Loanword adaptation as first-language phonological perception

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Loanword adaptation as first-language phonological perception[1]

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Abstract. We show that loanword adaptation can be understood entirely in terms of phonological and phonetic comprehension and production mechanisms in the first language. We provide explicit accounts of several loanword adaptation phenomena (in Korean) in terms of an Optimality-Theoretic grammar model with the same three levels of representation that are needed to describe L1 phonology: the underlying form, the phonological surface form, and the auditory-phonetic form. The model is bidirectional, i.e. the same constraints and rankings are used by the listener and by the speaker. These constraints and rankings are the same for L1 processing and loanword adaptation.

Figure 1 shows a simplified version of an existing model for first-language (L1) processing (Boersma 1998, 2000, 2007ab).[2] The model is bidirectional, i.e. it accounts for the behaviour of the listener (on the left) as well as the speaker (on the right). In both directions, processing is assumed to be handled by the interaction of Optimality-Theoretic constraints.

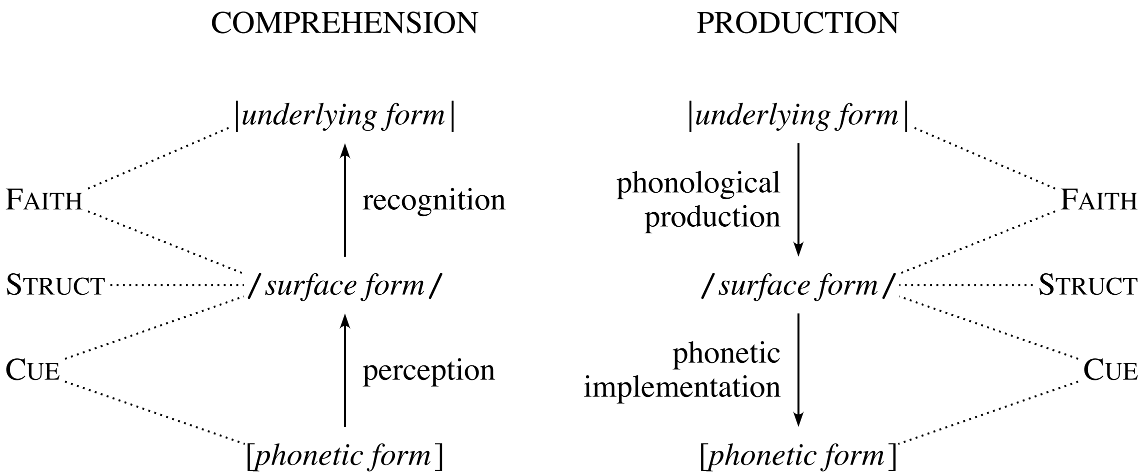

Fig. 1. A single model for L1 processing as well as loanword adaptation.

Phonological production (top right) is described in terms of an interaction between structural and faithfulness constraints (McCarthy & Prince 1995). Perception (bottom left) is described in terms of an interaction between structural and cue constraints (Boersma 2000, 2007ab). The remaining two processes, word recognition (top left) and phonetic implementation (bottom right), are (in this simplified version) described by one set of constraints each (faithfulness and cue constraints, respectively).

[1] An earlier version of this paper was presented at OCP 4 in Rhodes, January 20, 2007. We like to thank Adam Albright and Hyunsoon Kim for comments on the Korean data. All remaining errors are ours.

[2] We explain some simplifications in footnotes. One simplification is that a more elaborate model (Boersma 1998, 2007ab, Apoussidou 2007) requires additional representations, such as an articulatory form (below the auditory-phonetic form in Fig. 1) and a morpheme level (above the underlying form).

The roles of all the ingredients of the model in Fig. 1 will become clear in our discussion of the examples that follow. The idea to take home from Fig. 1 is that structural constraints play a role both in production and in comprehension, although they interact with different constraints in these two directions of L1 processing. We will show that the L1 model of Fig. 1 suffices to account for many loanword adaptation phenomena, thereby doing away with the loanword-specific devices that have appeared in other (earlier as well as later) proposals in the literature.

1 Superficial differences between Korean native phonology and loanword adaptation

Our first subject of discussion is the often commented fact that a process superficially describable as *vowel insertion* is much more common in loanword adaptation than in native phonologies. As our example in this paper, we analyze observations about vowel insertion in English loanwords in Korean (H. Kang 1996, 1999; Y. Kang 2003; Kabak 2003).

Illicit surface structures seem to be handled differently in the native Korean phonology than in English-to-Korean loanword adaptation. In native Korean phonology, such structures are typically avoided by processes of neutralization, assimilation, and deletion, but never by vowel insertion. The underlying form |pɑt^h| ‘field’ is produced as the surface structure /.pɑt./, an underlying |os| ‘clothes’ is produced as surface /.ot./, an underlying |kɑps| ‘price’ as /.kɑp./, and an underlying |kuk+min| ‘nation’ as /.kuŋ.min./. According to all authors, the avoidance of the faithful */.pɑt^h./ is due to a Korean structural restriction against aspirated codas, the avoidance of the faithful */.os./ is due to a Korean structural restriction against strident codas, the avoidance of the faithful */.kɑps./ (or */.kɑpt./) is due to a Korean structural restriction against coda clusters, and the avoidance of the faithful */.kuk.min./ is due to a Korean structural (phonotactic) restriction against segmental sequences like */km/. Crucially, all eight constraints involved here (faithfulness for aspiration, faithfulness for stridency, segmental faithfulness, faithfulness for manner, and the four structural constraints) could have been satisfied by inserting a vowel (/.pɑ.t^{h}ɨ./, /.o.sɨ/, /.kɑp.s’ɨ/, /.ku.kɨ.min./), but this is not what Korean speakers do. Apparently, the faithfulness constraint against surface vowels that have no correspondent in the underlying form (i.e. the constraint DEP-V), is ranked quite high in native Korean phonology.

At the same time, however, the adapted English words *deck*, *mass*, *false* and *picnic* can show up as /.tɛ.k^{h}ɨ./, /.mæ.s’ɨ./, /.p^{h}ol.s’ɨ./ and /.p^{h}i.k^{h}ɨ.nik./, respectively, i.e. with apparently inserted vowels. For a ‘minimal view’ of loanword adaptation, this poses a problem. Under such a minimal view, learners would first store the English surface forms as the segmentally closest Korean underlying forms |tɛk^h|, |mæs’|, |p^{h}ols’| and |p^{h}iknik|, and then run these underlying forms through the native Korean constraint ranking. If this were correct, the four words would have to show up as /.tɛk./, /.mæt./, /.p^{h}ol./ and /.p^{h}iŋ.nik./, but this is not what happens.[3] All OT analyses therefore agree (as do we) that this minimal close-copy-plus-L1-filtering is not how loanword adaptation proceeds. Apparently, loanword adaptation is either performed in production

[3] Forms like these, i.e. without vowel epenthesis, sometimes do occur; we discuss them in §4.3 and footnote 12.

with a different constraint ranking than the native phonology (e.g. with a low-ranked DEP-V), or the underlying forms of loanwords are not stored as close copies of the surface forms of the donor language (because the native Korean perception process changes the form first).

Both of these possibilities have been considered in the literature. All the production-based accounts have to invoke loanword-specific mechanisms, such as loanword-specific rankings or loanword-specific constraints. However, all the perception-based accounts that do not assume the three-level model of Fig. 1 have to invoke direction-specific rankings or constraints. In §2 to §5 we analyze the Korean facts in the three-level L1-only framework of Fig. 1, showing that our analysis does not have to invoke any loanword-specific mechanisms and works solely with rankings and constraints that are the same for speakers and listeners. In §6 we discuss previous analyses found in the literature and show why these fail to work when not assuming loanword- or direction-specific mechanisms. In §7 we discuss some interesting additional issues.

2 Native Korean phonological processes: no vowel insertion

Here we show in detail how the three processes of Korean phonological production mentioned in §1 work, and give an Optimality-Theoretic account that will lead us to establish a ranking in which DEP-V must be ranked high.

2.1 An L1 phonological process: coda neutralization

One way to satisfy Korean structural restrictions is to neutralize a featural contrast. Korean plosives, for instance, come in three manners: lax (/t/), aspirated (/t^h/), and fortis (/t'/). We denote them by the feature combinations /–tense,–asp/, /+tense,+asp/, and /+tense,–asp/, respectively (Iverson 1983, H. Kim 2005). In codas, all plosives surface as lax, i.e., any underlying |+tense| is turned into /–tense/ and any underlying |+asp| is turned into /–asp/. The Korean word meaning 'field', for instance, is underlyingly |pɑt^h|, as evidenced by the locative /.pɑ.t^{h}ɛ./ 'in the field', from underlying |pɑt^h+ɛ|. In final position, the underlying |pɑt^h| is produced as the surface form /.pɑt./, with a laryngeal neutralization that can be described in terms of an interaction between structural and faithfulness constraints. We write the structural constraint against aspirated codas as */+asp ./. This structural constraint must outrank a faithfulness constraint for underlying aspiration, e.g. IDENT(asp). Tableau (1) gives the interaction (after H.Kang 1996; also Y.Kang 2003: 224).

(1) *L1 Korean production: deaspiration*

|pɑt^h|	*/+asp ./	DEP-V	MAX-C	IDENT(asp)	*/C ./
/.pɑt^h./	*!				*
☞ /.pɑt./				*	*
/.pɑ.t^{h}ɨ./		*!			
/.pɑ./			*!		

Crucially, we see that DEP-V has to be ranked quite high: in order that aspiration faithfulness cannot force insertion of an epenthetic vowel, DEP-V has to outrank IDENT(asp); and in order that, say, a general constraint against codas cannot force vowel epenthesis, DEP-V has to outrank the structural constraint */C ./. We also see that MAX-C has to outrank both IDENT(asp) and */C ./. The ranking of DEP-V above MAX-C is explained in §2.2.

Coda neutralization is not restricted to laryngeal features. The Korean word meaning 'clothes', for instance, is underlyingly |os|, as evidenced by the nominative /.o.si./, from underlying |os+i|. In non-prevocalic position, |os| surfaces as /.ot./. This strident neutralization can be described in terms of an interaction between a structural constraint against strident segments in coda position, */+stri ./, and a faithfulness constraint for underlying strident specifications, IDENT(stri), as in (2).

(2) *L1 Korean production: strident neutralization*

|os|	*/+stri ./	DEP-V	MAX-C	IDENT(stri)	*/C ./
/.os./	*!				*
☞ /.ot./				*	*
/.osɨ./		*!			
/.o./			*!		

As in tableau (1), we see a high ranking of DEP-V: this constraint has to outrank IDENT(stri) so that the latter cannot force insertion of an epenthetic vowel.

2.2 Another L1 phonological process: deletion

Another way to satisfy Korean structural restrictions is to delete a consonant. Korean codas can have two consonants underlyingly, but only one will surface. For instance, the Korean word meaning 'price' is underlyingly |kɑps|[4], as evidenced by the form /.kɑp.s'i.s'ɑ.tɑ. / 'cheap', from underlying |kɑps+i s'ɑtɑ|. In final position, the underlying form |kɑps| is produced as the surface form /.kɑp./, with a deletion that can be accounted for in terms of an interaction of the structural constraint */CC ./ ("no complex codas") and the faithfulness constraint MAX-C ("an underlying consonant should have a correspondent in the surface form"). This is shown in tableau (3).

[4] Or |kɑps'|, because there is no underlying contrast between tense and lax post-obstruent sibilants. Any such contrast would be unobservable because on the surface, underlying sibilants neutralize after obstruents, where they are always tense (for an overview, see Ahn & Iverson 2004).

(3) *L1 Korean production: final consonant deletion*

|kɑps|	*/+stri ./	*/CC ./	DEP-V	MAX-C	IDENT(stri)	*/C ./
/.kɑps./	*(!)	*(!)				*
/.kɑpt./		*!			*	*
/.kɑp.sɨ./			*!			*
☞ /.kɑp./				*		*
/.kɑ./				**!		

Again, we see that DEP-V is ranked high. Here (unlike in §2.1) we can see that DEP-V has to be ranked above MAX-C: it is better to delete a consonant than to insert a vowel.

2.3 A third L1 phonological process: assimilation

The Korean noun meaning 'country' is underlyingly |kuk|, as evidenced by the form /.ku.kʌ./ 'Korean language'. Before nasal consonants, the form changes: an underlying |kuk+min| 'nation' is produced as the surface form /.kuŋ.min./. According to various authors (Iverson & Sohn 1994, Davis & Shin 1999), this change is due to the syllable contact law (Hooper 1976, Murray & Vennemann 1983, Vennemann 1988), which for Korean asserts that a coda should not be less sonorous than the following onset. Davis & Shin (also H. Kang 2002) therefore give an OT analysis in terms of an interaction of the structural constraint SYLLCON with various faithfulness constraints. As Davis & Shin notice, SYLLCON, DEP-V and MAX-C have to outrank faithfulness constraints for underlying sonority and/or nasality; a simplified version of their analysis is shown in tableau (4).[5]

(4) *L1 Korean production: nasal assimilation*

|kuk+min|	SYLLCON	DEP-V	MAX-C	IDENT(nas)	*/C ./
/.kuk.min./	*!				**
☞ /.kuŋ.min./				*	**
/.ku.kɨ.min./		*!			*
/.ku.min./			*!		*

Again we see a high ranking of DEP-V: in order that nasality faithfulness cannot force insertion of an epenthetic vowel, DEP-V has to outrank IDENT(nas).

2.4 A constraint ranking for native Korean phonological production

Together, the evidence from tableaus (1) to (4) shows that DEP-V is high-ranked in native Korean production: it outranks at least four faithfulness constraints and one structural constraint.

[5] A candidate /.kuk.pin./, which violates the same constraints as the winner in (4), can be ruled out by splitting IDENT(nas) into IDENT(son) and MAX(nas) (Davis & Shin 1999), or by realizing that IDENT(nas) could be ranked higher for underlying |+nas| segments than for underlying |−nas| segments, as an emergent result of frequency differences between |+nas| and |−nas| segments (Boersma 2008; cf. §5).

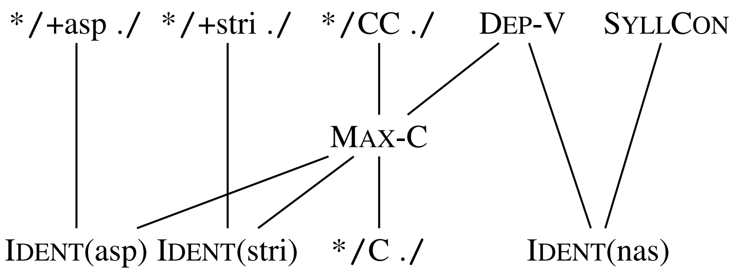

Fig. 2. Crucial rankings for native Korean phonological production.

The ranking in Fig. 2 again makes the point that vowel insertion is an avoided process in native Korean phonological production. In native Korean *perception*, the situation is rather different, as we show in the next section.

3 Native Korean perception of English sounds: ubiquitous vowel insertion

In this section we make plausible that in their native perception processes, Korean listeners routinely insert vowels, and that this causes the perceptual insertion of vowels into auditory-phonetic forms of English. In this we follow Y. Kang (2003), who convincingly argues that Korean listeners of English insert vowels. Unlike Kang, however, we provide an Optimality-Theoretic formalization of this perception process. Following Boersma (1998), this formalization is done in terms of the three levels depicted in Fig. 1, i.e., the term 'perception' refers only to the mapping from an auditory-phonetic form to a phonological surface structure. Following Boersma (2000, 2007ab), we formalize perception in terms of an interaction between cue constraints and structural constraints: cue constraints evaluate the relation between the input of the perception process (the auditory-phonetic form) and the output of the perception process (the phonological surface form), while structural constraints evaluate only the output of this process.

We will see that the structural constraints that play a role in native Korean perception are the same ones that play a role in native Korean production (Fig. 2). In perception, they will again turn out to be ranked high, as in production (Fig. 2). In perception, however, they interact not with faithfulness constraints (as they do in production) but with cue constraints, and the result is that the satisfaction of these structural constraints will in perception typically lead to vowel insertion rather than to any of the three processes that occur in production (§2).

3.1 Korean perception of English segments: cue constraints

We start our discussion of loanword adaptation with a discussion of foreign-language perception, because loanword adaptation must ultimately start from the *auditory-phonetic form* (the sound) of the word in the donor language. In this section we illustrate how the L1-only model of Fig. 1 handles the Korean perception of English vowels and plosives. Our main point here is to show how in words like *tag* and *deck* Korean listeners insert a vowel, i.e. how they interpret them as /.tʰæ.kɨ./ and /.tɛ.kʰɨ./.

In a narrow phonetic transcription, the sounds of the English words *tag* and *deck* look like [_ᵗʰá̠ːg˺‿ᵍ] and [_ᵈɛ̠̄k˺_ᵏʰ]. In these narrow auditory transcriptions, the underscore ("_") stands for the silence that occurs in plosives; "^{t}" and "^{k}" stand for the fortis alveolar and velar plosive release bursts, respectively; "^{g}" and "^{d}" stand for the lenis velar and alveolar plosive release bursts; "^{h}" stands for the (English-type) moderately strong aspiration noise; "a̞" and "ɛ̞" are the IPA transcriptions for the two English front vowels; "ː" reflects the typical English lengthening of vowels before voiced consonants (Heffner 1937, House & Fairbanks 1953); "g˺" and "k˺" stand for the formant transitions from a vowel into the velar stops; "ˊ" and "ˉ" stand for the high and mid-high fundamental frequency (F0) associated with English voiceless and voiced plosives in stressed syllables (House & Fairbanks 1953, Lehiste & Peterson 1961, Ohde 1984); and "‿" stands for the voicing murmur during the closure of a voiced plosive. All these details are what English listeners use all day to make sense of their surrounding speech: they are the cues that English listeners use for interpreting the surrounding speech in terms of English-specific phonological elements (features, segments, syllables). Together, these cues will lead an English listener to interpret the sounds [_thá̞ːg˺‿^{g}] and [_^{d}ɛ̞̄k˺_^{kh}] as the phonological surface structures /.tæg./ and /.dɛk./, where "." stands for a syllable boundary and e.g. the notation /t/ is a convenient shortcut for a more elaborate feature combination like [cor,–cont,–voi]. Importantly, auditory forms like [_thá̞ːg˺‿^{g}] and [_^{d}ɛ̞̄k˺_^{kh}] and surface forms like /.tæg./ and /.dɛk./ are representations that use different alphabets; the fact that our auditory and surface notations partially utilize some of the same symbols is purely coincidental.

When confronted with the sounds [_thá̞ːg˺‿^{g}] and [_^{d}ɛ̞̄k˺_^{kh}], a Korean listener will interpret the phonetic details in a different way from an English listener: a Korean listener will interpret these sounds in terms of Korean phonology. In this section we consider only the featural and segmental interpretations, leaving the interpretations in terms of syllable structure to §3.2, and phonotactically restricted interpretations to §3.3.

We start with the prevocalic English sounds [_th] and [_^{d}]. We assume that a Korean listener will perceive both of them as a Korean alveolar plosive, i.e. as /t/, /t'/ or /t^{h}/. In phrase-initial position, the plosives have the following pronunciations (Lisker & Abramson 1964, Han & Weitzman 1970, Hardcastle 1973, Hirose, Lee & Ushijima 1974, Kagaya 1974, Cho, Jun & Ladefoged 2002): /to/ is pronounced as [_$^{d̥}$ò], with a lenis voiceless burst (i.e. a positive voice onset time, with possible slight aspiration) and a lowered F0 on the vowel; /t'o/ is pronounced as [_^{t}ó], with a fortis release burst (no aspiration) and a raised F0 on the vowel; and /t^{h}/ is pronounced as [_^{thː}ó], with a fortis release burst, more aspiration noise than the English prevocalic /t/ has, and again with a raised F0. These differences in produced cues are reflected in the Korean perception of these three segments. When listening to initial plosives that vary in the degree of aspiration noise and in the height of F0, Korean listeners turn out to rely mainly on F0 to distinguish /t/ on the one hand (lowered F0) from /t'/ and /t^{h}/ on the other hand (raised F0); the distinction between /t'/ and /t^{h}/ is then made on the basis of aspiration noise (M.-R. Cho Kim 1994; Kim, Beddor & Horrocks 2002). Given these native Korean cue reliances, we can expect that Koreans interpret the plosives in the English sounds [_thó] and [_^{d}ō] as their phonemes /t^{h}/ and /t/, respectively. That they do this, has been confirmed in perception experiments (M.-R. Cho Kim 1994, Schmidt 1996, H. Park 2007) and is compatible with the loanword facts, as we will see.

Just asserting that English [_thó] and [_^{d}ō] tend to be classified by Korean listeners as /t^{h}o/ and /to/ does not suffice for our purposes: we need a formalization as well.

Boersma (1997, 1998, 2000, 2006, 2007ab, 2008), Escudero & Boersma (2003, 2004), Escudero (2005), Boersma & Escudero (to appear), Boersma & Hamann (to appear), and Hamann (to appear) provide such a formalization in terms of *cue constraints*. Just as faithfulness constraints do, cue constraints link two representations: whereas faithfulness constraints link underlying forms to phonological surface forms, cue constraints link auditory-phonetic forms to phonological surface forms (Fig. 1). The nature of cue constraints, though, is very different from that of faithfulness constraints: whereas faithfulness constraints link two discrete representations, cue constraints link a discrete representation (the surface form) to a continuously-valued representation, namely the auditory-phonetic form.

In order to establish the set of cue constraints for initial plosives, we have to establish first what the Korean representations look like. At the auditory-phonetic level, we already have the universal representations [_thó] and [_^{d}ō]. At the phonological surface level, we have used the Korean-specific segments /t/, /t'/, and /t^{h}/, but here we analyse these unitary phonemic symbols into the Korean-specific feature bundles /cor,–son,–cont,–tense,–asp/, /cor,–son,–cont,+tense,–asp/, and /cor,–son,–cont, +tense,+asp/, respectively. A relevant cue constraint, then, is *[^{h}]/–asp/, i.e. "moderately strong aspiration noise in the auditory form should not be perceived as the phonological feature value /–asp/ in the surface form". This constraint alone is enough to make sure that [_thó] is perceived as /t^{h}o/, as shown in tableau (5).

(5) *Korean perception of the English initial* /t/, *i.e. the sound* [_thó] *(first version)*

[_thó]	*[^{h}] /–asp/
/to/	*!
☞ /t^{h}o/	
/t'o/	*!

The perception tableau in (5) works as follows. The top left cell contains the input to perception, that is, the auditory-phonetic form [_thó]. The three candidate cells contain the three candidate outputs of perception, i.e. the three phonological surface forms /to/, /t^{h}o/, and /t'o/. The first candidate violates the constraint *[^{h}]/–asp/, because the input phonetic form contains the sound [^{h}] and the output phonological surface form /to/ contains the feature value /–asp/. For the same reason, the third candidate also violates this constraint. As a result of the two violations, the listener cannot perceive [_thó] as /to/ or /t'o/, and is left with no other option than to perceive [_thó] as /t^{h}o/. The perception tableau in (5), then, has provided a formalization of what we earlier expressed in plain English.

We now turn to the perception of [_^{d}ō], for which we have the same three candidate perceptions as for [_thó]. The sound [_^{d}ō] does not contain aspiration noise, so our old constraint *[^{h}]/–asp/ will not be able to distinguish between any of the three candidates. Instead, we can now use the counterpart of this constraint, which is *[*no noise*]/+asp/, i.e. "auditory absence of noisiness should not be perceived as the feature value /+asp/". As shown in tableau (6), this constraint helps to rule out the second candidate.

(6) *Korean perception of the English initial* /d/, *i.e. the sound* [_^{d}ō]

[_^{d}ō]	*[^{h}] /–asp/	*[*no noise*] /+asp/	*[¯] /+tense/	*[´] /–tense/
☞ /to/				
/t^{h}o/		*(!)	*(!)	
/t’o/			*!	

The second candidate violates *[*no noise*]/+asp/, because the input sound [_^{d}ó] contains no aspiration noise but the output structure /t^{h}o/ does contain the feature value /+asp/. The two aspiration cue constraints are powerless in ruling out the third candidate; for that, we need a cue constraint that addresses the feature value /+tense/ which is present in the candidate structure /t’o/ (as well as in /t^{h}o/). This constraint is *[¯]/+tense/, i.e. “an auditory normal F0 should not be perceived as the feature value /+tense/”. Since this is included in (6), /to/ remains as the only option for the perception of [_^{d}ō].

To complete our set of cue constraints for initial plosives, we notice that the counterpart of the constraint *[¯]/+tense/ is *[´]/–tense/, i.e. “an auditory raised F0 should not be perceived as the feature value /–tense/”. We included this constraint vacuously in (6), but tableau (7), an elaboration of tableau (5), shows that it could play a role in the Korean perception of the English initial /t/.

(7) *Korean perception of the English initial* /t/, *i.e. the sound* [_thó] *(final version)*

[_thó]	*[^{h}] /–asp/	*[*no noise*] /+asp/	*[¯] /+tense/	*[´] /–tense/
/to/	*(!)			*(!)
☞ /t^{h}o/				
/t’o/	*!			

Together, tableaus (6) and (7) illustrate that we can formulate the facts of perception alternatively in OT tableaus and in plain English. For instance, the first candidate row in (7) just states that two auditory cues contained in the sound [_thó] militate against perceiving this sound as the phonological structure /to/ (which contains the feature values /–asp/ and /–tense/).

The constraint set in (6) and (7) is still a bit too coarse-grained. In real life, auditory events can take on continuous values along multi-dimensional auditory continua, so a full set of cue constraints needed to describe a language requires more auditory values than are displayed in the constraints of (6) and (7). For instance, we meant the constraint *[^{h}]/–asp/ to refer to an English-like aspiration noise of 80 ms (Lisker & Abramson 1964:394). However, stronger (longer) aspiration noises, i.e. [^{hː}], are possible (in fact, they are typical of Korean /k^{h}/: Lisker & Abramson 1964:397, Kagaya 1974:168) and will even be less likely to be perceived as /–asp/. In other words, the cue constraint *[^{hː}]/–asp/ exists (and is ranked higher than *[^{h}]/–asp/: see §4.2). Working this out in full detail for the continua of aspiration noise and F0 is beyond the scope of this paper, whose focus is on vowel insertion. A more complete, ‘principled’, set of cue constraints than we could provide here appears in the next paragraphs, where we address the perception of the somewhat more straightforward auditory vowel height continuum.

In our discussion of the Korean perception of the English words *tag* and *deck*, we proceed with the English vowel sounds in these words, i.e. [a̝] and [ɛ̞]. An English listener interprets these as her phonemes /æ/ and /ɛ/, but how does a Korean listener classify them? Korean has the vowels /i, ɨ, u, o, ɛ, æ, ʌ, ɑ/, whose typical pronunciations are (or were) [i, ɨ̞, u, o, e̞, ɛ̝, ʌ, ɑ̟] (Yang 1996).[6] The two most reasonable candidates for the perception of the two English nonhigh front vowels are the two Korean nonhigh front vowels /ɛ/ and /æ/. Which of the two does the Korean listener choose for [a̝], and which for [ɛ̞]?

This question can be answered in perception experiments, and has been answered as follows (Ingram & Park 1997): (older) naive Korean listeners of English perceive the (Australian) English sound [ɛ̞] (from English /ɛ/) as the Korean vowel /ɛ/ and the English sound [a̝] (from English /æ/) as the Korean vowel /æ/.[7]

The auditory continuum that is responsible for the auditory distinction between Korean /ɛ/ and /æ/ is vowel height; a full, ‘principled’, set of cue constraints has to link every possible auditory vowel height to each of the two phonological categories. For instance, the vowel /ɛ/ is linked to just as many vowel heights as the auditory nerve discretizes the vowel height continuum into. For reasons of space, we divide the vowel height continuum into ten steps only. The ten cue constraints for /ɛ/ are thus *[i]/ɛ/, *[i̞]/ɛ/, *[e̝]/ɛ/, *[e]/ɛ/, *[e̞]/ɛ/, *[ɛ̝]/ɛ/, *[ɛ]/ɛ/, *[ɛ̞]/ɛ/, *[a̝]/ɛ/, and *[a]/ɛ/. In perception, the meaning of e.g. the constraint *[a̝]/ɛ/ is “the sound [a̝] should not be perceived as the vowel segment /ɛ/”.

One may think that such large constraint sets are too powerful. That is, with so many cue constraints one could model *any* kind of perception. However, Boersma’s (1997) proposal comes with a learning algorithm that ranks the cue constraints in such a way that the listener, after hearing a sufficiently large variety of tokens of every phonological category, becomes a *probability-matching listener*. That is, the listener will automatically rank her cue constraints in such a way that a given auditory event will be most likely perceived as the phonological category that was most likely intended by the speaker (Boersma 1997: 52–54, Escudero & Boersma 2003: 79–81). For the case at hand, this means the following. The sound [ɛ̞] is a possible realization of the Korean vowel /ɛ/ as well as of the Korean vowel /æ/. If Korean speakers, now, pronounce 70 [ɛ̞] tokens for /ɛ/ in the same time span as they pronounce 30 [ɛ̞] tokens for /æ/, a

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[6] Irritatingly, the two vowels we are talking about in this section, namely /ɛ/ and /æ/, are nowadays in a state of impending merger (Yang 1996, Ingram & Park 1997, Lee & Ramsey 2000, Tsukada, Birdsong, Bialystok, Mack, Sung & Flege 2005). The pronunciations hypothesized in this section are meant to refer to the situation at the moment of the adaptation of the words *tag* and *deck* (i.e., we lowered /æ/ slightly with respect to Yang’s measurements).

[7] Tsukada et al. (2005: 269) report quite different results for Korean listeners to an unspecified variety of (probably North-American) English, with English /æ/ mostly perceived as Korean /a/. Y. Kang’s list of borrowings indeed show some cases of /æ/ borrowed as /a/. In order to understand what vowels are borrowed how, one would have to consider the English donor variety as well as the receiving Korean variety at the time of borrowing (see also §7.4 for a complicating factor). We speculate that a possible shift in the donor variety may be responsible for the different vowels in /.sɨ.pʰot./ ‘spot’, /.tʰɨ.lot./ ‘trot’ versus /.hɑt./ ‘hot’, /.sjɑt./ ‘shot’.

Korean listener-learner will come to perceive [ɛ̞] 70 percent of the time as /ɛ/, and 30 percent of the time as /æ/. That is, the learning algorithm will gradually rank the cue constraint *[ɛ̞]/æ/ above the cue constraint *[ɛ̞]/ɛ/. It will rank the complete set of cue constraints approximately as in Fig. 3.

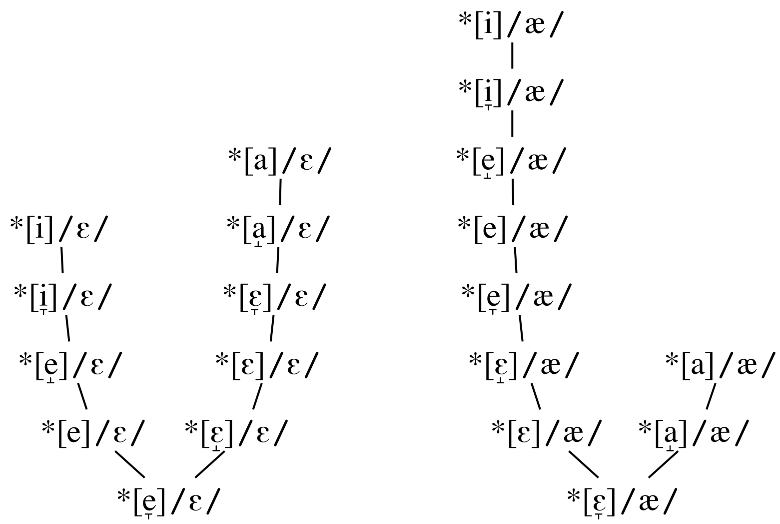

Fig. 3. Rankings of the cue constraints that connect auditory vowel height to the Korean vowel categories /ɛ/ and /æ/.

The figure assumes that the most typical realization of Korean /ɛ/ is [e̞], and the most typical realization of Korean /æ/ is [ɛ̞]. As a result, the constraints *[e̞]/ɛ/ and *[ɛ̞]/æ/ get ranked lowest. The remaining constraints get ranked by confusability and frequency (Boersma 2006, Boersma & Hamann to appear), which basically entails that they indirectly get ranked by auditory distance; thus, *[i]/æ/ will be ranked very high, because speakers are very unlikely to pronounce an intended /æ/ as the sound [i].

Tableaus (8) and (9) show that with the rankings of Fig. 3, the English sound [ɛ̞] is perceived as /ɛ/ and the English sound [a̝] as /æ/.

(8) *Korean perception of the English vowel* /ɛ/, *i.e. the sound* [ɛ̞]

[ɛ̞]	*[a̝] /ɛ/	*[ɛ̞] /ɛ/	*[e̝] /ɛ/	*[ɛ] /ɛ/	*[ɛ̞] /æ/	*[a] /æ/	*[e] /ɛ/	*[ɛ̞] /ɛ/	*[ɛ] /æ/	*[a̝] /æ/	*[e̞] /ɛ/	*[ɛ̞] /æ/
☞ /ɛ/								*				
/æ/					*!							

(9) *Korean perception of the English vowel* /æ/, *i.e. the sound* [a̝]

[a̝]	*[a̝] /ɛ/	*[ɛ̞] /ɛ/	*[e̝] /ɛ/	*[ɛ] /ɛ/	*[ɛ̞] /æ/	*[a] /æ/	*[e] /ɛ/	*[ɛ̞] /ɛ/	*[ɛ] /æ/	*[a̝] /æ/	*[e̞] /ɛ/	*[ɛ̞] /æ/
/ɛ/	*!											
☞ /æ/										*		

We have thus formalized perception on the basis of 'least confusable', not on the basis of 'most similar', or 'auditorily nearest'. This contrasts with approaches that assume that speakers have direct knowledge of the auditory distance between phonological elements, such as Steriade's (2001) P-map or Flemming's (1995) MINDIST constraints (for discussion see Boersma & Hamann, to appear: §7.4).

We now turn to the final consonants of English *tag* and *deck*. The cues in the final consonants are a superset of those of the initial consonants. In [_thǽ̤ːg˺‿^{g}], a Korean listener has no longer only the lenis burst cue [^{g}], but also: (1) the closure voicing [‿], which is compatible with the Korean /k/, which is the only of the three plosives that can ever be voiced (see §3.2); and (2) the vowel lengthening [ː], which occurs in Korean only before lax phonemes such as /k/ (see §4.3). In [_^{d}ɛ̤̄k˺_^{kh}], a Korean listener has the fortis burst [^{k}] and the aspiration [^{h}], which are the same cues as for /k^{h}/ in initial position. So it might seem reasonable that [_thǽ̤ːg˺‿^{g}] and [_^{d}ɛ̤̄k˺_^{kh}] are perceived as /.t^{h}æk./ and /.tɛk^{h}./, respectively. This is indeed a view that is widely held in theories on loanword adaptation (Silverman 1992, Yip 1993, H. Kang 1996, Yip 2006). With Y. Kang (2003), however, we regard it as unlikely. The next section explains why.

3.2 Korean perception of word-final release bursts: vowel hallucination

In §3.1 we asserted that the listener's perception process is defined as an attempt to retrieve the speaker's intended surface form. If this is correct, the Korean interpretations of the final sound sequences [ːg˺‿^{g}] and [k˺_^{kh}] are unlikely to be just the segments /k/ and /k^{h}/. This is because it is very unlikely that the sound sequences [ːg˺‿^{g}] and [k˺_^{kh}] can represent an intended final /k/ and /k^{h}/, which is because release bursts such as [^{g}] and [^{k}] do not occur in Korean codas.

Korean final plosives are pronounced without a release burst (Martin 1951, H. Kim 1998, Y. Kang 2003). Thus, the form /.pɑt./ in (1) has the auditory-phonetic form [_$^{b̥}$ɑt˺_] (where [t˺] stands for the formant transition from the vowel into the coronal closure), not the fully released *[_$^{b̥}$ɑt˺_^{t}]. For the listener, therefore, the presence of a release burst in Korean always indicates that the consonant is an onset and that it is followed by a vowel. We can express this fact as the cue constraint *[*burst*]/C(.)/, which stands for "an auditory release burst should not be perceived as a phonological consonant in coda."[8]

To satisfy the strong constraint *[*burst*]/C(.)/, the Korean listener has the option to perceive an onset instead of a coda. This entails perceiving [_thǽ̤ːg˺‿^{g}] and [_^{d}ɛ̤̄k˺_^{kh}] as /.t^{h}æ.kɨ./ and /.tɛ.k^{h}ɨ./, respectively. Both perceptions violate a cue constraint against interpreting nothingness as a vowel: *[ ]/ɨ/. To assess how highly ranked such a constraint could be, we have to realize that background noise often obliterates auditory cues in speech. For instance, the hypothetical Korean phonological sequences /.o.kɨ./ and /.o.k^{h}ɨ./ will ideally be produced as [og˺‿^{g}ɨ] and [ok˺_^{khː}ɨ], but may sometimes sound like the impoverished [og˺‿^{g}] and [ok˺_^{khː}], especially across a larger distance or if there is background noise. Such losses of direct positive auditory information are likely to occur in every language, and in Korean this is especially likely to happen if the final vowel is /ɨ/, which has been reported to be 'often deleted, especially in a weak, non-initial open syllable' (Kim-Renaud 1987, as quoted by Y. Kang 2003:236). The

[8] In the formulation of this constraint, the parentheses denote the environment; the remaining two elements, i.e. C and *burst*, are in *correspondence*, in the sense of Correspondence Theory (McCarthy & Prince 1995). An alternative formulation of the constraint is therefore *[*burst*$_i$]/C$_i$ ./.

learning algorithm discussed in §3.1 will then rank *[ ]/ɨ/ low. As a result, listeners will routinely fill in the missing information.

The interpretations of [_thḁ́ːg˺ ̮^{g}] as /.t^{h}æ.kɨ./ and of [_^{d}ɛ̥k˺_^{kh}] as /.tɛ.k^{h}ɨ./ could now be described in terms of the same cue constraints as in (6) and (7), with the addition of *[*burst*]/C(.)/ and *[ ]/ɨ/. However, we must realize that if a vowel is perceptually epenthesized, the final consonant becomes phonologically intervocalic, and this has consequences for the cues because in phonologically intervocalic position the Korean lax plosive is voiced (Kagaya 1974, Iverson 1983, Y.Y. Cho 1990, Jun 1995). Moreover, in noninitial syllables F0 cues are reduced (M.-R. Kim 2000, Kim & Duanmu 2004). The cue constraints that relate tenseness to F0 in (6) and (7) must therefore be reformulated as *[¯]/($[_{\phi}$)+tense/ and *[ˊ]/($[_{\phi}$)–tense/, and for the voicing cue we need the cue constraint *[*no voice*]/(V)–tense(V)/, which states that a voiceless silence cannot be perceived as a lax plosive between two phonologically present vowels, and its counterparts *[̮]/C(.)/ and *[̮]/+tense/, which state that a voiced closure cannot be perceived as a coda consonant and cannot be perceived as a fortis or aspirated plosive. The formalization is given in tableaus (10) and (11), which do not contain the cue constraints that refer to F0 as they are irrelevant for these cases.

(10) *Korean perception of the English word* tag

[_thḁ́ːg˺ ̮^{g}]	*[*burst*] /C(.)/	*[^{h}] /–asp/	*[*no noise*] /+asp/	*[̮] /C(.)/	*[̮] /+tense/	*[*no voice*] /(V)–tense(V)/	*[ ] /ɨ/
/.t^{h}æk./	*!			*			
/.t^{h}æk^{h}./	*!		*	*	*		
☞ /.t^{h}æ.kɨ./							*
/.t^{h}æ.k^{h}ɨ./			*(!)		*(!)		*
/.t^{h}æ.k’ɨ./					*!		*

(11) *Korean perception of the English word* deck

[_^{d}ɛ̥k˺_^{kh}]	*[*burst*] /C(.)/	*[^{h}] /–asp/	*[*no noise*] /+asp/	*[̮] /C(.)/	*[̮] /+tense/	*[*no voice*] /(V)–tense(V)/	*[ ] /ɨ/
/.tɛk./	*!	*					
/.tɛk^{h}./	*!						
/.tɛ.kɨ./		*(!)				*(!)	*
☞ /.tɛ.k^{h}ɨ./							*
/.tɛ.k’ɨ./		*!					*

In (10) and (11), the new cue constraint *[*burst*]/C(.)/ rules out the plosive-final candidates. The cue constraints *[*no noise*]/+asp/ and *[̮]/+tense/ rule out the remaining candidates with aspirated and fortis plosives in (10), and *[^{h}]/–asp/ and *[*no voice*]/(V)–tense(V)/ rule out the remaining candidates with the unaspirated plosives in (11). The cue constraint *[ ]/ɨ/ asserts that one should not hallucinate the vowel /ɨ/ if there is no direct corresponding auditory cue. It is the weakness of this constraint that causes the insertion of ‘illusory’ vowels in perception.

3.3 Korean loanword adaptation: structural constraints

If perception could be handled by cue constraints alone, perception would hardly interact with the phonology. That is, the surface elements that appear in the formulations of the cue constraints are phonological elements, but that would be all. However, according to Fig. 1 the integration of perception and phonology is much stronger than that: the output of the perception process itself is evaluated by *structural constraints*. As argued by Polivanov (1931), Boersma (2000, 2007ab), and Pater (2004), the same structural constraints that restrict phonological production (the top right of Fig. 1) also restrict prelexical perception (the bottom left of Fig .1). That is, perception is not handled by cue constraints alone, but by an interaction between structural and cue constraints. This renders perception thoroughly phonological itself. In other words, there is no longer any distinction between perception and phonology. In fact, the often discussed question whether loanword adaptation is ‘due to the phonology or due to perception’ is rendered moot (see also §6). The present section illustrates how structural constraints play a role in the perceptual vowel insertion in Korean loanwords from English.

Several structural constraints have been introduced in the phonological production tableaus of §2, but none of them were used in the perception tableaus of §3.1 and §3.2. One structural constraint could already have made its appearance in tableau (11), namely the constraint */+asp ./ that was crucial in tableau (1). If included in tableau (11), it would have helped to rule out the candidate /.tɛk^{h}./. But of course, this constraint would not have played a crucial role in that tableau, which works perfectly with cue constraints alone.

More crucial cases of structural constraints that guide perception were given by Polivanov (1931) in a discussion of Japanese perception of Russian ([_^{t}ak˺_^{k}] → /.ta.ku./, [̰^{d}rama] → /.do.ɾa.ma./), a case that was translated to the OT perception framework of Fig. 1 by Boersma (2007b).

A similar case as the Japanese vowel insertion in consonant clusters that Polivanov analysed, is found in the Korean avoidance of complex onsets in both native and loanwords. Thus, the English word *spike* is realized in Korean as /.sɨ.p^{h}ɑ.i.k^{h}ɨ./, and *flute* is realized as /.p^{h}ɨl.lu.t^{h}ɨ./ (Y. Kang 2003:262,266,244). Since this insertion generalizes to all onset clusters, the most straightforward way to account for it is by utilizing the structural constraint */.CC/.[9] Tableau (12) shows the analysis for *spike*, where we formalize only the adaptation of the initial cluster and thereby ignore the adaptation of the diphthong and the final consonant.

[9] It is always possible, though often awkward, to replace a structural constraint with a set of cue constraints. We elaborate on this possibility in §7.1.

(12) *Korean perception of the English word* spike

[s_^{p}aɪk˺_^{kh}]	*/.CC/	*[ ] /ɨ/
/.sp^{h}ɑ.i.k^{h}ɨ./	*!	
☞ /.sɨ.p^{h}ɑ.i.k^{h}ɨ./		*

In (12) we see that the structural constraint, by outranking the cue constraint, causes the perceptual insertion of an illusory vowel.[10]

To show that the same structural constraints play a role in perception and production, we consider the Korean avoidance of strident codas, which was illustrated for production in §2.1. The same structural constraint that caused coda neutralization in production (tableau (2)), causes vowel insertion in perception, as illustrated in tableau (13), which shows the Korean perception of the English word *mass*.

(13) *Korean perception of the English word* mass

[mæs]	*/+stri ./	*[*friction*] /−stri/	*[ ] /ɨ/
/.mæs./	*!		
/.mæt./		*!	
☞ /.mæ.s'ɨ./			*

In tableau (13), the most 'faithful' percept /.mæs./ violates the structural constraint */+stri ./. The candidate /.mæt./ violates the high-ranked cue constraint *[*friction*]/−stri/ which says that friction noise should not be interpreted as phonological nonstridency. The winning candidate is therefore the percept /.mæ.s'ɨ./, with an epenthesized vowel.[11]

A comparison between the perception tableau in (13) and the production tableau in (2) shows us that the forbidden strident coda consonant /-s./ is ruled out in both tableaus by the high-ranked structural constraint */+stri ./. The repair mechanisms, however, are different in L1 perception and L1 production. In both perception and production, the choice goes between the remaining surface forms /-t./ and /-.s'ɨ./. In perception, the constraint for honouring phonetic stridency information (*[*friction*]/−stri/) outranks the constraint against vowel insertion (*[ ]/ɨ/), leading to the surface form /-.s'ɨ./, whereas in production, the constraint against vowel insertion (DEP-V) outranks the constraint for honouring underlying phonological stridency (IDENT(stri)), leading to the surface form /-t./. Please note that these differences are not due to different constraint rankings between comprehension and production, but to

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[10] The attentive reader may notice that it is strange that the sound [_^{p}] is perceived as /p^{h}/, which is typically pronounced [_$^{ph:}$], rather than as /p'/, which is typically pronounced [_^{p}] (§3.1). This problem is discussed by Oh (1996), H.Kang (1996), Kenstowicz (2005), Ito, Kang & Kenstowicz (2006), Davis & Cho (2006), and Iverson & Lee (2006), and we return to it in §7.4.

[11] When comparing (13) with (12), we see that English [s] is adapted into Korean as plain /s/ if followed by a stop (in English), but as tense /s'/ if it is final (in English). The present paper makes no attempt to account for this difference. See Davis & Cho (2006) and H. Kim (2008/to appear) for more information.

different kinds of constraints in the 'phonological' part of the grammar (the top of Fig. 1) and the 'phonetic' part of the grammar (the bottom of Fig. 1). Please also note that this does not mean that the 'phonological' and 'phonetic' parts of the grammar can be viewed as separate modules: they utilize the same structural constraints.

Another potential case of a structural constraint in perception is the case of the constraint SYLLCON, which bans segmental sequences like /km/ from the output of Korean L1 production (§2.3). H. Kang (1996) notes that English words with word-internal plosive-nasal clusters are borrowed differently in Korean (namely, with vowel insertion) than English words with plosive-plosive clusters (which are borrowed without vowel insertion). As usual, we interpret this as the result of a difference in perception. Thus, we follow Y. Kang (2003) in assuming that *chapter* is perceived as /.ts^{h}æp.t^{h}ʌ./; we also assume that, by contrast, the word *picnic* (which Y. Kang mentions but does not analyse) is perceived as /.p^{h}i.k^{h}ɨ.nik./.[12]

According to H. Kang (1996), the adaptation of *chapter* as /.ts^{h}æp.t^{h}ʌ. / with a coda /p./ is due to the fact that the English source word is pronounced without an audible labial release, i.e. as [_^{tʃ}a̪p˺_thə]. We follow Y. Kang (2003) in assuming that this lack of release causes Korean listeners to perceive a coda /p/. We formalize this in tableau (14). With the same cue constraint that caused the insertion of a vowel in (10) and (11), namely *[*burst*]/C(.)/, the winning candidate now becomes the form without vowel insertion.

(14) *Korean perception of the English word* chapter

[_^{tʃ}a̪p˺_thə]	SYLLCON	*[C˺] / /	*[*burst*] /C(.)/	*[ ] /ɨ/
☞ /.ts^{h}æp.t^{h}ʌ./				
/.ts^{h}æ.pɨ.t^{h}ʌ./				*!
/.ts^{h}æ.p^{h}ɨ.t^{h}ʌ./				*!
/.ts^{h}æ.t^{h}ʌ./		*!		

In contradistinction with tableaus (10) and (11), the candidate without vowel insertion (/.ts^{h}æp.t^{h}ʌ./) now wins: since the input sound contains no labial release burst, this candidate does not violate *[*burst*]/C(.)/. The fourth candidate violates the cue constraint *[C˺]/ /, which is high-ranked because Korean listeners routinely have to interpret postvocalic formant transitions as true consonants.

The same ranking as in (14) works out differently for an English plosive-nasal cluster, such as in *picnic*. This word is pronounced in English as [_^{ph}ɪk˺_nɪk˺_], where we assume the same lack of release for the first consonant of the cluster (as a side issue, we also assume with Y. Kang 2003:261 that the word-final plosive is unreleased in English). The difference with the *chapter* case is that the syllable contact law is applicable. Tableau (15) shows that this forces vowel insertion.

[12] H. Kang notes that younger generations can produce this word as /.p^{h}iŋ.nik./. According to Kabak (2003:59), such adaptations are due to orthographical influence. See §7.3 for how this fits into our model.

(15) *Korean perception of the English word* picnic

[_^{ph}ɪk˺_nɪk˺_]	SYLLCON	*[C˺] / /	*[*burst*] /C(.)/	*[_] /+nas/	*[*no noise*] /+asp/	*[*no voice*] /(V)–tense(V)/	*[ ] /ɨ/
/.p^{h}ik.nik./	*!						
/.p^{h}iŋ.nik./				*!			
☞ /.p^{h}i.kɨ.nik./						*	*
☞ /.p^{h}i.k^{h}ɨ.nik./					*		*
/.p^{h}i.nik./		*!					

A new type of candidate in tableau (15) is /.p^{h}iŋ.nik./. If a Korean listener interpreted [_^{ph}ɪk˺_nɪk˺_] as /.p^{h}iŋ.nik./, she would ignore positive information, namely the silence [_], which is a reliable cue for the presence of a plosive rather than a nasal. In (15) this is expressed with the cue constraint *[_]/+nas/. The thing that crucially distinguishes tableau (15) from tableau (14), though, lies somewhere else. The crucial difference is that the candidate /.p^{h}ik.nik./ violates the syllable contact law. This causes the listener to insert a vowel. The choice between the third and fourth candidate in (15) has to be made on the basis of lower-ranked cue constraints; the attested /.p^{h}i.k^{h}ɨ.nik./ suggests that the absence of auditory voicing weighs heavier than the absence of auditory aspiration noise.[13]

It is crucial for our story that the difference between (14) and (15) can only be accounted for in terms of the structural constraint SYLLCON. That is, structural constraints are crucial in perception.

When comparing (4) with (15), we see that forbidden sonority sequences like /kn/ are repaired differently in L1 production than in L1 perception. Both in production and perception, SYLLCON rules out candidates with sequences like /kn/. In production, however, the ranking of the faithfulness constraints DEP-V >> IDENT(nas) decides that the repair is /ŋn/, whereas in perception the ranking of the cue constraints *[_]/+nas/ >> *[ ]/ɨ/ decides that the repair is /k^{h}ɨn/.

Thus, structural constraints are crucial in perception, and the repair strategies can be different in perception and production.

3.4 What is perception?

Not all readers will instantly accept our view (shared by Y. Kang 2003, Kabak & Idsardi 2007 and H. Kim 2008) that perception can introduce a vowel, as in (10), (11), (12), (13) and (15).

However, precisely such perceptual vowel insertion has been proposed several times before. Polivanov (1931) argues that Japanese listeners perceive the Russian word [_^{t}a_^{k}] 'so' as their native phonological structure /.ta.ku./, and the Russian word [‿^{d}rama] 'drama' as their structure /.do.ɾa.ma./. Polivanov attributes these perceptions to Japanese structural constraints against coda consonants and against complex clusters, respectively; indeed, a formulation in terms of an interaction between structural and cue

[13] The possible candidate /.p^{h}i.k'ɨ.nik./ has to be rules out in a different way. See §7.4.

constraints in OT, analogous to tableaus (12) and (15), is possible and has been carried out in detail by Boersma (2007b: 10–14).

Polivanov's proposal has been confirmed in the laboratory. Dupoux, Kakehi, Hirose, Pallier, Fitneva & Mehler (1999) showed that Japanese listeners could not discriminate between the sounds [ebzo] and [ebuzo], which strongly suggests that Japanese listeners perceive the sound [ebzo] as their native phonological surface structure /.e.bɯ.zo./.

We would like to stress here, however, that linguistic perception is not about discrimination, but about identification (for Korean vowel insertion, Kabak & Idsardi 2007:36 agree with this view). We regard perception as an active process: generally, perception is the mapping from raw sensory data to a more abstract mental representation that is ecologically appropriate; in linguistics, the listener's active perception process maps a sound to a native phonological structure, in order to arrive quickly at the morphemes that the speaker has intended to bring across. When computing a likely intended phonological structure, the listener has to take into account both the available auditory cues and knowledge about the structural restrictions of the language. With Boersma (2000, 2007ab), therefore, we formalize this computation in terms of interactions between structural and cue constraints, as in Fig. 1 and tableaus (12) to (15). Peperkamp & Dupoux (2003) propose the same three levels and four mappings for loanword adaptations as we employ in Fig.1, noting that such representations and mappings correspond to what psycholinguists would have to say about the stages of comprehension (McQueen & Cutler 1997) and production (Levelt 1989); however, they do not provide a linguistic modelling of these mappings and in fact regard perception as nonlinguistic.

In Optimality Theory, the idea that structural constraints play a role in perception has some history. It is related to the idea of *robust interpretive parsing* (Tesar 1997, Tesar & Smolensky 2000), in which listeners interpret an *overt form* (sound) as a phonologial (e.g. metrical) structure by using the same ranking of the structural constraints as they use for production.[14] Cue constraints turned up in Boersma (1997, 1998, 2000, 2006, 2008), Escudero & Boersma (2003, 2004), Escudero (2005), Boersma & Escudero (to appear), Boersma & Hamann (to appear), and Hamann (to appear), and their interaction with structural constraints was formalized in various degrees of similarity to the present proposal by Boersma (1998:164–171,364–396, 2000, 2007ab), Boersma, Escudero & Hayes (2003), and Pater (2004).

We like to urge phonologists to regard active perception as a just as intricate and interesting process as they have traditionally regarded production. A spectacular example was given by Boersma (2003: 32, 2007b: 27), who argues that Desano listeners interpret the sound [ʒuɐ̃ũ] (the Portuguese name *João*) as their native surface structure /.ɲũ./, forced by a structural constraint against tautosyllabic sequences of oral and nasal segments. In the loanword adaptation literature, perception is often regarded as a much less active, and therefore much less powerful, process. This view of perception has led researchers to fail to consider L1-specific perception phenomena as the explanans for loanword adaptation. In §6 we compare our account to some of these other proposals, as well as to proposals that do accept vowel insertion in perception but do not formalize it.

[14] The relation between robust interpretive parsing and perception is discussed in Boersma (2007b:21-23).

3.5 Conclusion

Section 3 has illustrated how Korean listeners interpret English sound sequences in terms of their own phonological cues and phonotactics. To illustrate that the exact same constraints and ranking work for the perception of native Korean words as well, tableau (16), which uses the same ranking as (10) and (11), shows that the auditory-phonetic form [_^{k}ɛ̰̀k˺_] (the normal unreleased pronunciation of the Korean word |kæk| 'guest') is perceived as /.kæk./.

(16) *L1 Korean perception*

[_^{k}ɛ̰̀k˺_]	*[*burst*] /C(.)/	*[^{h}] /–asp/	*[*no noise*] /+asp/	*[̰] /+tense/	*[*no voice*] /(V)–tense(V)/	*[ ] /ɨ/
☞ /.kæk./						
/.kæk^{h}./			*!			
/.kæ.kɨ./					*!	*
/.kæ.k^{h}ɨ./			*!			*
/.kæ.k'ɨ./						*!

While for the Korean perception of English forms in (10) and (11) the ranking resulted in vowel insertion, for the perception of a native Korean form in (16) it does not result in vowel insertion. The reason for this difference simply lies in the auditory input: Korean final plosives are unreleased, whereas final plosives in English are released (but see §4.3 for unreleased plosives in English).

In the next section we show that the perceptual adaptations of English words are sufficient to explain vowel insertion in loanwords.

4 Perception, storage and production of English loanwords in Korean

In §3 we illustrated the very first part of the loanword adaptation process, namely the mapping from an auditory-phonetic form (sound) to a native phonological surface structure. Loanword adaptation does not stop here: this foreign-language perception has to be followed by a process of lexical storage, which can then lead to the adapter's own productions of the borrowed word. This is the same process that any listener uses for the words of her native language.

4.1 Storage of English loanwords in the Korean lexicon

We assume that loanword adaptation has started with the L1 perception process exemplified in §3. For instance, the Korean loanword adapter has perceived [_thḁ́ːg˺ ̰^{g}] and [_^{d}ɛ̰̄k˺_^{kh}] as /.t^{h}æ.kɨ./ and /.tɛ.k^{h}ɨ./ (§3.2). Her next task is to store them in her lexicon as new underlying forms.

We assume that the storage of a new word in the lexicon follows the process that we call *recognition* in the top left of Fig. 1. In this process, the faithfulness constraints ensure that the learner stores into her lexicon the fully faithful forms |tʰækɨ| and |tɛkʰɨ|, as illustrated in tableaus (17) and (18).[15]

(17) *Korean lexical storage of the English word* tag

/.tʰæ.kɨ./	*/+asp ./	DEP-V	MAX-C	IDENT(asp)	*/C ./
|tʰækʰɨ|				*!	
☞ |tʰækɨ|					
|tʰæk|		*!			

(18) *Korean lexical storage of the English word* deck

/.tɛ.kʰɨ./	*/+asp ./	DEP-V	MAX-C	IDENT(asp)	*/C ./
☞ |tɛkʰɨ|					
|tɛkɨ|				*!	
|tɛkʰ|		*!			
|tɛk|		*!		*	

The structural and faithfulness constraints are the same as in (1), and they are ranked in the same order. We first note that the third candidate in (18) does not violate */+asp ./, because this constraint only evaluates surface forms; something analogous holds for the constraint */C ./, which incurs no violations for any candidates. Next, we see that DEP-V can still be high-ranked (note that in this direction of processing, DEP-V militates against *deletion* rather than insertion: correspondence constraints evaluate relations, not processes).

The remaining example words from §3 are stored fully faithfully as well: |sɨpʰɑikʰɨ|, |mæs’ɨ|, |tsʰæptʰʌ|, |pʰikʰɨnik|.

Building a lexicon mainly through faithfulness constraints, as in (17) and (18), constitutes a form of *lexicon optimization* (Prince & Smolensky 1993 [2004:225–231]). As a result, the lexicon comes to reflect some of the same phonotactic restrictions that surface forms have, an effect that Boersma (1998: 395) called *poverty of the base* (for exceptions see §7.3).

4.2 Production of English loanwords from a Korean lexicon

After storing the English word as the new underlying forms |tʰækɨ| and |tɛkʰɨ|, the loanword adapter is ready to subsequently use them in her own productions. She will produce them as the surface forms /.tʰæ.kɨ./ and /.tɛ.kʰɨ./ and as the auditory-phonetic forms [_ᵗʰːɛ̰́ːg˺‿ᵍɨ] and [_ᵈ̥ɛ̰̀k˺_ᵏʰːɨ], as the following four tableaus illustrate.

In phonological production, the underlying |tʰækɨ| and |tɛkʰɨ| are produced as /.tʰæ.kɨ./ and /.tɛ.kʰɨ./, as tableaus (19) and (20) show.

[15] Full faithfulness in word recognition is ensured only if the faithfulness constraints do not conflict with constraints at higher levels, which would come into play if alternations start to play a role. See §5 for examples.

(19) *Korean phonological production of the English loanword* t^{h}ækɨ

|t^{h}ækɨ|	*/+asp ./	DEP-V	MAX-C	IDENT(asp)	*/C ./
☞ /.t^{h}æ.kɨ./					
/.t^{h}æ.k^{h}ɨ./				*!	
/.t^{h}æk./					*!
/.t^{h}æ./			*!		

(20) *Korean phonological production of the English loanword* tɛk^{h}ɨ

|tɛk^{h}ɨ|	*/+asp ./	DEP-V	MAX-C	IDENT(asp)	*/C ./
/.tɛ.kɨ./				*!	
☞ /.tɛ.k^{h}ɨ./					
/.tɛk^{h}./	*!				*
/.tɛk./				*(!)	*(!)

In these production tableaus, we employ the same constraints as in the production tableau for the native form |pɑt^{h}| in (1), and in the recognition tableaus (17) and (18). Deletion of final underlying |ɨ| is prevented by the low-ranked */C ./ (this obviates the need for MAX-V, at least for the cases discussed here). Likewise, the other sample words are produced equally faithfully as /.sɨ.p^{h}ɑ.i.k^{h}ɨ./, /.mæ.s’ɨ./, /.ts^{h}æp.t^{h}ʌ./, /.p^{h}i.k^{h}ɨ.nik./.

The surface form /.t^{h}æ.kɨ./ that results from the phonological production in (19) is subsequently pronounced as [_$^{th:}$ɛ̰́g˺‿^{g}ɨ], as tableau (21) shows. Here we employ the same cue constraints as in perception, i.e. cue constraints are just as bidirectional as the faithfulness constraints and the structural constraints. For instance, the constraint *[^{h}]/–asp/, which meant in perception “if there is moderately strong auditory-phonetic noise, then do not perceive the phonological surface structure /–asp/”, now means in production “the phonological surface structure /–asp/ should not be realized with moderately strong auditory-phonetic noise”. This constraint is ranked at the same height in production and perception.

(21) *Korean phonetic implementation of the English loanword* t^{h}ækɨ

/.t^{h}æ.kɨ./	*[$^{h:}$] /–asp/	*[*burst*] /C(.)/	*[^{h}] /–asp/	*[*no noise*] /+asp/	*[*no voice*] /(V)–tense(V)/	*[ ] /ɨ/	*[^{h}] /+asp/
[_$^{th:}$ɛ̰́k˺_$^{kh:}$ɨ]	*!				*		
[_$^{th:}$ɛ̰́k˺_^{kh}ɨ]			*!		*		
[_$^{th:}$ɛ̰́k˺_^{k}ɨ]					*!		
☞ [_$^{th:}$ɛ̰́ːg˺‿^{g}ɨ]							
[_$^{th:}$ɛ̰́ːg˺‿^{g}]						*!	
[_$^{th:}$ɛ̰́k˺_^{k}]					*!	*	
[_$^{th:}$ɛ̰́k˺_]					*!	*	

The *phonetic implementation tableau* (21) employs some of the same cue constraints as the perception tableaus (10) and (11), ranked in the same order. However, the cue constraints in (10) and (11) only had to deal with English sounds. Here, in order to make the correct Korean-specific choice of auditory forms, we need cue constraints that cover the whole spectrum of auditory values. For aspiration, we have the ranking *[$^{\text{hː}}$]/–asp/ >> *[$^{\text{h}}$]/–asp/, because it is worse to aspirate an unaspirated consonant strongly than to aspirate it only moderately (the two /+asp/ cue constraints are explained below). Intervocalic voicing of the lax plosive in production is here achieved by the same *[*no voice*]/(V)–tense(V)/ that works in the perception tableaus (11), (15) and (16); it is violated by all voiceless candidates, even the ones with phonetic vowel deletion (because intervocality is defined at the phonological level). Please note that none of the candidates violate *[*burst*]/C(.)/, because the input is not consonant-final. Further, phonetic /ɨ/-deletion is punished by the constraint *[ ]/ɨ/ that we saw before; in perception, the low ranking of this constraint allowed the perception of an illusory vowel (§3.2); here in phonetic implementation, this constraint suddenly becomes crucial in making sure that the surface vowel /ɨ/ is pronounced at all. The second best candidate is [_$^{\text{thː}}$é̞ːg˺‿$^{\text{g}}$]; its second-bestship expresses the idea that the voicing cue (between *phonologically present* vowels) is more important than the audibility of the vowel /ɨ/; this candidate could be realized if an articulatory (laziness) constraint (Kirchner 1998, Boersma 1998) is ranked at about the same height as *[ ]/ɨ/ (in the model of Fig. 1, articulatory constraints such as *[ɨ] evaluate the phonetic form directly).

The surface form /.tɛ.k$^{\text{h}}$ɨ./ that results from (20) is pronounced as [_$^{\text{d̥}}$è̞k˺_$^{\text{khː}}$ɨ], as (22) shows.

(22) *Korean phonetic implementation of the English loanword* tɛk$^{\text{h}}$ɨ

/.tɛ.k$^{\text{h}}$ɨ./	*[$^{\text{hː}}$] /–asp/	*[*burst*] /C(.)/	*[$^{\text{h}}$] /–asp/	*[*no noise*] /+asp/	*[‿] /+tense/	*[ ] /ɨ/	*[$^{\text{h}}$] /+asp/
☞ [_$^{\text{d̥}}$è̞k˺_$^{\text{khː}}$ɨ]							
[_$^{\text{d̥}}$è̞k˺_$^{\text{kh}}$ɨ]							*!
[_$^{\text{d̥}}$è̞k˺_$^{\text{k}}$ɨ]				*!			
[_$^{\text{d̥}}$è̞ːg˺‿$^{\text{g}}$ɨ]				*(!)	*(!)		
[_$^{\text{d̥}}$è̞k˺_$^{\text{khː}}$]						*!	
[_$^{\text{d̥}}$è̞k˺_$^{\text{k}}$]				*!		*	
[_$^{\text{d̥}}$è̞k˺_]				*!		*	

The full cue constraint ranking that we need for aspiration is *[*no noise*]/+asp/ >> *[$^{\text{h}}$]/+asp/ >> *[$^{\text{hː}}$]/+asp/: the less noise there is in the auditory form, the less likely it is that a /+asp/ segment is present. The end result is that Koreans pronounce the borrowed English word *deck* with more aspiration than was present in the English source sound, i.e., while perception has introduced an illusory vowel in this word, the phonetic implementation has given the word an additional Korean accent.

Together, tableaus (19) to (22) perform production as a serial process: first phonological production, then phonetic implementation, where the output of the former is the input to the latter. The two partial production processes can also be done in parallel (Boersma 2007ab, 2008), with the same ultimate result as tableaus (19) to (22) yield. An example of a parallel production tableau is given in §7.1.

Tableaus (21) and (22) round up our account of the Korean adaptation of the English words *tag* and *deck*. It started with the observed English sounds [_thá̠ːg˺ ‿^{g}] and [_^{d}ɛ̠̄k˺_^{kh}], and ended with the observed Korean sounds [_^{thː}ɛ̠́ːg˺ ‿^{g}ɨ] and [_$^{d̥}$ɛ̠̀k˺_^{khː}ɨ]. What happens in between these two pairs of sounds is something that is not directly observable, and therefore open to widespread hypothesization by linguists. The account that we have brought here is the only one that utilizes exclusively first-language processing, as summarized in (23).

(23) *Korean adaptation of the English words* deck *and* gag

tag: [_thá̠ːg˺ ‿^{g}] → /.t^{h}æ.kɨ./ → |t^{h}ækɨ| → /.t^{h}æ.kɨ./ → [_^{thː}ɛ̠́ːg˺ ‿^{g}ɨ]
deck: [_^{d}ɛ̠̄k˺_^{kh}] → /.tɛ.k^{h}ɨ./ → |tɛk^{h}ɨ| → /.tɛ.k^{h}ɨ./ → [_$^{d̥}$ɛ̠̀k˺_^{khː}ɨ]

The first two steps in (23) form part of the comprehension process, and the last two form part of the production process. The four steps of loanword adaptation are handled by a single constraint ranking, which is the same as the one used for native Korean production and comprehension. In this model, auditory similarity between the phonetic forms of the donor language and the borrowing language is achieved by the bidirectionality of the cue constraints; this bidirectionality obviates the need for supposed mechanisms by which speakers have direct knowledge of the auditory distance between phonological elements, such as Steriade's (2001) "P-map", which has been invoked very often in loanword adaptation research (§6.1).

A complete ranking is given in §7.5.

4.3 Variation

For English words with a final /g/ or /k/, a vowel is not always appended in Korean. Kim-Renaud (1977: 252) and Y. Kang (2003: 235) attribute this variation to the variability of the release burst in English (Rositzke 1943, Crystal & House 1988, Byrd 1992, Cruttenden 1994: 145, H. Kim 1998). To understand this, we investigate how tableaus (10) and (11) will change if the release burst is inaudible. First, the constraint *[*burst*]/C(.)/ will not be violated in any candidate. But there is more. One first has to realize that articulatorily, a release must exist, even if it is inaudible (H. Kim 1998). The release burst, then, is rendered inaudible by a low subglottal pressure. In the input of tableau (11), this low pressure must have an influence on the following aspiration noise, which will become inaudible itself: in (11), therefore, the auditory input will be [_^{d}ɛ̠̄k˺_], the constraint *[^{h}]/–asp/ can no longer be violated, and the candidate /.tɛk./ will win (because /.tɛk^{h}./ is ruled out by the high-ranking */+asp ./). In the input of tableau (10) the low subglottal pressure during the release will reduce the subglottal pressure during the closure phase as well, so that closure voicing diminishes: in (10), therefore, the auditory input will be [_thá̠ːg˺ ‿̆] (where the breve stands for reduction), the constraints *[‿]/C(.)/ and *[‿]/+tense/ can no longer be violated (althought the lower-ranked *[‿̆]/C(.)/ and *[‿̆]/+tense/ can), and the candidate /.t^{h}æk./ will win. For both cases we will then end up with final unaspirated plosives in the underlying forms, and subsequently with unreleased plosives in the produced auditory-phonetic forms.

As a result of this variation in English production, some listeners will lexicalize *tag* with an unreleased plosive, some will lexicalize it with vowel epenthesis. As more people borrow the same word, the two underlying forms will start competing with each other (at the level of surface form), and it is likely that one form wins in the end. Ultimately, the language will end up with some words ending in unreleased plosives, other words ending in epenthesized vowels, and some words may continue to show variation for some time. Y. Kang (p.253–4) shows that this is indeed the case, and she proposes the mechanism just mentioned (but without mentioning the lexicon).

Apart from the variation in the English plosives, there could also be variation in the rankings of the listener's constraints, as we will see below (25).

Y. Kang (2003) provides explanations for three phonological factors that influence whether vowel insertion appears in Korean adaptation of English words.

First, words with English tense vowels tend to insert a vowel more often than words with English lax vowels: *week* becomes /.wi.k^{h}ɨ./, whereas *quick* becomes /.k^{h}wik./. Kang (pp. 235–244) argues convincingly that this difference is due to the fact (Parker & Walsh 1981, Y. Kang 2003:239–241) that final consonants in English are more often released after tense than after lax vowels. In our account, this means that the auditory-phonetic input less often contains releases like [^{k}] after lax vowels than after tense vowels. For instance, the word *quick* was pronounced without a release (i.e. as [_^{kh}wík˺ _]) upon its borrowing into Korean. With tableau (16) we see that it was perceived as /.k^{h}wik./. Hence, the form that was adapted is |k^{h}wik|, which is produced as /.k^{h}wik./, which sounds as [_$^{kh:}$wík˺_] or [_$^{kh:}$ýk˺_].

Second, words with English voiced stops in postvocalic word-final position tend to insert a vowel more often than those with voiceless stops: *MIG* becomes /.mi.kɨ./, whereas *kick* becomes /.k^{h}ik./. Kang (pp. 244–249) argues convincingly that this difference is not due to a difference in release frequencies but to the facts that Korean intervocalic lax plosives are phonetically voiced (Kagaya 1974, Y.Y. Cho 1990, Jun 1995) and that Korean, as does English, lengthens its vowels before voiced consonants (Lim 2000, as reported by Y. Kang 2003: 247). The following tableaus, with many of the same constraints as in (10) and (11), show how the reduced voicing cue makes the difference if there is no release burst (similar tableaus can be devised for the lengthening cue):

(24) *Korean perception of the English word* MIG

[mɪːg˺ ˘̰]	*/+asp ./	*[*burst*] /C(.)/	*[^{h}] /–asp/	*[*no noise*] /+asp/	*[˘̰] /C(.)/	*[˘̰] /+tense/	*[ ] /ɨ/
/.mik./					*!		
/.mik^{h}./	*!			*	*	*	
☞ /.mi.kɨ./							*
/.mi.k^{h}ɨ./				*!		*	*
/.mi.k'ɨ./						*!	*

(25) *Korean perception of the English word* kick

[_^{kh}ík˺_]	*/+asp ./	*[*burst*] /C(.)/	*[^{h}] /–asp/	*[*no noise*] /+asp/	*[*no voice*] /(V)–tense(V)/	*[ ] /ɨ/
☞ /.k^{h}ik./						
/.k^{h}ik^h./	*!			*		
/.k^{h}i.kɨ./					*!	*
/.k^{h}i.k^{h}ɨ./				*!		*
/.k^{h}i.k'ɨ./						*!

In (24), the cue constraint *[̬]/C(.)/ expresses the idea that if a Korean listener hears even a little bit of voicing, she cannot interpret that as belonging to a final plosive. The existence of Korean forms like /.pik./, borrowed from English *pig*, show that for some borrowers, *[̬]/C(.)/ must be ranked below *[ ]/ɨ/.[16]

Third, words with English dorsal stops in postvocalic word-final position tend to insert a vowel more often than those with labial stops, a fact that Kang attributes to the fact that dorsals are more often released in English than labials are (Rositzke 1943: 41, Crystal & House 1988, Byrd 1992). Our model straightforwardly formalizes this explanation with tableaus like (24) and (25). Interestingly, however, coronal plosives are more often borrowed with a release than labial or dorsal plosives, despite the fact that they are less often released than dorsals (Rositzke 1943: 41, Crystal & House 1988, Byrd 1992, Y. Kang 2003) or labials (Y. Kang 2003)[17]: *hit* becomes /.hi.t^{h}ɨ./, whereas *tip* and *kick* become /.t^{h}ip./ and /.k^{h}ik./, respectively. Kang explains this special behaviour of coronals as a paradigm uniformity effect related to the alternation that we discuss below in §5; Kang's proposal is plausible, but we do not attempt to give a formalization of this paradigm uniformity effect here.

4.4 Conclusion

In §3 and §4 we have provided an account of all four processes involved in loanword adaptation, without proposing any loanword-specific mechanisms, especially without any loanword-specific ranking of DEP-V. The following section addresses a necessary refinement.

5 Native alternations in loanwords

In the cases of §4, the underlying forms of the loanwords were completely faithful to the phonological surface forms. This could be expected on the basis of the fact that the only type of constraints involved were faithfulness constraints. In this section we discuss a case where faithfulness is violated, namely the adaptation of English words that end in *-t*. As we saw in §4.3, many of such words are borrowed without vowel insertion, for example /.sjɑt./ from *shot*. The interesting thing, now, is that these words

[16] Candidates like /.mik'./ and /.k^{h}ik'./ are ruled out by a top-ranked */+tense ./ (§2.1).

[17] Although Kang searched the same database as Byrd (TIMIT), Kang found an opposite difference between coronals and labials than Crystal & House and Byrd. Unlike these other authors, Kang restricted herself to postvocalic plosives, and labelled glottal stops as unreleased coronal plosives.

show signs of ending in an underlying |s|: the accusative of *shot* is /.sjɑ.sɨl./. Thus, the underlying form will be |sjɑs|, analogously to the native underlying form |os| (§2.1).

In order to be able to handle cases like these, we have to use a more granular set of faithfulness constraints than before. In fact, our set of faithfulness constraints has to express arbitrary relations between underlying and surface form, just as the cue constraints express arbitrary relations between surface form and sound (Fig. 3). First, we make the formulation of IDENT(stri) dependent on position, because its ranking may depend on the position. For instance, IDENT(stri(.)), which means "in coda position, the underlying and surface values of stridency should be identical", is likely to be ranked lower than its prevocalic counterpart IDENT(stri(V)), because stridency faithfulness is especially unimportant in coda position. Next, we split up IDENT(stri(.)) for its possible arguments /+stri(.)/ and /–stri(.)/, giving the faithfulness constraints *|+stri|/+stri(.)/ and *|–stri|/–stri(.)/. Finally, we include the 'anti-faithfulness' constraints *|+stri|/–stri(.)/ and *|–stri|/+stri(.)/, so that we now have a complete set of arbitrary constraints that link stridency in underlying and surface form.

Of the four constraints, *|+stri|/+stri(.)/ and *|–stri|/+stri(.)/ are of little relevance, given the presence of the high-ranked structural constraint */+stri ./. We are thus left with the two constraints *|–stri|/–stri(.)/ and *|+stri|/–stri(.)/.

The next question is how *|–stri|/–stri(.)/ and *|+stri|/–stri(.)/ are ranked with respect to each other. We observe that underlying final |s|, which always surfaces as /t(.)/, is much more common in Korean than underlying final |t| or |t^h|. Learning algorithms that are sensitive to frequencies in the data will therefore come to rank *|–stri|/–stri(.)/ over *|+stri|/–stri(.)/ (Boersma 2008). We now show that if we replace the ranking */+stri ./ >> IDENT(stri) by the ranking */+stri ./ >> *|–stri|/–stri(.)/ >> *|+stri|/–stri(.)/, we will handle the Korean native production, Korean native recognition, and loanword adaptation correctly.

In production, tableau (2) turns into tableau (26), where *|+stri|/–stri(.)/ has simply taken over the role of IDENT(stri).

(26) *L1 Korean production: strident neutralization*

|os|	*/+stri ./	DEP-V	MAX-C	*|–stri| /–stri(.)/	*/C ./	*|+stri| /–stri(.)/
/.os./	*!				*	
☞ /.ot./					*	*
/.o.sɨ./		*!				
/.o./			*!			

Next, tableau (27) shows that an underlying final |t^h| still surfaces as /t./. The requirement is only that *|–stri|/–stri(.)/ is ranked below MAX-C.

(27) *L1 Korean production: strident neutralization*

|pɑtʰ|	*/+asp ./	*/+stri ./	DEP-V	MAX-C	IDENT(asp)	*|−stri| /−stri(.)/	*/C ./
/.pɑtʰ./	*!					*	*
☞ /.pɑt./					*	*	*
/.pɑ.tʰɨ./			*!			*	
/.pɑ./				*!			
/.pɑs./		*!					*

The same constraints are used in recognition. For the native Korean surface form /.ot./, the listener has at least three options for recognition, namely the candidate underlying forms |os|, |otʰ|, and |otsʰ|. However, the lexicon links |os| to the morpheme <clothes>, whereas it does not link |otʰ| to any morpheme and it links |otsʰ| to <lacquer>, not to <clothes>. We can express this within a grammar model in which underlying forms are freely generated candidates in an OT tableau (Boersma 2001, Escudero 2005:214–236, Apoussidou 2007:ch.6). In this model, the relation between underlying forms and morphemes is expressed by *lexical constraints* such as *<clothes>|os| "the morpheme <clothes> does not link to the underlying form |os|". As a result, /.ot./ will be recognized as the underlying form |os|, as in tableau (28).

(28) *Korean recognition of 'clothes'*

/.ot./	*< >	*<clothes> |otʰ|	*|−stri| /−stri(.)/	*|+stri| /−stri(.)/	*<clothes> |os|
|otʰ| < >	*!		*		
|otʰ| <clothes>		*!	*		
☞ |os| <clothes>				*	*

The first candidate does not violate any lexical constraints, but it links to no morpheme and is therefore ruled out by *< > (Boersma 2001). The choice between the second and third candidate is handled by the ranking *<clothes>|otʰ| >> *<clothes>|os|, which expresses the idea that the Korean morpheme <clothes> is more strongly connected to the candidate underlying form |os| than to the candidate underlying form |otʰ|. The tableau assumes that the recognition of the underlying form runs in parallel with the recognition of the morpheme.[18]

All existing words are recognized with the help of lexical constraints, as in (28); for instance, the Korean native sound [_ᶢ̊uŋmin] will be unsurprisingly perceived as /.kuŋ.min./, but recognized as the nonfaithful underlying form |kuk+min|; likewise, [_ᵇ̥ɑt̚] will be perceived as /.pɑt./ but recognized as |pɑtʰ|; sometimes, the decision can be made by the lexicon alone, and in other cases (of surface homonymy) syntactic, semantic and pragmatic processing has to be involved; details are outside the scope of

[18] The candidate |otsʰ| <lacquer> has to be ruled out by higher-level considerations, such as the pragmatic context, which are not modelled here.

the present paper (see the references above). For new loanwords, however, the situation is different: they are not in the lexicon yet, so lexical constraints cannot play a role. As (29) indicates, for example, the only way to recognize /.sjɑt./ is to link it to no morpheme. The underlying form is then determined by the ranking *|−stri|/−stri(.)/ >> *|+stri|/−stri(.)/.

(29) *Korean recognition of ‘shot’*

<table>
<tr><th>/.sjɑt./</th><th>*< ></th><th>*<clothes>
|ot^h|</th><th>*|−stri|
/−stri(.)/</th><th>*|+stri|
/−stri(.)/</th><th>*<clothes>
|os|</th></tr>
<tr><td>|sjɑt^h| < ></td><td>*</td><td></td><td>*!</td><td></td><td></td></tr>
<tr><td>☞ |sjɑs| < ></td><td>*</td><td></td><td></td><td>*</td><td></td></tr>
</table>

The winning candidate |sjɑs| is thus ultimately determined by frequency: the frequency-dependent ranking of faithfulness constraints causes loanword adapters to posit the underlying final segment that most frequently corresponds to it in the rest of the vocabulary.[19] The learner can subsequently create a new lexical item |sjɑs| <shot>. In (29), we finally see the reason for splitting up the faithfulness constraints.

6 Comparison to other models

Our model explains both the auditory similarity and the differences between the forms of the donor language and the borrowing language. Auditory similarity is achieved by the bidirectionality of the cue constraints (§4.2) and to a lesser extent the bidirectionality of the faithfulness constraints (§5); differences occur as a result of crosslinguistic differences in the rankings of cue constraints, which affect loanword perception (§3.1–2) as well as loanword production (§4.2), and differences in the rankings of structural constraints, which affect loanword perception (§3.3). In this section we discuss how other authors have handled Korean loanwords within their models, or how they probably would have handled them if they had discussed Korean within their models. It turns out that by regarding perception as a less active process than we do, all these models have had to posit and incorporate loanword-specific devices.

6.1 The “all phonology is production” assumption

Many authors assume that loanword adapters store the donor language’s phonetic or surface form more or less directly as an underlying form in the receiving language, and that subsequently, the (production) grammar performs the adaptation to the native phonology. The role of perception in the first step (the storage process) is either absent (Paradis & LaCharité 1997), or restricted to a limited number of extragrammatical adaptations to the segmental or tonal inventories of the receiving language (Silverman 1992, Yip 1993). The role of perception in the second (production) step is either absent, or reflected in the ranking of faithfulness constraints (Steriade 2001).

[19] This does not happen only to loanword adapters. Albright (2002: 112) mentions that Korean is going through a change in which the most frequent underlying forms that correspond to surface final /t/, namely |s| and |ts^h|, are taking over *native* paradigms with original underlying |t^h| (and |ts|), sometimes piecemeal. Thus, next to the locative /.pɑ.t^{h}ɛ./ we find topic forms such as /.pɑ.sɨn./ and /.pɑ.ts^{h}ɨn./.

In these views, perception is therefore extragrammatical and only indirectly influences the production. Maintaining such a view turns out to run into several problems, such as loanword-specific constraints, loanword-specific rankings, or failures to handle the data. In the following paragraphs we discuss several specific approaches.

For the Korean case, H. Kang (1996) assumes that the English word *stress* is stored as the underlying form |st^{h}rɛs’| (in our notation). After this, the phonology converts this |st^{h}rɛs’| to the surface form /.sɨ.t^{h}ɨ.rɛ.s’ɨ./. Kang therefore concludes that in loanword phonology, IDENT(stri) outranks DEP-V (otherwise the surface form would have ended in /t./). Meanwhile, Kang notices that an underlying native |os| surfaces as /.ot./. Kang therefore concludes that in the native phonology, the anti-vowel-insertion constraint DEP-V outranks the faithfulness constraint IDENT(stri). In other words, the same constraints are ranked differently in loanword adaptation than in native phonology (this is a typical problem in the loanword literature: also Itô & Mester 1995, Shinohara 2004). In our model, no such loanword-specific rankings are required: vowel insertion is allowed in perception by the ranking *[*friction*]/−stri/ >> *[ ]/ɨ/, following the general observation that listeners routinely have to work with missing cues (§3.2), whereas vowel insertion is disallowed in production by the ranking DEP-V >> IDENT(stri).

Production-based accounts often involve storing phonetic detail in underlying forms; a high ranking of faithfulness then forces this detail to the surface. For Korean, Y. Kang (2003:253) states that the English word *jeep* is borrowed with a phonetically detailed underlying form, namely variably (in our notation) as | _^{ts}ijp˺_^{ph}| (with a release) or as | _^{ts}ijp˺_ | (without a release). A single constraint ranking then maps e.g. | _^{ts}ijp˺_^{ph}| to the surface form /.tsi.p^{h}ɨ./ (or [_$^{dʑ̥}$ìp˺_^{phː}ɨ]; Kang makes no difference between phonetic and surface form). As a result, Kang states that a faithfulness constraint like MAX[*release*] has to outrank DEP-V. There are two problems with this proposal. First, it is usual in phonology to regard underlying forms as economical representations without phonetic detail. Second, it contains a contradiction: although Kang explicitly states that vowel insertion takes place in perception (as we acknowledged throughout §3 and §4), her proposed underlying forms do not contain any inserted vowels. This is a contradiction because psycholinguistic models of speech comprehension generally state that lexical representations have been filtered by the perception process (Cutler & McQueen 1997, Peperkamp & Dupoux 2003, also our Fig. 1), so that if the perception process inserts a vowel, this vowel should end up in the underlying form as well. Kang’s OT proposal can therefore be repaired by formalizing the observed loanword adaptation in two steps: first the perception of the sound [_^{dʒ}ījp˺_^{ph}] as the surface structure /.tsi.p^{h}ɨ./ (formalized with OT perception tableaus), followed by the production of the resulting underlying form |tsip^{h}ɨ| as /.tsi.p^{h}ɨ./ and [_$^{dʑ̥}$ìp˺_^{phː}ɨ] (formalized with OT production tableaus). This is what we have done in §3; no phonetic detail appears in the economical underlying form, and the underlying form honours all filterings by the perception process, including the insertion of a vowel.

The existence of a high-ranked MAX (often with a low-ranked DEP) in loanword adaptation has been raised to the status of a “preservation principle”, according to which elements that are present in the form provided by the donor language tend to survive in the receiving language (Paradis & LaCharité 1997, 2005; Rose & Demuth 2006). In our model, this “principle” has a direct explanation in terms of high-ranked cue constraints for positive auditory cues (and concomitant low-ranked cue constraints against inserting ‘illusory’ phonological material) (Boersma 2007a: footnotes 26 and 27).

Some production-based accounts reject loanword-specific rankings for the same reasons as we do. However, such accounts often require loanword-specific *constraints* that ensure faithfulness to the auditory information of the donor language. Examples are Davidson & Noyer’s (1996) constraint MATCH, Kenstowicz’s (2005) phonetic output-output faithfulness, and Yip’s (2006) constraint MIMIC. To account for the Korean facts, these models would indeed require such constraints (as exemplified by Kenstowicz 2005:§3.1; also Smith 2006 for Japanese), because these models still regard perception as at most a passive low-level extragrammatical device that allows only the interpretation of nonnative sounds in terms of the native phoneme inventory, and deletions in case of poor audibility. These models cannot handle perceptual insertion, because that would require an integration of perception and phonology, as we have shown.

Within the tradition started by Silverman, only Peperkamp & Dupoux (2003; followed by Iverson & Lee 2006) agree that perception can insert vowels. They propose that all loanword adaptations take place in an extragrammatical perception module, and that the set of adaptations includes not just Silverman’s mapping to native segments and tones, but also a mapping to native syllables, which allows insertion. Peperkamp & Dupoux’ proposal cannot handle the difference between /.ts^{h}æp.t^{h}ʌ./ and /.p^{h}i.k^{h}ɨ.nik./, which is due to a phonotactic (*phonological*) constraint and cannot be regarded as a difference in syllable perception.

To sum up: all these authors assume that phonologically-informed adaptations can only be made in production, and that perception is a passive process (also Hall & Hamann 2003, Miao 2005, Kenstowicz & Suchato 2006, Davis & Cho 2006, Adler 2006, Uffmann 2006; explicitly: Shinohara 2006). However, to account for the Korean facts without loanword-specific rankings or constraints, one has to acknowledge instead that phonologically-informed loanword adaptation occurs to a large part in perception (for exceptions see §7.3), and that therefore perception is just as phonological as production, as it is in the L1-based model of Fig. 1.

6.2 Perception is phonological as well

Perception, then, is phonological itself. That is, vowels are inserted in Koreans’ perception of English words partly because alternative candidates violate Korean-specific phonological constraints.

H. Kim (2008) provides a non-OT account of Korean loanwords in which she uses a ‘feature-driven’ model: a first ‘perception’ stage (following Peperkamp & Dupoux) matches the English auditory cues to Korean-specific features and syllables and can therefore insert vowels; in a second ‘grammar’ stage, still in the comprehension direction, structural constraints can exert their influence. Of the latter, Kim gives an example of a phonotactic restriction against homorganic glide-vowel sequences like */jɛ/, which causes English /ʃ/ to be borrowed before front vowels as /sw/ (/.swɛl./ ‘Shell’) instead of as the auditorily preferred /sj/. We agree with both types of influence that Kim proposes. As we have seen, though, in the examples of English complex onsets and of /.ts^{h}æp.t^{h}ʌ./ versus /.p^{h}i.k^{h}ɨ.nik./, vowel insertion (in Kim’s first stage) is itself influenced by phonotactic restrictions (Kim’s second stage), so it seems to be more parsimonious to model them in a single perception stage, as can be done in Optimality Theory, as we have shown.[20]

That the same phonotactic restrictions influence perception as well as production does not mean that the *repair* of the forbidden phonological structure is the same in perception and production. Thus, the forbidden structure /k.m/ is repaired as /kɨ.m/ in perception (§3.3) but as /ŋ.m/ in production (§2.3). This asymmetry was noted by Kabak & Idsardi (2007), who concluded that "native phonological rules" (nasalization of /k/ in production) do not "affect the perceptual processing" of strings like [km] (p.48). It is indeed not the native phonological *rule* (nasalization of /k/) that affects the perceptual processing of [km], but the native phonological *constraint* (the syllable contact law) that affects the perceptual processing of [km], namely by inserting a vowel. The possibility of having the same constraint but different kinds of repairs is typical of analyses in Optimality Theory, and it is therefore our use of OT in modelling perception as well as production that led us to regard the perception of [km] as /kɨ.m/ and the production of |km| as /ŋ.m/ as two diffferent outcomes of the same phonological restriction.

We are not the only ones who have attempted to model both perception and production in OT. Kenstowicz (2001) proposes that in loanword adaptation, the "loan source" is first filtered through an OT "perception grammar", which results in a "lexical representation". This lexical representation (underlying form) is then filtered by an OT "production grammar", which results in the "output". However, as Silverman and Yip, Kenstowicz regards vowel insertion as a task of the production grammar; the nature of the inserted material is then determined by the principle of "minimal saliency" (Shinohara 1997: fn.32, Steriade 2001: 238; also Kenstowicz 2003). A more general problem is that although Kenstowicz uses the term "perception grammar", he regards this as a direct mapping from sound to underlying form, unlike Boersma (1998), who introduced this term as the first step in a two-stage comprehension process (here, Fig. 1). This means that Kenstowicz would often have to propose (as he does) that constraint rankings are different in comprehension than in production.

Some authors agree with us (and with Polivanov 1931) that the lexicon can contain underlying forms that have been filtered by the perception process on the basis of language-specific structural restrictions (and not just segmental similarity). Broselow (2003, 2005/to appear) does propose structural constraints in comprehension: Broselow (2003) proposes that the "perception grammar" contains the strong constraint "any stressed foot is followed by a word edge", which causes the Spanish form [garabáto] to be stored in the Huave lexicon as |garabát|. In a new version of her paper, Broselow (2005) extends this view to vowel insertion (without formalization): she reports with approval a proposal by Schütz (1978) that Fiji listeners of English indeed hear the word *whiskey* as /.wi.si.ki./ (as Y. Kang 2003 does for the Korean, case, Schütz reportedly relies on arguments of releases and vowel degradation).

However, just as Kenstowicz, Broselow regards the perception grammar (contra Boersma 1998) as being a direct mapping from sound to underlying form. Such a two-

[20] Another concern with Kim's model is that the grammar has to influence perception in the first stage as well, since it restricts the inventory of phonological elements that build the output of perception (as Kim states explicitly). Having the language-specific handling of cues interact with language-specific phonotactic constraints in parallel, as is done in the present paper, automatically alleviates this concern.

level view of representations poses a general problem. In Broselow's proposal, structural constraints can only apply to the output of the entire comprehension process, i.e. to the underlying form, and this is indeed what she proposes. But it is usual in phonology to regard underlying forms as economical representations that are devoid of structures such as feet, syllables, and codas. Even for Broselow's own constraint "any stressed foot is followed by a word edge", this is already problematic, because the underlying form does not contain any feet; instead, feet are properties of phonological surface structures, so the comprehension mapping should be [garabáto] → /gara(bát)/ → |garabát|, and the relevant constraint should be the cue constraint "an auditorily stressed vowel should be perceived as being final in its foot". For the general case, a two-level account such as Broselow's would only be possible if all structural constraints could refer to underlying material (segments, word boundaries) alone, and not to metrical elements. For Korean, the constraints would have to refer to structures like #CC, CCC, and CC#, thereby losing the generalization that Korean phonotactics can be expressed in terms of the simple syllable structure constraints */.CC/ and */CC./. A remarkable feature of Broselow's proposal is that the output of production does have metrical structure, whereas the input to comprehension has not (it is more 'phonetic'); hence, these two 'surface' representations do not seem to be the same; in some sense, then, Broselow's model does seem to require three different representations; it seems to be only a small step to conclude that all three representations must play a role in both comprehension and production, as they do in the older model of Fig. 1.

We conclude that a full account of loanword adaptation requires the same three levels of representation that a full account of L1 phonology and phonetics requires. A three-level model allows us to work with structural constraints on surface forms, both in production and in perception.

7 Discussion

In this section we discuss a number of remaining issues, and end by giving a complete ranking.

7.1 Phonology without structural constraints

One could argue that structural constraints are not necessary for formalizing perception, because their effects can equally well be described with the right number of cue constraints. This is true. The structural constraint */+stri ./ could be replaced with a large number of cue constraints such as *[s]/+stri ./, *[t˺]/+stri ./ and *[bzɪltʃ]/+stri ./; and if we simplifyingly write SYLLCON as the structural constraint */k.n/, we see that we can replace it with a large number of cue constraints *[X]/k.n/, where [X] is any auditory form. Replacing structural with cue constraints in this way gives up on the formalization of generalizations, which is why we did not do it in this paper; but we cannot deny that it is *possible*.

From these observations, one might argue that perception and production require different formalizations, because the formalization of production does require structural constraints, and the formalization of perception could be (awkwardly) performed with a massive number of cue constraints. However, the fact is that once all these cue constraints exist, they can handle production as well! This is illustrated in tableau (30).

(30) *L1 Korean production without structural constraints*

|os|	*[s] /+stri ./	*[t˺] /+stri ./	DEP-V	MAX-C	IDENT(stri)
/.os./[os]	*!				
/.os./[ot˺_]		*!			
☞ /.ot./[ot˺_]					*
/.o.sɨ./[osɨ]			*!		
/.o./[o]				*!	

In (30), phonological production (the mapping from underlying to surface form) and phonetic implementation (the mapping from surface to phonetic form) are handled in parallel, as in Boersma (2007ab, 2008); that is, the candidates are pairs of surface and phonetic form, and faithfulness and cue constraints interact with each other. We see that the surface structure /.os./ is ruled out by the cue constraints *[s]/+stri ./ and *[t˺]/+stri ./, and that no structural constraints are needed.

We conclude that if structural constraints can be replaced with cue constraints for formalizing perception, they can also be replaced with cue constraints for formalizing production (at least if the phonology and the phonetics are handled in parallel). Therefore: whether or not we use structural constraints for describing linguistic processes, perception and production will be modelled as equally 'phonological'.

7.2 Nonnative phonotactics in loanword adaptation

It has been observed that loanwords often introduce nonnative phonotactics (Haugen 1950: 217,226; for Korean liquids: Kenstowicz 2005:24). For instance, the English word *shot* is borrowed into Korean as the surface form /.sjɑt./ despite the fact that in the native Korean vocabulary syllables rarely start with /.sj/ and the sequence /jɑ/ is rarely preceded by an onset consonant. Apparently, Korean has the structural constraints */.sj/ and */.Cjɑ/. How then is it possible that *shot* is borrowed as /.sjɑt./?

The answer is that in perception it is possible (given factorial typology) that some cue constraints outrank some structural constraints. Tableau (31) shows the interaction for *shot*.

(31) *Korean perception of the English word* shot

[ʃɒt˺_]	*[*friction*] / /	*[*high F2*] / /	MAX-C	*/.sj/	*/.Cjɑ/
/.sɑt./		*!			
/.jɑt./	*!				
☞ /.sjɑt./				*	*

Perceiving [ʃɒt˺_] as /.sɑt./ would ignore the auditory event [*high F2*], which in Korean is a strong cue in favour of the palatal segments /j/ or /i/. Perceiving [ʃɒt˺_] as /.jɑt./ would ignore the auditory event [*friction*], which in Korean is a strong cue in favour of the sibilant consonants /s/ or /ts/. Thus, the perceived form is /.sjɑt./, the underlying form, mentioned in (29), is |sjɑs|, and the produced form is /.sjɑt./, assuming that MAX-C outranks the two structural constraints in (31).

We conclude that regarding perception as an interaction between structural and cue constraints predicts the existence of nonnative phonotactics in loanword adaptation, which is indeed attested. According to computer simulations of a bidirectional learning algorithm (Boersma 2008), cue constraints are expected to be ranked high if confusibility is low (i.e. if auditory salience is high or the native language lacks confusing phonological competitors) or if the phonological element's frequency in the native language is moderately low.

7.3 Loanword adaptation that takes place outside perception

In this paper we have focussed on cases of loanword adaptation that take place in perception. The model of Fig. 1 predicts that there are several other processes in which loanword adaptation can take place.

One of those processes is recognition, i.e. the mapping from phonological surface form to underlying form. We saw an example of adaptation in recognition in (29), where a final /t/ in the surface form was installed in the lexicon as a final |s|. The phonological production process, i.e. the mapping from underlying to surface form, then causes this |s| to appear as /s/ in the accusative /.sjɑ.sɨl./.

Another process is phonetic implementation, i.e. the mapping from phonological surface form to phonetic form. We saw an example of adaptation in phonetic implementation in (21) and (22), where the Korean ranking of cue constraints ensured that English loanwords are pronounced with a Korean accent.

Beside perception, recognition, and production, there may be other sources of loanword adaptation. Orthography has been claimed to have introduced the form /.p^{h}iŋ.nik./ into Korean (Kabak 2003: 59). In Fig. 1 this would be viewed as an interpretation of the English spelling *picnic* in terms of the two Korean syllabic characters 픽닉, which are then mapped to the Korean underlying form |p^{h}ik-nik|, which is subsequently produced as /.p^{h}iŋ.nik./ by the rules of Korean phonology.

7.4 Loanword adaptation by bilinguals

It is likely that loanword adaptation is partly performed by advanced L2 speakers (Paul 1880, Haugen 1950, Paradis & LaCharité 1997, LaCharité & Paradis 2005). If this occurs, English loanwords may be filtered by L2 English perception rather than by native Korean perception, because L2 listeners have been found to shift their perceptual boundaries depending on the language they think they hear (Elman, Diehl & Buchwald 1977; Boersma & Escudero to appear). Also, lexical storage may occur in terms of an L2 English inventory rather than in terms of the native Korean inventory, because L2 listeners have been found to reuse their native inventories in lexical representations (Boersma & Escudero to appear). For example, bilinguals may analyse English as having only lax plosives such as /p/ and aspirated plosives such as /p^{h}/, and therefore as lacking /p'/. This means that the English word *bye* is interpreted as starting with /p/ and *pie* as starting with /p^{h}/. For the labial plosive in *spy* they would have two options; if the voicing cue weighs heavier than the aspiration cue, they will interpret the plosive as /p^{h}/. This may be the explanation behind the aspirated plosives that appears in loanwords like |sɨp^{h}ɑik^{h}ɨ| (as well as the avoidance of /.p^{h}i.k'ɨ.nik./ mentioned in footnote 13). In subsequent production in Korean, the bilinguals will then use the native Korean grammar. In an L2 version of the model of Fig. 1, comparable facts have been accounted for by modelling the acquisition of L2 underlying forms with a morpheme-driven learning algorithm (Escudero 2005: 214–236, Weiand 2007); for English *spy*, there would be a long-lasting competition between |sɨp^{h}ɑi| and |sɨp’ɑi|, which would ultimately be won by |sɨp^{h}ɑi| because of its more peripheral auditory correlates (this confirms a hypothesis by Kenstowicz 2005, although it does not require his formalization in terms of MINDIST constraints). As a result of the need to map [sp-] to |sɨp^{h}-|, Korean bilinguals will adapt their perception of English in such a way that the boundary between their L2 intervocalic /p/ and /p^{h}/ falls in between that of the English *bye* and *spy* (thus, the cue constraints for the voice-onset-time continuum will be ranked differently in L1 and L2). The same mechanism could help L2 learners to equate the English /æ/-/ɛ/ contrast with the Korean /æ/-/ɛ/ contrast, despite the acoustic differences (§3.1). Modelling these facts would require computer simulations such as those performed by Weiand.

7.5 The complete grammar

The grammar in (32) combines all the constraints that we used in this paper, except the 20 cue constraints for the front vowels in §3.1, and the specific lexical constraints of §5. The ranking is a possible division into four strata.

(32) *Native Korean grammar, which also accounts for the adaptation of English words*

{ */+asp ./ DEP-V SYLLCON *[*burst*]/C(.)/ *[̰]/+asp/ *[^{hː}]/−asp/
*/+tense ./ */+stri ./ */CC ./ */.CC/ *[C˺]/ /
*[*friction*]/−stri/ *[*friction*]/ / *[_]/+nas/ *< > *[*high F2*]/ / }

>>

{ MAX-C *[*no noise*]/+asp/ *[^{h}]/−asp/ *[¯]/+tense/ *[´]/−tense/
*[̰]/C(.)/ *[̰]/+tense/ *[*no voice*]/(V)−tense(V)/ }

>>

{ IDENT(asp) IDENT(stri(V)) *|−stri|/−stri(.)/ IDENT(nas)
*[̰̆]/C(.)/ *[̰̆]/+tense/ */C ./ */.sj/ */.Cjɑ/ }

>>

{ *[ ]/ɨ/ *[^{h}]/+asp/ *|+stri|/−stri(.)/ (articulatory constraints) }

Every constraint in this single ranking is needed for comprehending and/or producing Korean in everyday use. The very same ranking also explains all the loanword adaptation phenomena that we discussed in this paper.

We like to stress that the ranking in (32), despite its size, does not contain any unlikely rankings or interaction tricks: the structural and faithfulness constraints are ranked on the basis of relatively uncontroversial facts of Korean phonological production (although the ranking works for comprehension as well), and the cue constraints are ranked as follows: constraints against strengthened ‘contrary’ cues at the top, constraints against ‘normal’ contrary cues in the second stratum, constraints against ‘reduced’ contrary cues in the third stratum, and constraints against ‘friendly’ cues in the fourth stratum. We also note that the set of cue constraints in (32), despite its size, is still rather minimalistic: a full set would require much finer-grained auditory distinctions. For instance, we ignored in this paper the fact that the lax plosives are slightly aspirated, that the aspirated plosives tend to have a higher F0 than the tense plosives, that aspirated plosives are less aspirated in intervocalic position, and that lax plosives are shorter than tense plosives.

8 Conclusion

In the present paper we have applied an existing bidirectional model of L1 phonology and phonetics (Fig. 1) to several cases of loanword adaptation in Korean. By regarding perception as equally phonological as production, this L1 model turns out to handle the loanword adaptation facts without assuming any additional (i.e. loanword-specific) rankings, constraints, or other devices. Instead, loanword adaptation is fully explained by the behaviour of listeners in their native language. As a side effect, we have reconciled the phonology-versus-perception debate in loanword adaptation research: perception simply *is* phonological. The assumptions that have proven crucial for achieving this result (all visible in Fig. 1) are the distinction between phonological and phonetic representations, the bidirectionality of cue and faithfulness constraints, and the use of structural constraints both in perception and production. All these assumptions have proven necessary for L1 phonology as well (Boersma 2007ab, 2008; Boersma & Hamann to appear) and are therefore not specific to loanword adaptation.

By doing away with loanword-specific phonology, we hope to have reduced the mystery of loanword adaptation. Korean has provided many interesting examples, and our model handled all of them in a straightforward way. It will be interesting to see how ourt model performs on languages that might exhibit types of loanword adaptations that we did not discuss.

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