listeners still show accurate discrimination of English stop contrasts, it is likely that there are cross-linguistic acoustic differences between Thai and naturally unreleased English stops and that, even in the absence of release bursts, English stops contain more acoustic information than Thai stops do. If, on the other hand, Thai monolinguals' response patterns mirror those of the AE listeners', i.e., accurate discrimination only in their L1, then the results in this experiment must be a reflection of Thai bilinguals' L2 perceptual learning.

It is also puzzling that the Thai bilinguals discriminated English final stops more poorly than did the AE listeners. Thai final stops are always unreleased and are expected to contain less acoustic information than English final stops. It is possible that the release burst in English stops provide extra, but irrelevant, information to native Thai listeners, which does not enhance their perceptual processing of L2 sounds.

3. Experiment 2: Identification

In this experiment, English-speaking and Thai listeners' ability to identify the place of articulation of final stops in English, Thai and Korean was examined.

3.1. Method

3.1.1. Stimuli

Words ending with /p t k/ were used as stimuli. These words belonged to one of the following types: English words spoken by AE speakers, English words spoken by Thai bilinguals (TE), Thai words spoken by native Thai speakers and Korean words spoken by native Korean speakers. The Korean stimuli were included in order to evaluate the hypothesis that Thai listeners are able to identify the stop place in an unknown language more accurately than the English-speaking listeners owing to the phonetic similarity between their L1 and Korean, i.e., unreleased final stops.

Except for the Korean speakers who were recorded at the University of Alabama at Birmingham, USA, all speakers were recorded in MARCS Auditory Laboratories at University of Western Sydney, Australia. The recorded speech materials were processed as in Experiment 1. Only naturally unreleased AE tokens were included in this experiment to test if the absence of release burst might affect listeners' identification of stop place. The TE tokens predominantly occurred with an audible release burst despite the expectation that Thai bilinguals might frequently produce unreleased stops in English due to an influence from their L1. All the tokens from four stimulus types described above were presented to each listener in a randomized order in a single block.

3.1.2. Listeners

The 23 Thai bilinguals in Experiment 1 together with a group of 23 AE listeners (5 male, 18 female) with a mean age of 22.5 years (*sd* = 7.3, *range* = 18 – 48) participated in this experiment. Ten of these AE listeners participated in Experiment 1. They were all enrolled in first-year Psychology course at University of Western Sydney and received course credit for their participation. None of the participants had any knowledge of Korean and the AE participants had no knowledge of Thai, either. The participants were tested individually in a single session lasting about 45 to 60 minutes. The Thai participants took part in the identification test after they finished the CDT.

3.1.3. Task

In the identification test, listeners were asked to listen to test words via headphones at a self-selected comfortable level and decide what the last sound of each word was (marked 'P', 'T' and 'K' on the computer screen). The percentage of correct identification was calculated for each listener for each stimulus type. The participants were informed that they would hear words in their own language and unfamiliar language(s). They were told to guess if uncertain. As in Experiment 1, a response was required for each stimulus before the next stimulus was presented 1 s later. The first ten tokens were for practice and were not analyzed. The stimuli could be replayed, but responses could not be changed once given.

3.2. Results

Fig. 2 shows mean correct identification in percentage for four sets of stimuli by AE and Thai listeners. Two groups hardly differed when they listened to English stops spoken by native Thai speakers: 98.8% (*sd* = 1.9, *range* = 93 – 100) for AE listeners and 97.6% (*sd* = 5.7, *range* = 73 – 100) for Thai bilinguals, respectively. For the other three types of stimuli, the results for two listener groups clearly diverged as reported below.

Accepted after full paper review

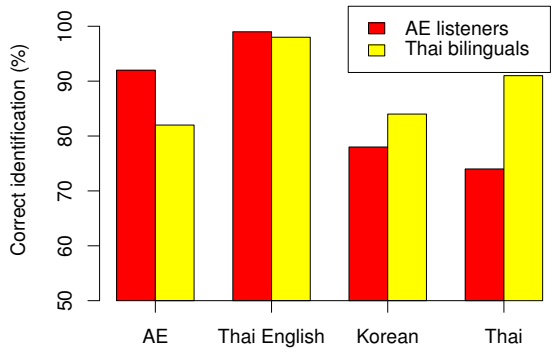

Figure 2: *Mean correct identification (%) for Australian English, Thai-accented English, Korean and Thai.*

A two-way ANOVA with listeners' L1 (Thai, AE) as a between-subjects factor and Stimulus type (AE, Thai English, Thai, Korean) as a within-subjects factor was carried out. The main effect of L1 did not reach significance [$F(1, 44) = 2.8$, *ns*], but the main effect of Stimulus type and a two-way interaction did [Stimuli: $F(3, 132) = 98.4$, $p < 0.001$, L1 x Stimuli: $F(3, 132) = 52.2$, $p < 0.001$]. The significant two-way interaction was explored by simple effects tests. The simple effect of Stimuli was significant for both listener groups [AE: $F(3, 66) = 103.2$, $p < 0.001$, Thai: $F(3, 66) = 43.6$, $p < 0.001$], but identification accuracy across four stimulus types differed for the two groups. The English-speaking listeners' identification accuracy was highest for English stops spoken by native Thai speakers, second highest for AE stops followed by Korean stops. Their accuracy was poorest for Thai stops. Tukey's tests revealed that all pair-wise between stimulus type differences reached significance ($p < 0.05$). The Thai listeners identified English stops spoken by fellow Thai speakers most accurately, too. Their identification of these non-native English stops was significantly better than their identification of L1 Thai stops (98% vs. 91%). They identified Thai stops significantly more accurately than Korean and AE stops.

The simple effects of L1 were significant for all stimulus types except for TE stops (As is seen in Fig. 2, both listener groups identified this stimulus type correctly more than 98% of the time). The AE listeners identified AE stops more accurately (92% vs. 82%) [$F(1, 44) = 19.6$, $p < 0.001$], but Korean (78% vs. 84%) and Thai (74% vs. 91%) stops more poorly than did the Thai listeners [Korean: $F(1, 44) = 5.0$, $p < 0.05$, Thai: $F(1, 44) = 34.8$, $p < 0.001$]. It appears that a lack of release burst in the AE tokens affected the Thai bilinguals more than the AE listeners.

3.3. Discussion

The aim of this experiment was to examine AE listeners' and Thai bilinguals' ability to identify stop place in their L1 and non-native languages. Both groups of listeners identified English stops spoken by non-native speakers most accurately. This may be because Thai speakers produced English stops with a clearly audible release burst and this probably aided listeners' identification as to the place of articulation of stops. An observation that non-native English speech is often characterized by strong final consonant release bursts has been made in recent research (Bent and Bradlow 2003; Smith, Bradlow, and Bent 2003).

A positive transfer effect was observed when the Thai listeners heard Korean stops. In fact, Thai listeners' identification was poorer (albeit non-significantly) for AE stops than for Korean stops, even though none of the Thai participants had any knowledge of Korean.

Compared to the 19 American English speakers who were tested for identification of four final stops (/p t k ʔ/) in Thai by Abramson and Tingsabadh (1999), the AE listeners in this study identified the Thai stops less accurately (74% vs. 86% (calculated from Table 3 in Abramson and Tingsabadh (1999))). This may be due to a methodological difference between the two studies. Unlike the American English speakers, the AE listeners needed to respond to Thai tokens in addition to native and non-native English tokens and Korean tokens within the same block. Although English tokens probably did not pose them much difficulty, constantly changing stimuli in a mixed language condition may have deprived them of opportunities to adjust their perception to a specific type of stimuli.

4. Effect of LOR on speech perception

The Thai bilinguals in this study differed greatly from one another in their length of residence in English-speaking countries. If L2 learning affects not only L2 but also L1 performance, it may be informative to examine how variation in L2 experience might influence speech perception. An LOR in L2-speaking environment is commonly used as a variable in L2 research. Thus, the Thai bilinguals were divided into two groups with an LOR of 50 months as a cutoff point and follow-up analyses were conducted for discrimination and identification data. Table 1 shows mean characteristics of the two groups of bilinguals. The two groups differed significantly in LOR ($p < 0.05$), but not in Age or AOA.

Table 1: *Mean characteristics (in years) of the two groups of Thai-English bilinguals. Standard deviations are in parentheses.*

Group	N	Age	AOA	LOR
Shorter LOR	10	26.7 (7.5)	24.8 (6.6)	1.9 (1.3)
Longer LOR	13	33.7 (12.5)	24.9 (7.8)	8.2 (7.2)

4.1. Discrimination

The discrimination scores for the longer LOR group were slightly higher than those of the shorter LOR group for both Thai (0.91 vs. 0.88) and English (0.94 vs. 0.88). However, the LOR (short, long) x Language (Thai, AE) ANOVA did not yield any significant effects. The two-way interaction was non-significant. Thus, the results of this analysis suggests that the two groups of Thai bilinguals varying in

LOR did not differ from each other in discriminating Thai or English stop contrasts.

4.2. Identification

Similar to the discrimination results, the group with a longer LOR obtained somewhat higher identification scores than did the group with a shorter LOR (90.8 vs. 86.0). The LOR (short, long) x Stimulus type (AE, Thai English, Thai, Korean) ANOVA yielded a significant main effect of Stimulus type [$F(3, 63) = 42.0$, $p < 0.001$], but the LOR effect did not reach significance. The two-way interaction was not significant. The Thai listeners' identification scores were 97.6% for TE stops, 91.1% for Thai, 83.7% for Korean and 82.2% for AE stops. TE stops were significantly more intelligible than Thai stops which, in turn, were more intelligible than both Korean and AE stops. The last two did not differ significantly.

4.3. Discussion

Despite a large variation in LOR, the two groups of Thai bilinguals perceived English and Thai stops in a comparable manner in both discrimination and identification tests. Perhaps, the between-group difference in LOR was not sufficiently large in this study. It is possible that these bilinguals differ from Thai monolinguals in their L1 perception, but for adult bilinguals, the LOR effect may be quite limited especially in the L1. For example, the participant with the longest LOR (30 years) did not stand out either in discrimination or identification scores.

5. General discussion

The AE speakers and Thai bilinguals demonstrated different patterns of results in perceiving final stops in various stimuli types. The Thai bilinguals who lived in English-speaking environments for more than 5 years on average were highly successful in discriminating L1 stop contrasts. These Thai bilinguals discriminated L2 English stops as accurately as Thai stop contrasts, but their discrimination of English stop contrasts was less accurate than the AE listeners'. It appears that the Thai listeners did not benefit from extra acoustic information conveyed by release bursts in English stops.

The results of the identification experiment were consistent with those of the discrimination experiment. The Thai bilinguals correctly identified the stop place 91% of the time in Thai and 82% of the time in Australian English. The opposite pattern was observed for the native speaker of Australian English. There was a clear L1 effect and listening to one's native language gave an advantage to both groups of listeners. Whether or not adult L2 speakers will ever attain native-like proficiency must be ascertained by examining individuals with greater experience with L2.

Although English final stops are sometimes unreleased, the experience of listening to such unreleased stops in an L1 did not appear to assist the AE listeners in perceiving Thai final stops. In order to determine whether their difficulty was due to cross-linguistic acoustic differences between English and Thai or if some other explanations are possible, it is necessary to examine the perception of English stops by monolingual Thai speakers who do not have much experience in listening to English.

By including Thai monolinguals in the study, we can also address the issue of if and to what extent L2 learning influences one's L1 perception and production. If bilinguals' two language systems interact with each other, it may be inevitable that Thai-English bilinguals in Sydney are not identical to Thai monolinguals in Bangkok in the accuracy with which they perceive their L1 stops. However, given bilinguals' good discrimination and identification of their L1 stops, we could tentatively conclude that L1 perception is very robust and that L2 learning does not impede one's L1 perceptual abilities, at least for adult bilingual participants. It would be interesting to study if and how other factors such as L2 learners' chronological age, amount of L1 use and so forth might influence the L1-L2 interaction.

6. Conclusion

Native and non-native listeners' perception of Thai and English final stops were examined in two experiments. Listeners demonstrated distinct response patterns of results according to their L1. While it is not possible to conclude that bilinguals' L1 perception has remained intact after an extensive exposure to L2, the results obtained in this study are interpreted as suggesting that L2 learning does not impact negatively on one's L1 perception system.

In this study, overall results averaged across different contrasts (CDT) and places of articulation (identification test) were presented. Discrimination accuracy of each of the three contrasts tested (i.e., /p/-/t/, /p/-/k/, /t/-/k/) and identification patterns of each place of articulation are currently being analyzed.

7. Acknowledgements

This research was supported by UWS seed grant. Financial support from MARCS Auditory Laboratories for my conference attendance is gratefully acknowledged. I thank Jim Flege for help with Korean speech materials, J. Liang for subject recruitment and data collection, and R. Roengpitya, S. Rungrojsuwan and C. Schoknecht for advice on Thai speech materials.

References

Abramson, A. S. and K. Tingsabadh (1999). Thai final stops: cross-language perception. *Phonetica 56*, 111–122.

Beach, E. F., D. Burnham, and C. Kitamura (2001). Bilingualism and the relationship between perception and production: Greek/English bilinguals and Thai bilabial stops. *The International Journal of Bilingualism 5*(2), 221–235.

Bent, T. and A. R. Bradlow (2003). The interlanguage speech intelligibility benefit. *The Journal of the Acoustical Society of America 114*(3), 1600–1610.

Bond, Z. S. and T. J. Moore (1994). A note on the acoustic-phonetic characteristics of inadvertently clear speech. *Speech Communication 14*, 324–337.

Accepted after full paper review

Byrd, D. (1992). Preliminary results on speaker-dependent variation in the TIMIT database. *Journal of the Acoustical Society of America 92*, 593–596.

Byrd, D. (1993). 54,000 American stops. *UCLA Working Papers in Phonetics 83*, 97–115.

Byrd, D. (1994). Relations of sex and dialect to reduction. *Speech Communication 15*, 39–54.

Crystal, T. H. and A. S. House (1988). Segmental durations in connected-speech signals: current results. *Journal of the Acoustical Society of America 83*, 1553–1573.

Flege, J. E. (2002). Methods for assessing the perception of vowels in a second language. In E. Fava and A. Mioni (Eds.), *Issues in clinical linguistics*, pp. 3–28. Padova: UniPress.

Flege, J. E. (2003). Assessing constraints on second-language segmental production and perception. In N. O. Schiller and A. S. Meyer (Eds.), *Phonetics and phonology in language comprehension and production*, pp. 319–355. New York: Mouton de Gruyter.

Flege, J. E. and J. Hillenbrand (1984). Limits on phonetic accuracy in foreign language speech production. *The Journal of the Acoustical Society of America 76*, 708–721.

Flege, J. E. and I. R. A. MacKay (2004). Perceiving vowels in a second language. *Studies in Second Language Acquisition 26*, 1–34.

Flege, J. E., I. R. A. MacKay, and D. Meador (1999). Native Italian speakers' perception and production of English vowels. *The Journal of the Acoustical Society of America 106*, 2973–2987.

Gottfried, T. L. and P. S. Beddor (1988). Perception of temporal and spectral information in French vowels. *Language and Speech 31*(1), 57–75.

Guion, S. G. (2003). The vowel systems of Quichua-Spanish bilinguals: age of acquisition effects on the mutual influence of the first and second languages. *Phonetica 60*, 98–128.

Guion, S. G., J. E. Flege, R. Akahane-Yamada, and J. C. Pruitt (2000). An investigation of current models of second language speech perception: the case of Japanese adults' perception of English consonants. *The Journal of the Acoustical Society of America 107*, 2711–2724.

Guion, S. G., J. E. Flege, and J. D. Loftin (2000). The effect of L1 use on pronunciation in Quichua-Spanish bilinguals. *Journal of Phonetics 28*, 27–42.

Halle, M., G. W. Hughes, and J.-P. Radley (1957). Acoustic properties of stop consonant. *Journal of the Acoustical Society of America 29*, 107–116.

Householder, F. W. J. (1956). Unreleased PTK in American English. In Halle, Lunt, McLean, and van Schooneveld (Eds.), *For Roman Jakobson*, pp. 235–244. The Hague: Mouton.

Lisker, L. (1999). Perceiving final voiceless stops without release: effects of preceding monophthongs versus nonmonophthongs. *Phonetica 56*, 44–55.

Malécot, A. (1958). The role of releases in the identification of released final stops. *Language 34*, 370–380.

Parker, F. and T. Walsh (1981). Voicing cues as a function of the tense/lax distinction in vowels. *Journal of Phonetics 9*, 353–358.

Pater, J. (2003). The perceptual acquisition of Thai phonology by English speakers: task and stimulus effects. *Second Language Research 19*(3), 209–223.

Picheny, M. A., N. I. Durlach, and L. D. Braida (1985). Speaking clearly for the hard of hearing I: intelligibility differences between clear and conversational speech. *Journal of Speech, Language and Hearing Research 28*, 96–103.

Picheny, M. A., N. I. Durlach, and L. D. Braida (1986). Speaking clearly for the hard of hearing II: acoustic characteristics of clear and conversational speech. *Journal of Speech, Language and Hearing Research 29*, 434–446.

Smith, B., A. R. Bradlow, and T. Bent (2003). Production and perception of temporal contrasts in foreign-accented English. In M. J. Solé, D. Recasens, and J. Romero (Eds.), *Proceedings of the 15th International Congress of Phonetic Sciences*, Barcelona, Spain, pp. 519–522.

Snodgrass, J. G., G. Levy-Berger, and M. Haydon (1985). *Human experimental psychology*. New York: Oxford University Press.

Tingsabadh, K. and A. Abramson (1993). Thai. *Journal of the Internationl Phonetic Association 23*(1), 24–28.

Wang, W. S.-Y. (1959). Transition and release as perceptual cues for final plosives. *Journal of Speech, Language and Hearing Research 2*, 66–73.

Williams, L. (1979). The modification of speech perception and production in second-language learning. *Perception and Psychophysics 26*, 95–104.

Accepted after full paper review