

Laryngeal contrasts in second language phonology¹

Ellen Broselow

Stony Brook University

1. Introduction

Among the strongest candidates for typological universals in phonology are three generalizations that pertain to laryngeal contrasts. The first generalization refers to **avored contrast position**: a language that exhibits laryngeal contrasts in final position (whether syllable-final, word-final, or phrase-final) will exhibit laryngeal contrast in initial positions as well. The second generalization concerns **avored segment type**: where a language limits or suppresses laryngeal contrasts in final position, the obstruents most likely to surface in this position are voiceless. And the third generalization addresses **avored repair**: languages that ban voiced obstruents in final position typically enforce this ban by devoicing underlyingly voiced obstruent, despite the in-principle availability of alternative strategies such as consonant deletion, vowel insertion, and nasalization (e.g., Blevins 2004, Steriade 2001/2008, among many others).

If these generalizations are true universals, we expect them to meet the criteria defined by Blevins (2010), following Kiparsky (2008):

- (1) Prerequisites for true phonological universals (Blevins 2010, Kiparsky 2008)
 - a. Phonological universals should have no exceptions.
 - b. Phonological universals should constrain change.
 - c. Phonological universals should emerge spontaneously within grammars (e.g., as in the final devoicing often associated with children's L1 English productions).
 - d. Learners will not construct grammars that violate universals.
 - e. Universals are part of every grammar.

Potentially fruitful test cases for criteria (1c) and (1d) involve new linguistic systems, among them the patterns of speakers acquiring a novel language. Typological markedness has frequently been invoked to explain the emergence of patterns in second language phonology that appear to have no basis in either the native or the foreign language grammars (e.g., Eckman 1977, 1984). A surprising number of L2 studies have reported that for speakers of native languages that lack final laryngeal contrasts, or that lack any final obstruents, the mastery of final voiceless obstruents precedes the mastery of final voiced obstruents. This finding has served as a veritable poster child for arguments that second language learning is guided by universal principles, even in the absence of direct supporting evidence in the input to the learner.

The goal of this paper is to survey the literature on the L2 acquisition of laryngeal contrasts, in order to determine first, the extent to which second language patterns align with typological generalizations, and second, whether the second language data can shed light on the nature and source of these typological generalizations. To begin, we distinguish two opposing views (along a broad spectrum) concerning the nature of typological asymmetries. On one view,

¹I am grateful to audiences at Oxford, CUNY, and Stony Brook and particularly to Larry Hyman for comments that have improved this paper.

typology reflects what Moreton (2008) calls *channel bias*: factors based in articulation and perception make certain structures less likely to survive in the transmission of language across generations (Blevins 2004, Ohala 1981, among many others), and listeners' imperfect perception of more fragile contrasts ultimately results in phonologization of a system lacking these contrasts (Hyman 1976). The numerous aerodynamic and acoustic factors that make voicing difficult to maintain and to perceive in final positions (reviewed in Blevins 2004, 2006 and Myers 2012) make the typological generalizations concerning laryngeal contrasts very strong candidates for this sort of explanation. However, some L2 evidence has been argued to support the view that at least some typological generalizations reflect what Moreton calls *analytic bias*, defined as "cognitive biases which facilitate the learning of some phonological patterns and inhibit that of others" (Moreton 2008: 84). On this view, language learners simply will not entertain the hypothesis that the system they are learning fails to conform to the relevant typological generalization. In surveying the second language literature, we will consider the fit of the second language data, particularly the finding that second language learners frequently master some L2 structures earlier than other equally novel structures, with typological generalizations. We will consider explanations of the L2 patterns ranging from the articulatory and perceptual difficulty of particular structures (channel bias effects) to learning biases potentially rooted in universal grammatical constraints (analytic bias effects).

Before proceeding, a caveat is in order regarding the scope of this survey. First, in considering the acquisition of final obstruents, we will consider only single obstruents in final position, since the introduction of consonant clusters introduces additional factors that cloud the debate. Second, the term 'second language acquisition' casts a wide net, including learners ranging from children to adults, with varying levels of proficiency and exposure, and situations ranging from naturalistic learning to formal instruction. Furthermore, the studies in the L2 literature below include a wide range of methodologies which makes comparison across studies difficult. We will see, however, that certain patterns emerge across a wide range of subject populations and methodologies.

Section 2 reviews the typological claims concerning the favored positions for laryngeal contrasts in native language systems, as well as favored segment types in different positions. In section 3 we will see that studies of speakers from a wide range of native languages show more success in mastering the typologically more natural structures, and we will consider possible explanations of individual cases. Section 4 focuses on the question of whether the preferred repair strategy for those learners who fail to successfully produce final voiced obstruents is devoicing of the obstruent, as predicted by Steriade's (2001/2008) proposal. Here we will consider the interaction of devoicing with speaker-dependent factors such as proficiency as well as linguistic factors such as word size and the manner and place of articulation of the target final obstruents. We conclude by discussing the implications of the second language data for theories of typology.

2. Preferred position of contrast and preferred segment type

The typological literature on laryngeal contrasts presents convincing evidence for two generalizations: (i) laryngeal contrasts in nonfinal positions are more common than such contrasts in final positions; and (ii) when contrast is absent or actively suppressed in final position, voiceless obstruents are the likely survivors. Of the fifty-one languages surveyed by Keating et al. (1983),

eighteen displayed “at least some neutralization of voicing-related contrasts among stops” in final position (Westbury and Keating 1986: 160).

However, the facts demand more fine-grained distinctions than simply final vs. nonfinal positions. Contrasting word-final and word-internal syllable-final positions, both Wetzels and Mascaró (2001) and Myers (2012) argue that devoicing in syllable-final position implies devoicing in word-final position, but not vice versa. Thus, Myers (2012) presents examples of languages in which devoicing affects only word-final obstruents (e.g., Russian, Walloon, and Uyghur) as well as languages in which syllable-final obstruents, both within and at the end of words, are voiceless (e.g., Takelma, Breton, and Malay). However, languages with devoicing only in word-internal syllable-final position appear to be unattested. A further distinction between word-final and utterance-final positions is made by Westbury and Keating (1986), who argue that “some effects commonly reported as ‘word’ effects are in fact constrained by pause – i.e. they are utterance effects” (Westbury and Keating 1986: 161). Blevins (2006) and Myers (2012), reviewing the factors that favor devoicing in prepausal position, provide convincing arguments for a diachronic scenario in which both word-final and subsequent syllable-final devoicing develop from the generalization of utterance-final devoicing. Consistent with this proposal, Myers and Padgett (2015) provide evidence that participants exposed in artificial language learning experiments to utterance-final obstruent devoicing extended devoicing to utterance-medial word-final coda obstruents (though the converse did not hold: participants exposed to utterance-final voicing did not extend devoicing to utterance-internal syllable codas).

In addition to position in the syllable, word, and utterance, preceding and following segmental context are crucially important factors for laryngeal contrast. Thus, even heterosyllabic obstruents within a cluster frequently assimilate in voicing (see, e.g., Lombardi 1995 for a set of grammatical constraints meant to reflect the typological possibilities). Steriade (1999) argues that the relevant factor determining the possibility of voicing contrasts is not prosodic structure *per se* but rather the extent to which specific contexts allow the realization of acoustic cues that signal the contrast (for example, the possibility of release). Steriade proposes the hierarchy below (adapted here from Gordon’s 2007 summary), in which a language the possibility of contrast in one position on the hierarchy implies the possibility of contrast in all positions to the left (examples of languages along the hierarchy appear below each cutoff point):

(2) Implicational hierarchy (after Steriade 1999, Gordon 2007)²

Voicing contrasts preferred	Voicing contrasts dispreferred
Intersonorant.....presonorant.....word-finally.....preobstruent.....all positions	
Totontepec Lithuanian Hungarian Arabic Khasi	
Mixe	

The question of preferred member of contrasting laryngeal sets also demands finer-grained distinctions than those embodied in the common assumption that voiceless obstruents are less

²As Larry Hyman points out (personal communication), the absence of a context ‘postsonorant’ in this hierarchy accords with the fact that voicing contrasts are frequently neutralized following nasals.

marked than voiced obstruents; the choice of preferred laryngeal specification is related both to the position in which the obstruent appears and to the nature of the laryngeal contrast in individual languages. The term ‘voicing contrast’ as used in both the typological literature and the second language phonology literature often conflates two distinct types of contrast: voicing contrasts, which oppose voiceless and voiced consonants (short lag VOT vs. prevoiced), and aspiration contrasts, which oppose aspirated and unaspirated consonants (long lag vs. short lag VOT). These differences have typological consequences in terms of preferred segment type. In final position, the favored member of a voiceless-voiced contrast is typically the voiceless member, while in languages relying on a contrast between voiceless aspirated and unaspirated pairs, aspirated stops may emerge as the output of neutralization (Westbury and Keating 1986, Vaux and Samuels 2005). Cross-linguistic study reveals interactions between contrast type and contrast position; Keating et al. (1983) argue that languages with a true initial voicing contrast (such as Arabic, Dutch, and Japanese) generally show the same contrast possibilities in initial and medial positions, while languages with an initial aspiration contrast (such as Gaelic, Mandarin, and Swedish) frequently show deaspiration and/or voicing of intervocalic medial stops.

The phonological specifications that best characterize the different types of laryngeal contrast are a matter of some debate, rooted in larger debates concerning binary vs. unary features, the role and extent of underspecification, and the notion of universal markedness hierarchies implying a single least marked member of a series. Voiceless unaspirated stops are characterized as [-voice] by Wetzels and Mascaró (2001), who argue for binary specification of voicing, but as lacking any specified laryngeal features by Lombardi (1995), who argues for privative [voice] and [aspiration], with voiceless unaspirated stops representing the unspecified (and least marked) value. However, Vaux and Samuels (2005) argue that the universal output of laryngeal neutralization in stops is a segment that is underspecified for laryngeal features, and that languages vary in the surface realization of the underspecified stop, which may be either aspirated or unaspirated. Arguments for full specification are provided by Beckman et al. (2011), who claim that the two-way laryngeal contrast in Swedish is best characterized as a contrast between fully specified [spread glottis] and [voiced]). Iverson and Salmons (2011) present a typology of final laryngeal neutralization that provides ten options defined in terms of insertion or deletion of the features [voice], [spread], and [constricted]-- of which at least seven are, they argue, attested. The possibility that languages might differ not only in the phonetic realization of a contrast but also in the phonological specification of what might appear to be similar contrasts across languages highlights the difficulty of deciding at what level a typological generalization must hold in order to be considered universal (a point made in detail in Hyman’s (2008) discussion of the distinction between ‘descriptive universals’ and ‘analytical universals’). An additional complication comes from disagreement in the correct analyses of individual languages--see, for example, the disagreement between Blevins (2004, 2006, 2010) and Yu (2004) who argue for the existence of productive final voicing, and Kiparky (2008), who argues that closer inspection of the putative voicing languages does not support the existence of final obstruent voicing as a true phonological process.

Despite disagreements of analysis, however, some cross-linguistic generalizations about the preferred position of voicing contrasts and the preferred output of contrast suppression have emerged as relatively uncontroversial: final position is the most likely position to exhibit

impoverished contrast, and the presence of final voiced obstruents implies the presence of voiceless obstruents in final position. These generalizations therefore serve as a starting point for the investigation of the acquisition of voicing contrasts in second language learning. As we see below, numerous studies have documented that L2 learners tend to master the typologically less marked laryngeal structures more readily than the more marked structures, even when both are equally novel for the learner.

3. Hierarchy of difficulty in L2 voicing contrasts

Not surprisingly, the L2 literature contains no studies of L2 production that have manipulated and controlled every positional variable that may affect the realization of obstruent laryngeal contrasts (position in the word and the utterance; context in terms of word and sentence stress and intonation; and preceding and following segmental contexts). Nonetheless, studies using a variety of methods and a variety of contexts have converged on the finding of a *hierarchy of difficulty* (Broselow and Kang 2013): L2 learners are more successful in producing novel voicing contrasts in typologically less marked (i.e., nonfinal) positions, and are more successful in producing final voiceless than voiced obstruents. We consider the results on the acquisition of L2 final laryngeal contrasts in terms of the learners' native language backgrounds: languages with no final obstruents; languages with only voiceless final obstruents; languages with a final laryngeal contrast; and languages that lack a voicing contrast even in nonfinal positions.

3.1. L1 has no final obstruents

Perhaps the most well documented cases of laryngeal contrast acquisition involve speakers of a native language with no final obstruents whose target language contains both voiceless and voiced final obstruents. For these speakers, both classes of final obstruent are equally novel, so asymmetry in the mastery of one class over the other cannot, at least at first glance, be ascribed to either the native or the target language. Yet numerous studies have documented greater accuracy in the production of English final voiceless than voiced obstruents by native speakers of Mandarin (Eckman 1981, Flege and Davidian 1984; Weinberger 1987; Wang 1995, Yavas 2009), Tswana (Wissing and Zonneveld 1996), the Tibeto-Burman languages Angami and Ao (Wiltshire 2006), and Japanese (Eckman 1981, Edge 1991, Yavas 2009)--all languages that lack word-final (and, in many cases, syllable-final) obstruents. Despite large differences across studies in the rates of target-like productions, final voiceless obstruents still show substantially higher accuracy than final voiced obstruents. In Wang's (1995) word production task, for example, 19% of final voiceless stops produced by Mandarin speakers in English pseudowords were identified as target-like, as opposed to only 2% of final voiced stops. For Wissing and Zonneveld's (1996) Tswana speakers, percentages of target-like final obstruents were much higher overall, but the difference between voiceless vs. voiced final obstruents was still large (74% vs. 52%). The earlier mastery of final voiceless stops is of course in line with typological generalizations, and the literature reveals no reports of learners who are more successful in producing final voiced than voiceless obstruents.

All of the studies mentioned above involve English as the target language. Unfortunately, a study of Mandarin speakers learning Swedish (Abrahamsson 2003) focused only on changes in rates of epenthesis and deletion over time; productions with voicing change were coded as

correct, and no report was made of individual error rates for final voiceless and voiced obstruents. The paucity of studies addressing the acquisition of final-contrast languages other than English is a lamentable gap in the L2 acquisition literature, and without such studies it is difficult to distinguish English-specific effects from more general effects.

3.2. L1 has only voiceless final obstruents

Earlier mastery of final voiceless than voiced obstruents is expected among speakers whose native language limits final obstruents to voiceless, and this pattern is well attested, both for speakers of languages with productive voicing alternations (German, Smith et al. 2009; Dutch, Simon 2009, 2010; Polish, Flege and Davidian 1984; Catalan, Cebrian 2000) and for speakers of languages that lack such alternations but nonetheless restrict final obstruents to voiceless (Cantonese, Edge 1991, Peng and Ann 2004; Taiwanese Mandarin, Wang 1995; Japanese, Edge 2004; and Thai, Hancin-Bhatt 2000).

Greater accuracy in the production of final voiceless obstruents has been found not only for learners of English, but also for Cantonese-speaking learners of French (Cichocki et al. 1993) and German-speaking learners of Swedish (Hammarberg 1990). While we cannot eliminate the native language as the (possibly sole) source of this asymmetry, it is important to note that final voicing is realized very differently in French and Swedish than in English. In French and Swedish, closure voicing in final stops is a major cue to the final voicing contrast (Blevins 2004, Helgason and Ringen 2008), whereas in English, final obstruents are often at least partially devoiced, and voicing during closure does not appear to be a necessary cue for English speakers to identify a final stop as voiced (Hillenbrand et al. 1984). Thus, these studies suggest that the asymmetric mastery of final voiceless vs. voiced obstruents in L2 acquisition cannot be ascribed solely to facts about the way this contrast is realized in English.

3.3. L1 has a final voicing contrast

The assumption that L2 learners take their native language system their starting point predicts that speakers of languages with only final voiceless obstruents will show greater difficulty in producing L2 voiced than voiceless final obstruents. Similarly, where both the L1 and the L2 employ laryngeal contrasts in final position, we might reasonably expect learners to be equally proficient in producing L2 voiceless and voiced final obstruents. In fact, however, devoicing of English final obstruents has been noted among native speakers of two languages that are reported to have a two-way laryngeal contrast in final position, Farsi (Eckman 1984) and Hungarian (Altenberg and Vago 1983). These findings are unexpected if the native language grammar serves as the starting point for second language acquisition, and are perhaps equally surprising if we approach the problem as one of cross-language differences in phonetic implementation; since Hungarian final stops are reported to have significant voicing during closure (Gosy and Ringen 2009), transfer of the L1 articulatory routines would seem to suggest that Hungarian speakers' final stops in English should sound, if anything, even more fully voiced than native speakers' final English stops. We will return to possible explanations of this phenomenon in section 3.5.

3.4. L1 has no voice contrast

An ideal testing ground for a hierarchy of difficulty involving position of laryngeal contrast

is provided by learners whose native languages lack laryngeal contrast not only in final position but in any position. For speakers of such languages, L2 contrasts in final and nonfinal positions are equally novel. While there do not seem to be any studies of this ideal combination (L1 lacking laryngeal contrasts in all positions and L2 with allowing both final and nonfinal laryngeal contrasts), Hansen (2004) studies English learners of Vietnamese, a language in which she reports that laryngeal contrast, even in initial position, is possible only for coronal stops and for labiodental and velar fricatives. Hansen carried out a longitudinal study of two Vietnamese speakers learning English, including three lengthy interviews and word list reading tasks spaced over one year. While the focus of her study was on the speakers' production of English codas, she does informally report that accuracy was consistently higher for onsets than for codas, supporting a hierarchy of difficulty effect for position. Hansen's data also provide additional support for a hierarchy of difficulty for voiceless vs. voiced final obstruents. Although in Vietnamese neither voiced nor voiceless fricatives occur in final position, where the only possible consonants are voiceless stops, nasals, and glides, she reports that "voiceless consonants emerged before their voiceless counterparts...a finding consistent for every voiceless-voiced pair" (Hansen 2004: 113). This asymmetry held for both participants, in both the interview data and the word list task.

A language that lacks a voicing contrast in any position is Korean. Although Korean does employ a three-way laryngeal contrast among tense, aspirated, and plain voiceless stops in nonfinal positions, voicing *per se* is never contrastive; unaspirated stops are predictably voiced in intersonorant positions, voiceless elsewhere. Major and Faudree (1996) investigated Korean speakers' productions of English obstruents in initial, intervocalic medial, and final positions. In a word list reading task, Major and Faudree found no positional effect for voiceless obstruents, 98% of which were judged as target-like in all three positions. For voiced obstruents, however, productions in final position were significantly less target-like (38%) than those in initial or medial positions (98% or above for both). Since voiced obstruents do not occur in either word-initial or word-final position in Korean, this result is not readily attributable to the native language, but is consistent with the typological generalization that voicing contrasts are more marked in final position than in pre-sonorant positions.

Major and Faudree's (1996) study was designed to investigate the claim of Eckman (1977) that the presence of voicing contrast in final position implies a contrast in medial position, which in turn implies initial contrast. This claim conflicts with Steriade's (1999) hierarchy, which identifies intersonorant position as the most favored position for voicing contrasts (with the implication that intersonorant contrast implies initial contrast). The fact that the Korean speakers' productions of voiceless stops were judged equally target-like in medial and initial positions, despite the native language process of intersonorant voicing, might be taken as support for Steriade's claim that intersonorant position is the most favored for voicing contrasts, since this is the position where native language effects could make voiceless obstruents difficult to produce. However, an alternative explanation is that the Korean speakers identified the English stops with their native language aspirated stops, which do not undergo intersonorant voicing. This is consistent with the adaptation of voiceless stops in English words borrowed into Korean, which are typically adapted as aspirated (e.g., [p^ho:k^ha] 'poker'), even when the original stop is unaspirated in English (Oh 1996, Kenstowicz 2005).

3.5. Possible explanations of the difficulty hierarchies

The studies reviewed above provide evidence for hierarchies of difficulty consistent with typological generalizations: L2 learners show evidence of greater accuracy in producing voicing contrasts in nonfinal than in final positions, and greater accuracy in producing final voiceless than voiced obstruents.³ These asymmetries are particularly interesting when they appear to be emergent—that is, when neither the native nor the target language provides evidence for the asymmetry. There are essentially three categories of explanations for learners' relative lack of success in producing final voiced obstruents, which can be summarized as follows:

- (3) Possible explanations of failure to produce final voiced obstruents in L2
 - a. Perception-based: Non-native speakers perceive voiced final obstruents as voiceless.
L2 speaker's output target: voiceless
L2 productions perceived by native speakers as voiceless
 - b. Articulation-based: Non-native speakers produce non-target like voiced obstruents.
L2 speaker's output target: voiced
L2 productions perceived by native speakers as voiceless
 - c. Grammatically-based: Non-native speakers' (interlanguage) grammars ban final voiced obstruents.
L2 output target: voiceless
L2 productions perceived by native speakers as voiceless

These accounts are not, of course, necessarily mutually exclusive. Blevins (2006) reviews multiple factors that make final voiced obstruents difficult both to produce and to perceive: laryngeal spreading or closing at phrase boundaries, which interferes with the maintenance of voicing; phrase-final lengthening, which may obscure durational cues to voice contrasts; and the absence of audible release in final position. Learners' difficulties in producing target-like final voiced obstruents have been demonstrated in various studies; e.g., Flege, McCutcheon, and Smith (1987) found that Mandarin speakers' voicing during the closure of English final voiced stops was significantly shorter than that of native speakers, and Wissing and Zonneveld (1996) found that Tswana speakers differed significantly from native speakers both in voicing into closure and in the lengthening of vowels before voiced obstruents, a major cue to voicing in final position in English (Raphael 1972).

Difficulties in perception are also in evidence in the L2 literature, though in some cases production has been shown to lag perception. For example, Wissing and Zonneveld's Tswana speakers correctly identified 70% of English final voiced stops as voiced in a forced choice task, but produced only 52% of English final voiced stops as target-like. For speakers of Dutch, where final obstruents are devoiced, Broersma (2005) found categorization accuracy for both voiced and voiceless English final obstruents comparable to that of native speakers of English, though Dutch

³Vaux and Samuels (2005) mention several cases in which the product of neutralization in second language forms is not only devoiced but also aspirated (Vaux and Samuels 2005: 422). Study of these cases is warranted in order to determine the nature of this final aspiration, which might represent release associated with hyperarticulation, rather than a true aspirated target.

speakers are not necessarily entirely successful in producing English-like final voicing contrasts (Simon 2009, 2010). A considerable body of literature on cross-language perception indicates that even where speakers perform well on tests of their ability to perceive contrasts, they may be using different cues than are used by native speakers; for example, Flege and Wang (1989) found that removing burst cues from English final stop stimuli resulted in a significant worsening of discrimination by Cantonese speakers but not by native speakers of English. Thus, perception and production are crucially intertwined: listeners need to both recognize and produce the cues that the target language relies on to signal a contrast.

Approaches that locate L2 patterns in the developing L2 grammar have long appealed to markedness, defined as typologically-based preferences for less marked over more marked structures (e.g., Eckman 1977). In versions of Optimality Theory that directly connect typology and acquisition by encoding typologically-motivated constraints as part of every grammar, such hierarchies of difficulty can be analyzed as the effect of markedness constraints, the effects of which become visible only when the target language provides learners with novel structures that violate these constraints (Broselow, Chen, and Wang 1998, Hancin-Bhatt 2000, Eckman 2004, Peng and Ann 2004, Wiltshire 2006, Cardoso 2007, among others). Thus, the existence of languages like Mandarin and Tswana motivates a universal (but violable) constraint banning all final obstruents (*FINALOBSTRUENT). The existence of languages like German and Catalan, which restrict final obstruents to voiceless, motivates a universal (though violable) constraint *FINALVOICEDOBSTRUENT, which will be ranked low in languages like English but high in languages like German (see, e.g., Lombardi 1995)--and, by default, in Mandarin, on the assumption that markedness constraints rank as high as is consistent with the data of the target language (e.g., Smolensky 1996). On this view, Mandarin speakers' more successful production of final voiceless than voiced obstruents can be seen as reflecting an intermediate stage between the native and target language grammars, in which the constraint banning final obstruents of any type has been demoted, but the constraint banning final voiced obstruents remains highly ranked.

(4) Proposed Grammars (Broselow et al. 1998)

a. Mandarin Grammar:

*FINALVOICEDOBSTRUENT, *FINALOBSTRUENT, >> Faithfulness

b. English Grammar:

Faithfulness >> *FINALVOICEDOBSTRUENT, *FINALOBSTRUENT

c. Interlanguage Grammar (Mandarin-speaking learners of English):

*FINALVOICEDOBSTRUENT >> Faithfulness >> *FINALOBSTRUENT

Broselow (2004) argues that the intermediate ranking falls out of the Gradual Learning Algorithm approach (Boersma and Hayes 2001), in which the rate of constraint demotion is an effect of the frequency of input tokens that violate the constraint. Since the constraint banning all final obstruents will of necessity be violated more frequently than the constraint banning only voiced final obstruents, the general constraint is demoted more rapidly than the more specific constraint. Another application of the Gradual Learning Algorithm approach, in which constraint rankings are stochastic and variable across different speech events, is to predict variation; Cardoso (2007) uses the GLA to model the variable productions he finds in his study of Brazilian Portuguese

learners of English.

While the constraint-based approach appears to be compatible with the earlier mastery of L2 voiceless than of voiced final obstruents for speakers of languages like Mandarin (with no final obstruents) or like German (with only voiceless final obstruents), this approach faces a challenge from the cases of asymmetry mentioned above involving speakers of languages with final voicing contrasts. Speakers of Hungarian (Altenberg and Vago 1983) and Farsi (Eckman 1984), which allow both voiced and voiceless final obstruents, should approach the L2 with a native language grammar that has the same constraint ranking as English. To account for these learners' greater success in producing English voiceless than voiced final obstruents, a proponent of the grammar-based approach might argue that while the grammars of Hungarian and Farsi permit final voiced obstruents, the phonetic realization of voiced targets is sufficiently different from the realization of voicing in English that the learners' attempts to produce voiced stops are not recognized as such by native English speakers. However, this explanation faces the difficulty that in Hungarian, final voiced stops are actually more fully voiced than are their English counterparts (Gosy and Ringen 2009), a fact that might lead us to expect that transfer of native language articulatory routines should make final voicing easy to hear.⁴ An alternative explanation could appeal to a difference in the phonological feature specifications that define the laryngeal contrasts in English vs. in the other languages. If, as proposed in Iverson and Salmons 1995, Jessen and Ringen 2002, Vaux and Samuels 2005, and many others, the relevant feature distinguishing stops is [spread glottis] for aspirating languages like English but [voice] for voicing languages like Hungarian, then the grammars of Hungarian and Farsi may not in fact be identical to that of English. The validity of these approaches can only be evaluated in the context of detailed study of the acoustics of the relevant languages, explicit analyses of the grammars of the two languages, and explicit theories of phonological specification.

An additional explanation for the developmental asymmetry that should be considered is the possibility of asymmetries in the data available to the learner. If final voiceless obstruents are significantly more frequent in the target language than are final voiced obstruents (that is, if input to the learners contains significantly more tokens of final voiceless than voiced obstruents), this could explain why learners might acquire the former before the latter, with no recourse to markedness considerations.⁵ As Broselow and Xu (2004) point out, the order in which new English structures are mastered by Mandarin-speaking learners does not correlate in any obviously

⁴However, as Larry Hyman points out (p.c.), this very difference in the realization of voicing might lead Hungarian speakers to identify English final voiced obstruents with their native language voiceless series; in this case, for example, a Hungarian speaker might perceive and therefore produce English words like *bed* as ending in a voiceless stop.

⁵Note that this is a different use of frequency than that assumed in the Gradual Learning Algorithm approach sketched above, in which the crucial measure was not the relative frequency of voiceless vs. voiced obstruents, but rather the frequency of violations of each markedness constraint (*FINALOBSTRUENT, *FINALVOICEDOBSTRUENT). In the GLA account, L2 forms violating the more specific constraint constitute a subset of those violating the more general constraint, regardless of the relative frequency of voiced and voiceless final obstruents in the L2).

way with the frequency of different English coda types as outlined by Kessler and Treiman (1997), though systematic studies of frequency in learner input are lacking.

In summary, the L2 data provides convincing evidence for hierarchies of difficulty: for learners from a variety of native language backgrounds, L2 final voiced obstruents seem to be harder to successfully produce than either L2 nonfinal voiced or final voiceless obstruents. We now examine the nature of L2 learners' unsuccessful productions of final voiced obstruents.

4. L2 repair of final voiced obstruents: Too many solutions?

Steriade (2001/2008) identifies the 'too many solutions' problem in Optimality Theory: the theory predicts that languages will vary in their strategies for realizing underlying structures that are banned on the surface, but all or most languages seem to converge on a single repair for particular prohibited structures. This problem arises from the assumptions that the choice of repair in a language is a function of the ranking of faithfulness constraints defining preferred input-output correspondence relationships, along with the assumption that constraints are freely rankable across languages. We do indeed find cross-linguistic differences in the repair of many structures: for example, structures containing vowel hiatus are variously realized by deletion of a vowel, coalescence of the two vowels into a single vowel or a diphthong, gliding of a vowel, or insertion of a consonant between the vowels. Yet, although speakers have in principle a number of options for repairing structures containing final voiced obstruents (deletion of the obstruent; epenthesis of a vowel following the obstruent, sonorization of the obstruent), Steriade argues that the only productive repair found across languages is final devoicing.

Steriade proposes to solve this problem by assuming that faithfulness constraints are not necessarily freely rankable; she argues that the ranking of some constraints is set by the P-Map, which defines the perceptual distance between different structures (Steriade 2001/2008). Rankings that produce the maximal perceptual similarity between input and output structures are favored by the P-Map. Her claim is that devoicing is the chosen repair for final voiced obstruents because devoicing produces an output that is perceptually more similar to the input—for example, input /Vb/ is more similar to output [Vp] than it is to [VbV], [V], or [Vm]. The universal ranking of faithfulness constraints penalizes other changes more harshly than a change in voicing:

(5) Ranking of faithfulness constraints favoring devoicing

MAX(C), DEP(V) >> IDENT(VOICE)

Since Steriade's claim is based in typology, we would expect the preference for devoicing over other repairs to be instantiated in second language phonology as well as in first languages. However, before considering whether the preference for final devoicing holds for L2 phonological data, we note that the typological facts are not entirely straightforward, since language using strategies other than final devoicing are attested. One example is adduced by Kiparsky (2008), who points out, citing Cahill 1999, the use of vowel epenthesis is used to prevent the creation of a voiced obstruent in coda position in Konni (northern Ghana). This language has a productive voicing assimilation process whereby an obstruent assimilates in voicing to a following obstruent. However, where voicing assimilation would give rise to a voiced coda obstruent, assimilation is blocked by the insertion of a vowel between the obstruents:

- (6) Konni (Kiparsky 2008, citing Cahill 1999)
- | | | |
|--------------|----------------|----------------------------------|
| a. /tig-ka/ | <i>tikka</i> | ‘the village’ |
| b. /biis-bu/ | <i>biisibu</i> | ‘the breast’ (* <i>biiz-bu</i>) |

These facts do not directly contradict Steriade’s claim that final devoicing is the universally preferred strategy for transforming final voiced obstruents to some other structure, since in Konni, vowel insertion functions not to remove an underlying voiced obstruent, but rather to block the creation of a new voiced obstruent in coda position. However, if perceptual similarity is the major motivation for choice of repair, Steriade must argue that in this case, the output *biisibu* is more similar to input /biisbu/ than would be the output **biizbu*.

A stronger challenge to the universality of final devoicing is posed by the facts of Noon, a Cangin language of Senegal. Merrill (2015) provides evidence that Noon systematically nasalizes voiced stops that are brought into coda position by morpheme concatenation:

- (7) Northern Noon (Merrill 2015)
- | | | | |
|----------------|--------|--------------------|----------------|
| bare verb | | perfect <i>-in</i> | |
| a. nasal-final | | | |
| tam | tam-in | | ‘be hot’ |
| an | an-in | | ‘drink’ |
| daŋ | daŋ-in | | ‘be viscous’ |
| b. stop-final | | | |
| tam | tab-in | | ‘be forbidden’ |
| man | mad-in | | ‘resemble’ |
| daŋ | dag-in | | ‘be taut’ |

Merrill argues that the nasalization process arose from two earlier processes: at an earlier stage, all voiced stops were prenasalized; subsequently, prenasalized stops became plain stops in onset position but became nasals in coda. Although the nasalization pattern arose through separate sound changes, it seems to have become established in the synchronic grammar by learners who have not been exposed to the separate stages that gave rise to this pattern. This disqualifies the preference for final devoicing for the status of true phonological universal, according to Kiparsky’s criteria (reviewed in section 1), which include the claim that learners will never construct grammars that violate a true universal.

Nonetheless, it is clear that the overwhelming majority of languages do choose final devoicing as the preferred option. A weaker version of Steriade’s claim would be to ascribe the preference for final devoicing to a default, initial-state ranking which holds in the absence of evidence to the contrary, but which could be adjusted when learners are exposed to evidence contradicting this ranking. On this view, the responsibility to explain the rarity of repairs other than final devoicing would rest with channel bias effects, rather than on the formal grammar.

However, attempts to investigate channel bias effects in repair of final voiced obstruents are not entirely consistent with the perceptual similarity hypothesis. Kawahara and Garvey (2010), in an online experiment, elicited direct judgments of perceptual similarity by asking participants to compare forms with final voiced obstruents (e.g., *ab*) with possible corresponding forms (e.g.,

am, a, aba, ap) and to rate the similarity of each pair. In trials that involved orthographic presentation of forms, the devoicing option was chosen as most similar to the final-obstruent form, consistent with Steriade's claim. But when forms were presented auditorily, the form with final epenthetic schwa was judged most similar to the final-obstruent form. Kawahara and Garvey note that the final obstruents in the auditory stimuli were released, and although the release was spliced off, sufficient information may have remained to bias listeners toward the vowel insertion form. These facts suggest that determining the closest perceptual match may rely on a complex combination of subtle phonetic details.

With these facts in mind, we now turn to the question of whether learners' nontarget-like productions provide evidence for devoicing as the preferred (if not necessarily universal) repair. We consider the relative proportions of different repairs (consonant deletion, vowel insertion, and final devoicing) in various studies, and the effect of choice of repair on several factors: learner proficiency, task, and grammatical context; the existence of an active devoicing process in the native language; word size and stress; and manner and place of articulation.

4.1. Learner proficiency, task effects, and grammatical context

While the second language literature contains numerous reports of devoicing of final obstruents, it also contains many examples of vowel insertion and consonant deletion. This is not in itself a counterexample to Steriade's claim that final devoicing is the preferred option, since devoicing is only a possibility if the learner can produce some sort of obstruent in final position. A more serious problem for Steriade would be cases in which final voiced obstruents were systematically nasalized by learners, while voiceless obstruents were produced faithfully. I am not aware of such patterns in the second language literature.

The interesting question from the standpoint of Steriade's proposal is whether it is the case that once speakers begin to acquire final obstruents, devoicing becomes the norm. Devoicing is indeed a common phenomenon, though we find a good deal of variation in devoicing rates across different studies, even for speakers of the same native language; for example, Wang's (1995) Mandarin speaker participants, who had been in the U.S. less than one year, had a devoicing rate of 9%, while Flege and Davidian's (1984) Mandarin participants, with five or more years in the US, show a devoicing rate of 29.5%. The lower devoicing found among the less advanced learners correlated with higher rates of consonant deletion and vowel epenthesis, consistent with the course of development suggested by Abrahamsson (2003) for speakers of native languages without final obstruents: consonant deletion > vowel epenthesis > feature change (devoicing) > target value.

Choice of repair is also clearly affected by the experimental task. For example, Edge (1991) found that in a word list reading task, Japanese speakers produced 30% of the word-final voiced obstruents with an epenthetic vowel, but that the rate of epenthesis dropped to less than 5% in tasks involving connected speech. It is not surprising that reading tasks, in particular, might favor epenthesis.

Another factor that may affect both accuracy and choice of repair is the grammatical status of the final consonant. Hansen (2004) found much higher accuracy for past tense /d/ (43%) than for stem-final /d/ (11%), although for some reason, similar effects did not obtain for plural vs. stem-final /z/.

4.2. Native language devoicing

Speakers whose native language has an active devoicing process can be expected to transfer this process to a second language, and indeed, many do; Cebrian (2000) reports 97.8% devoicing in prepausal forms by Catalan speakers; Flege and Davidian (1984) report a devoicing rate of 48.3% for Polish speakers; and Hammarberg (1990) reports that almost all the errors of the Swedish-learning German speakers involved devoicing. However, speakers of a language with alternations that support a productive devoicing process do necessarily devoice L2 forms more often than speakers whose language lacks such a process—or even than learners with no native language final obstruents. Comparison across studies is problematic, given differences in methodology, proficiency of subjects, etc., but Flege and Davidian’s study involved native speakers of three typologically distinct languages: Mandarin (no final obstruents), Polish (active final devoicing), and Mexican Spanish (final obstruents limited in occurrence; voiced stops spirantize following continuants). The devoicing rates of the three groups (29.5%, 48.3%, and 43%) were not significantly different, though there was a high degree of within-group variation. The three native language groups in Flege and Davidian’s study were chosen to investigate the extent to which native language processes affected the production of the second language; thus, the comparison of Spanish speakers, with an active spirantization process, and Polish speakers, with an active devoicing process, is instructive. While the likelihood of L2 devoicing was not significantly higher for Polish speakers than for the other two groups, the rate of final stop spirantization was much higher for the Spanish speakers (19.3%) than for either Polish (1.2%) or Chinese (0.8%) speakers. Thus, while the likelihood of L2 spirantization correlated with the existence of a native language spirantization process, L2 devoicing appeared even when unsupported by the native language.

4.3. Word size and stress

For speakers of a language which (like Mandarin) disallows obstruent codas, deletion of a final obstruent and insertion of a vowel are equally valid strategies for creating possible native language syllable types. Several studies have presented evidence that the English of Mandarin-speaking learners shows evidence of a correlation between repair strategy and output word size, with a preference for disyllabic words as the determining factor (Heyer 1986, Weinberger 1987, Wang 1995, Steele 2002). For example, Wang (1995) found that the size of the source word had a significant effect on the learners’ choice of repair of pseudoword forms, with a preference for vowel insertion in monosyllables but deletion in disyllables:

(8) Mandarin speakers’ repair by word size (Wang 1995)

input size	C deletion	V insertion	C devoicing	Target-like
monosyllable	8%	72%	10%	10%
disyllable	63%	18%	8%	11%

Wang also investigated the effect of word stress on the choice of deletion vs. insertion. Her disyllabic forms were equally divided between those with initial stress and those with final stress. Epenthesis was more likely in the final-stress disyllables than in the initial-stress disyllables,

suggesting that in the absence of word size effects, stress did have an effect. However, in a comparison of monosyllables with final-stress disyllables, the overall rate of epenthesis was still significantly higher for monosyllables than for final-stress disyllables.

Additional evidence of word size effects comes from Cardoso's (2007) study of six speakers of Brazilian Portuguese, a language in which the only possible coda obstruent is /s/. The speakers in this study either produced coda stops correctly, or inserted a vowel following the coda stop (which he argues is a productive native language strategy for syllabifying stops (though he notes that devoicing has been reported in other studies of Brazilian Portuguese-English interlanguage). Cardoso's study included learners at three levels, and while the lowest level speakers produced almost no codas successfully (i.e., inserted a following vowel), the intermediate and advanced learners were far more likely to produce coda stops in polysyllabic words (37% and 59%, respectively), than in monosyllables (16% correct production for intermediate and 31% correct production for advanced learners). As Cardoso notes, Brazilian Portuguese contains a number of highly frequent monosyllables, as does English, though in English, monosyllabic content words must arguably be bimoraic. He argues that "the language learner opts for minimal word disyllabicity, a structure that is enforced neither in BP nor in English, over bimoraicity, which represents the target-like structure" (Cardoso 2007: 227).

Thus, while devoicing is extremely common in second language phonology, it is not necessarily the favored strategy, even for learners who have the ability to produce obstruents in final position. These facts are consistent with the view that the choice of final devoicing over other repairs represents at most a strong preference rather than an absolute universal, and one that may interact with other universal preferences. In fact, the word size effects are reconcilable with Steriade's claim that the universal preference for final devoicing represents a default ranking of faithfulness constraints, given the architecture of Optimality Theory grammars. So long as the faithfulness constraints are outranked by markedness constraints demanding a disyllabic word minimum, vowel insertion will be chosen over deletion or devoicing for final obstruents in monosyllables, even when the ranking of faithfulness constraints defines devoicing as the generally preferred option. This is illustrated in the tableau below (where D indicates any voiced obstruent):

(9) Word size effect ranking

/CVCVD/	MINWORD	*FINALVOICEDOBSTRUENT	DEP(V)	IDENT(VOICE)
a. CVCVD		*!		
b. CVCVT				*
c. CVCVD _v			*!	

/CVD/	MINWORD	*FINALVOICEDOBSTRUENT	DEP(V)	IDENT(VOICE)
a. CVD		*!		
b. CVT	*!			*
c. CVD _v			*	

In this ranking (essentially that proposed in Broselow et al. 1998 to describe the Mandarin learners' patterns) the constraint banning vowel insertion, DEP(V) outranks IDENT(VOICE), the constraint forbidding devoicing, consistent with Steriade's proposed ranking. However, the higher-ranked MINWORD (words must be at least disyllabic) will rule out the devoicing option for monosyllables.

Thus, a grammar that adheres to Steriade's proposed ranking of faithfulness constraints need not necessarily entail that devoicing will be the only choice in every context. This brings us back to the typological question: if this is a possible grammar, then we should expect to find native languages in which the L2 pattern of insertion in monosyllables and devoicing in polysyllables has become grammaticalized. One language in which devoicing is related to word size is Turkish, where Becker et al. (2011) demonstrate that monosyllables are more likely than longer words to preserve voiced obstruents in final position (e.g., [ad] 'name'). However, the resistance to devoicing in these forms does not change word size; Becker et al. attribute the preservation of voice to a cross-linguistic tendency toward greater faithfulness to word-initial syllables. At this point it appears that the tendency toward epenthesis in monosyllables and devoicing in polysyllables seen in the English of native speakers of Mandarin and Brazilian Portuguese does not appear to have been grammaticalized in any language--though it is possible that such a pattern, if it did arise, might be unstable, since the next generation of learners might be led to reanalyze the originally monosyllabic forms as underlying disyllabic.

4.4. Manner effects

Final devoicing typically affects both stops and fricatives, despite differences in the realization of voicing in these two classes. Thus, it is interesting to see whether voiced stops and fricatives pattern similarly in second language phonology.

An asymmetry between stops and fricatives emerges in Simon's (2009, 2010) investigation of Dutch speakers' productions: though all obstruents are devoiced in final position in Dutch, the Dutch speakers in her study produced English final voiced stops significantly more successfully

than final voiced fricatives (the respective rates of devoicing were 76% for fricatives vs. 49% for stops). As Simon points out, this pattern is consistent with the cross-linguistically greater rarity of voiced fricatives than voiced stops, which can be explained by the fact that the glottal opening required for frication is antithetical to the cross-glottal pressure differential required to sustain voicing (Ohala 1983). Voiced stops and fricatives differ in terms of perceptibility as well; Myers (2012) found a tendency for English speakers to identify utterance-final voiced fricatives as voiceless, while a similar tendency was not found for utterance-final voiced stops.

A pattern that appears to be the reverse of the Dutch pattern is attested in Hansen’s (2004) study of two Vietnamese speakers’ productions. Hansen includes all voicing errors in the category of feature change errors, but her discussion makes it clear that the normal feature change for stops was devoicing. While 49% of final voiced stops underwent feature change, only 4% of final fricatives did (the opposite of the Dutch pattern, in which fricatives were more likely to be devoiced):

(10) Vietnamese speakers’ choice of repair (Hansen 2004)

		Target-like	Deletion	Epenthesis	Feature Change
voiceless stops	/p/	88%	0	12%	0
	/t,k/	52%	29%	15%	2%
voiceless fricatives	/f, s/	59%	23%	12%	6%
voiced stops	/b,d,g/	19%	24%	3%	49%
voiced fricatives	/v, z/	19%	47%	25%	4%

A closer look at the choice of repair for stops and fricatives is intriguing. The rate of target-like productions was the same for voiced stops and voiced fricatives; the major difference lies in the higher rates of deletion and epenthesis for voiced fricatives (72% combined) vs. voiced stops (27% combined). This may be a native language effect: Vietnamese has no final fricatives, but does have final stops (albeit only voiceless ones). Thus, the higher rate of devoicing for stops than fricatives may simply reflect the fact that devoicing is not an option for final fricatives, since these speakers cannot yet successfully produce fricatives in final position. However, it is puzzling that for voiceless stops and fricatives, the rates of target-like productions were comparable (leaving out the surprisingly high rates for /p/). Thus, while the Vietnamese data provide clear support for a difficulty hierarchy involving voiceless vs. voiced final fricatives, their significance with respect to the relationship between manner and the likelihood of devoicing is less clear.

If we take the Dutch pattern – greater likelihood of devoicing of final fricatives than final stops– as representative of phonetically-grounded factors disfavoring voiced fricatives, it seems likely that we should find languages in which the pattern of devoicing final fricatives but not final stops has become phonologized. Myers (2012) addresses this question in the context of his proposal that word-final and syllable-final devoicing processes arise historically from the generalization of utterance-final devoicing: “One might expect from this that utterance-final fricative devoicing should be the most common version of the pattern of final devoicing...But it

certainly does not seem as if such cases are more common than...devoicing of all obstruents including stops” (Myers 2012: 173). Myers cites only one language, Gothic, where final devoicing is limited to fricatives. Thus, while the Dutch speakers’ L2 patterns are congruent with aerodynamic and perceptual factors that appear to make a final voicing contrast in stops more natural than one in fricatives, it does not seem to be the case that this asymmetry has become widely grammaticalized. If such an asymmetry emerges frequently in second language phonology but never as a pattern in a first language, it might provide an argument for an analytic bias against a grammar that allows devoicing for one set of obstruents but not another, although at this point the evidence from second language production is too limited to support this claim. A related question is whether the same or different feature specifications govern laryngeal contrasts for stops and fricatives, and whether stop devoicing and fricative devoicing should be treated as different processes in grammars (see Vaux 1998 for the proposal that the unmarked opposition for voiceless and voiced fricatives is [+spread glottis] vs. [-spread glottis], and van Oostendorp 2007 for the proposal that for at least some Dutch dialects, the fricative contrast is better explained in terms of length rather than laryngeal features).

4.5. Place of articulation

Another factor related to voicing is place of articulation: because voicing requires that supraglottal pressure be lower than air pressure below the glottis, a smaller oral cavity makes voicing more difficult to sustain. Thus, velar stops tend to be less fully voiced than stops made farther front (Ohala 1983, Maddieson 1984). Despite the connection between constriction location and difficulty of sustaining voicing, there seem to be no languages that, say, devoice final velar stops but maintain voicing contrasts for coronals and labials. Nor are there clear examples of such patterns in L2 phonology, although there is evidence for differences in degree of voicing across place of articulation. Yavas (2009) studied the production of final English bilabial, coronal, and velar stops by native speakers of Mandarin, Japanese, and Portuguese, and found that although the amount of closure voicing did not differ significantly by place of articulation, there was an interaction between the place of the stop and the height of the preceding vowel: velars were significantly less voiced, but only when they followed high vowels:

(11) Mean percentage of closure voicing (Yavas 2009)

	bilabial	alveolar	velar
after high vowel	28.2%	24.2%	18%
after low vowel	30.1%	28.9%	27%

Native speakers also showed less voicing in the high vowel-velar case than in other cases, but their percentage of voicing was, for each vowel-consonant combination, significantly higher than that of native speakers (e.g., 65.5% voicing during a velar closure following a high vowel).

While it makes sense that the smaller oral cavity associated with velars and the narrower constriction of high vowels should have an additive effect on voicing, this does not appear to be a phonologized pattern in languages; Moreton (2008) argues that few languages show systematic interactions of vowel height and voicing, and those interactions that are attested take the form of

the raising of vowel height before voiced consonants and the lowering of vowel height before voiceless consonants (though see Yu 2011 for a different interpretation of Moreton's data). Thus, place and vowel height effects, though they appear in the phonetic detail of both native and non-native speakers, appear not to have been grammaticalized in either first language or interlanguage phonology. Again, this is an area where research is relatively sparse.

5. Conclusion

We set out to determine first, whether the facts of second language phonology are compatible with typological generalizations, and second, whether the second language facts can shed light on the source of typological generalizations.

We found numerous cases supporting a difficulty hierarchy for final voiceless vs. voiced stops in second language phonology, and this difficulty hierarchy aligns with the typological generalizations on preferred segment type. Across a range of native languages, including those with no final obstruents, those with only voiceless final obstruents, and those with a final laryngeal contrast, speakers successfully produced L2 final voiceless obstruents before final voiced obstruents. In no case was there evidence of speakers acquiring the more marked structure (final voiced obstruents) before the less marked structure (final voiceless obstruents). Whether these facts reflect articulatory and perceptual factors or the effects of formal grammatical constraints is difficult to resolve--since the structural constraints of Optimality Theory are generally grounded in articulatory and perceptual considerations, there is considerable overlap between the approaches. However, we note that locating the difficulty of final voiced obstruents in articulatory and perceptual difficulty alone predicts that the likelihood of a difficulty hierarchy emerging in L2 acquisition should be a function of the phonetic robustness of the contrast in the target language; for example, languages in which final stops are uniformly released should provide the learner with more cues to the voicing contrast than languages without such release. Systematic study of the productions of both native and second language speakers across a range of languages is necessary to address this question.

We also found that final devoicing was quite common in second language phonology, although it was by no means the only strategy used. Since speakers must be able to produce obstruents in final position before they can devoice them, the fact that vowel insertion and consonant deletion were also common repairs of L2 forms does not in itself invalidate Steriade's (2001/2008) claim that final devoicing is the only solution to the final obstruent problem. We did, however, find evidence that some speakers exhibit a systematic relationship between choice of repair and preferred word size. It is intriguing that this pattern was found for speakers of two different languages, Mandarin and Brazilian Portuguese, but is not clearly attested in any native language system.

Effects of aerodynamic factors that contribute to the difficulty of sustaining appeared in some studies, at the level of relatively fine phonetic detail: Dutch speakers' final fricatives were less voiced than stops (Simon 2010), and Mandarin, Japanese, and Portuguese speakers' velars were less voiced than alveolars and bilabials, though only after high vowels (Yavas 2009). On the channel bias account, we might expect these differences to give rise to systems in which the phonetic asymmetries become phonologized. Yet such systems seem either rare or unattested; Myers (2012) cites only one language, Gothic, in which fricatives, but not stops, are regularly

devoiced.

A reasonable place to look for systems that have phonologized the effects found second language phonology is in regionalized varieties of English, where what generally began as a second language has now become standardized. A striking number of regional Englishes show evidence of at least some final devoicing. In a survey of English varieties of Africa, South Asia, and Southeast Asia, Mesthrie (2004) reports final devoicing in St. Helens English, Cape Flats English, Black South African English, Nigerian English, Ghanaian English, Cameroon English, Cameroon Pidgin, Singapore English, and Malaysian English. Final devoicing is also reported in Fiji English (Tent and Mugler 2004), Tok Pisin (Smith 2004), and Liberian Settler English (Singler 2004). The prevalence of final devoicing suggests that speakers did indeed converge on this repair as their systems stabilized. It is notable that none of these descriptions identify epenthesis or deletion as regular productive processes targeting single final voiced obstruents, and no systems are identified as showing different treatment of final stops and fricatives or systematic effects of place of articulation that are independent of the substrate language. Thus, at least some of the well-founded phonetic effects that emerge in L2 phonology do not seem to acquire the status of regular phonological processes.

References

- Altenberg, E. and R. Vago. 1983. Theoretical implications of an error analysis of second language phonology production. *Language Learning* 33, 427-448.
- Becker, M., N. Ketrez, and A. Nevins. 2011. The surfeit of the stimulus: analytic biases filter lexical statistics in Turkish laryngeal alternations. *Language* 87, 84-125.
- Beckman, J., P. Helgason, B. McMurray, and C. Ringen. 2011. Rate effects on Swedish VOT: Evidence for phonological overspecification. *Journal of Phonetics* 39, 39-49.
- Blevins, J. 2004. *Evolutionary Phonology: The Emergence of Sound Patterns*. Cambridge: Cambridge University Press.
- Blevins, J. 2006. A theoretical synopsis of Evolutionary Phonology. *Theoretical Linguistics* 32, 117-166.
- Blevins, J. 2010. Phonetically-based sound patterns: Typological tendencies or phonological universals? In C. Fougeron, B. Kühnert, M. D'Imperio, and N. Vallée (eds.), *Papers in Laboratory Phonology X: Variation, phonetic detail and phonological modeling*. Berlin: Mouton de Gruyter, 201-224.
- Broersma, M. 2005. Perception of familiar contrasts in unfamiliar positions. *Journal of the Acoustical Society of America* 117 (6), 3890-3901.
- Broselow, E. 2004. Unmarked structures and emergent rankings in second language phonology. *International Journal of Bilingualism* 8, 51-65.
- Broselow, E., S. Chen, and C. Wang. 1998. The emergence of the unmarked in second language phonology. *Studies in Second Language Acquisition*, 261-280.
- Broselow, E. and Y. Kang. 2013. Second language phonology and speech. In J. Herschensohn and M. Young-Scholten (eds.) *The Cambridge Handbook of Second Language Acquisition*, 529-554. Cambridge: Cambridge University Press.
- Broselow, E. and Z. Xu. 2004. Differential difficulty in the acquisition of second language phonology. *International Journal of English Studies* 4 (special issue: *Advances in Optimality Theory*), 135-163.
- Cardoso, W. 2007. The variable development of English word-final stops by Brazilian Portuguese speakers: a stochastic Optimality Theory account. *Language Variation and Change* 19, 219-248.
- Cebrian, J. 2000. Transferability and productivity of L1 rules in Catalan-English interlanguage. *Studies in Second Language Acquisition* 22, 1-26.
- Cichocki, W., A. B. House, A. M. Kinloch, and A. C. Lister. 1993. Cantonese speakers and the acquisition of French consonants. *Language Learning* 43, 43-68.
- Eckman, F. 1977. Markedness and the contrastive analysis hypothesis. *Language Learning* 27, 315-330.
- Eckman, F. 1981. On the naturalness of interlanguage phonological rules. *Language Learning* 31, 195-216.
- Eckman, F. 1984. Universals, typology, and interlanguage. In W. Rutherford (ed.) *Language universals and second language acquisition*. Amsterdam: John Benjamins, 79-105.
- Eckman, F. 2004. From phonemic differences to constraint rankings: Research on second language phonology. *Studies in Second Language Acquisition* 26, 513-549.

- Edge, B. 1991. The production of word-final voiced obstruents in English by L1 speakers of Japanese and Cantonese. *Studies in Second Language Acquisition* 13, 377-393.
- Flege, J. E. and R. D. Davidian 1984. Transfer and developmental processes in adult foreign language speech production. *Applied Psycholinguistics* 5, 323-347.
- Flege, J. E., M. J. McCutcheon, and S. C. Smith. 1987. The development of skill in producing word-final English stops. *Journal of the Acoustical Society of America* 82, 433-447.
- Flege, J. and C. Wang. 1989. Native-language phonotactic constraints affect how well Chinese subjects perceive the word-final English /t/-/d/ contrast. *Journal of Phonetics* 17, 299-315.
- Gordon, M. 2007. Typology in Optimality Theory. *Language and Linguistics Compass* 1/6, 750-769.
- Gosy, M. and C. Ringen. 2009. Everything you always wanted to know about VOT in Hungarian. Talk presented at the International Conference on the Structure of Hungarian 9. Debrecen, Hungary.
- Greenberg, J., C. Ferguson, and E. Moravcsik. 1978. *Universals of Human Language. Volume 2: Phonology*. Stanford, CA: Stanford University Press.
- Hammarberg, B. 1990. Conditions on transfer in phonology. In R. James and J. Leather (eds.) *New Sounds 90: Proceedings of the 1990 Symposium on the Acquisition of Second-Language Speech*. Dordrecht: Foris, 198-215.
- Hansen, J. G. 2004. Developmental sequences in the acquisition of English L2 syllable codas. *Studies in Second Language Acquisition* 26, 85-124.
- Helgason, P. and C. Ringen. 2008. Voicing and aspiration in Swedish stops. *Journal of Phonetics* 36, 607-628.
- Heyer, S. 1986. English final consonants and the Chinese learner. Unpublished master's thesis, Southern Illinois University Edwardsville.
- Hyman, L. 1976. Phonologization. In A. Juillard (ed.) *Linguistic Studies Offered to Joseph Greenberg, Volume 2*. Saratoga, CA: Anna Libri, 407-418.
- Hyman, L. 2008. Universals in phonology. *The Linguistic Review* 25, 83-137.
- Iverson, G. and J. Salmons. 1995. Aspiration and laryngeal representation in Germanic. *Phonology* 12, 369-396.
- Iverson, G. and J. Salmons. 2011. Final devoicing and final laryngeal neutralization. In M. van Oostendorp, C. Ewen, E. Hume, and K. Rice (eds.) *The Blackwell Companion to Phonology*. Blackwell Publishing.
- Jessen, M. and C. Ringen. 2002. Laryngeal features in German. *Phonology* 19, 189-218.
- Kawahara, S. and K. Garvey. 2010. Testing the P-map hypothesis: coda devoicing. Rutgers Optimality Archive.
- Keating, P., W. Linker, and M. Huffman 1983. Patterns in allophone distribution for voiced and voiceless stops. *Journal of Phonetics* 11, 277-290.
- Kenstowicz, M. 2005. The phonetics and phonology of loanword adaptation. In Rhee, S.-J. (ed.) *Proceedings of ECKL 1: Proceedings of First European Conference on Korean Linguistics*. Hankook Publishing, 316-340.
- Kessler, B. and R. Treiman. 1997. Syllable structure and the distribution of segments in English syllables. *Journal of Memory and Language* 37, 295-311.

- Kiparsky, P. 2006. The amphichronic program vs. evolutionary phonology. *Theoretical Linguistics* 32, 217-236.
- Kiparsky, P. 2008. Universals constrain change; change results in typological generalizations. In J. Good (ed.) *Language Universals and Language Change*. Oxford: Oxford University Press, 23-53.
- Lombardi, L. 1995. Laryngeal neutralization and syllable well-formedness. *Natural Language and Linguistic Theory* 13, 39-74.
- Maddieson, I. 1984. *Patterns of sounds*. Cambridge: Cambridge University Press.
- Major, R. and M. Faudree. 1996. Markedness universals and the acquisition of voicing contrasts by Korean speakers of English. *Studies in Second Language Acquisition* 18, 69-90.
- Merrill, J. 2015a. Nasalization as a repair for voiced obstruent codas in Noon. Talk presented at the Annual Meeting of the LSA, January, 2015.
- Merrill, J. 2015b. Nasalization as a repair for voiced obstruent codas in Noon. *LSA Annual Meeting Extended Abstracts*.
<http://journals.linguisticsociety.org/proceedings/index.php/ExtendedAbs/article/view/3014>
- Mesthrie, R. 2004. Synopsis: the phonology of English in Africa and South and Southeast Asia. In E. Schneider, K. Burrige, B. Kortmann, R. Mesthrie, and C. Upton (eds.) *A Handbook of Varieties of English*. Berlin, New York: Mouton de Gruyter, 1099-1110.
- Moreton, E. 2008. Analytic bias and phonological typology. *Phonology* 25, 83-127.
- Myers, S. Final devoicing: production and perception studies. In Borowsky, T., S. Kawahara, T. Shinya and M. Sugahara (eds.) *Prosody Matters: Essays in Honor of Elisabeth Selkirk*. Equinox, 148-180.
- Myers, S. and J. Padgett. 2015. Domain generalisation in artificial language learning. *Phonology* 31, 399-434.
- Oh, M. 1996. Linguistic input to loanword phonology. *Studies in Phonetics, Phonology, and Morphology* 2, 117-126.
- Ohala, J. 1981. The listener as a source of sound change. In C. Masek, R. Hendrick, and M. Miller (eds.) *Papers from the Parasession on Language and Behavior*. Chicago: Chicago Linguistics Society, 178-203.
- Ohala, J. 1983. The origin of sound patterns in vocal tract constraints. In P. MacNeilage (ed.) *The Production of Speech*. New York: Springer, 189-216.
- Oostendorp, M. van. 2007. Exceptions to final devoicing. In J. van de Weijer and E. van de Torre (eds.) *Voicing in Dutch: (De)voicing - phonology, phonetics, and psycholinguistics*. Amsterdam: John Benjamins, 81-98.
- Peng, L. and J. Ann. 2004. Obstruent voicing and devoicing in the English of Cantonese speakers from Hong Kong. *World Englishes* 23, 535-564.
- Raphael, L. 1972. Preceding vowel duration as a cue to the perception of the voicing characteristic of word-final consonants in American English. *Journal of the Acoustical Society of America* 51, 1296-1303.
- Simon, E. 2009. Acquiring a new second language contrast: an analysis of the English laryngeal system of native speakers of Dutch. *Second Language Research* 25, 377-408.
- Simon, E. 2010. Phonological transfer of voicing and devoicing rules: evidence from NL Dutch and L2 English conversational speech. *Language Sciences* 32, 63-86.

- Singler, J. 2004. Liberian Settler English: phonology. In E. Schneider, K. Burridge, B. Kortmann, R. Mesthrie, and C. Upton (eds.) *A Handbook of Varieties of English*. Berlin, New York: Mouton de Gruyter, 874-884.
- Smith, G. 2004. Tok Pisin in Papua New Guinea: phonology. In E. Schneider, K. Burridge, B. Kortmann, R. Mesthrie, and C. Upton (eds.) *A Handbook of Varieties of English*. Berlin, New York: Mouton de Gruyter, 710-728.
- Smolensky, P. 1996. On the comprehension/production dilemma in child language. *Linguistic Inquiry* 27, 720-731.
- Steele, J. 2002. L2 learners' modification of target language syllable structure: prosodic licensing effects in interlanguage phonology. In A. James and J. Leather (eds.) *New Sounds 2000: Proceedings of the 4th International Symposium on the Acquisition of Second Language Speech*. Klagenfurt: University of Klagenfurt, 315-324.
- Steriade, D. 1999. Phonetics in phonology: the case of laryngeal neutralization. *UCLA Working Papers in Phonology* 3, 25-146.
- Steriade, D. 2001/2008. The phonology of perceptibility effects: The P-Map and its consequences for constraint organization. In K. Hanson and S. Inkelas (eds.) *The nature of the word*. Cambridge: MIT Press, 151-179.
- Tent, J. and F. Mugler. Fiji English: phonology. In E. Schneider, K. Burridge, B. Kortmann, R. Mesthrie, and C. Upton (eds.) *A Handbook of Varieties of English*. Berlin, New York: Mouton de Gruyter, 750-779.
- Vaux, B. 1998. The laryngeal specification of fricatives. *Linguistic Inquiry* 29, 497-511.
- Vaux, B. and B. Samuels. 2005. Laryngeal markedness and aspiration. *Phonology* 22, 395-346.
- Wang, C. 1995. *The acquisition of English word-final obstruents by Chinese speakers*. Unpublished doctoral dissertation, Stony Brook University.
- Weinberger, S. 1987. The influence of linguistic context on syllable simplification. In G. Ioup and S. H. Weinberger (eds.) *Interlanguage phonology: the acquisition of a second language sound system*. Rowley, MA: Newbury House, 401-417.
- Westbury, J. and P. Keating. 1986. On the naturalness of stop consonant voicing. *Journal of Linguistics* 22, 145-166.
- Wetzels, L. and J. Mascaró. 2001. The typology of voicing and devoicing. *Language* 77, 207-244.
- Wiltshire, C. 2006. Word-final consonant and cluster acquisition in Indian Englishes. In D. Bamman, T. Magnitskaia, and C. Zaller (eds.) *Online Proceedings Supplement, Boston University Conference on Language Development* 30.
- Yu, A. 2004. Explaining final obstruent voicing in Lezgian: phonetics and history. *Language* 80, 73-97.
- Yu, A. 2011. On measuring phonetic precursor robustness: a response to Moreton. *Phonology* 28, 491-518.