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LOANWORD PHONOLOGY AND PERCEPTUAL MAPPING: COMPARING TWO CORPORA OF KOREAN CONTACT WITH ENGLISH

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This article compares an extensive collection of English loanwords into Korean with a corpus of perceptual responses to English productions by Korean students of English in Korea. The analysis selects ten obstruents situated in four prosodic contexts: initial, final, and pre- and post-stress intervocalic positions. Analyses compare the mapping of the obstruents onto Korean categories in the two databases, finding a strong logistic relationship between them, which indicates a process of loanword adaptation as a regularization of the cross-language perception patterns. This conclusion is also supported by differences in the maps across the prosodic positions, wherein loanword differences are correlated with perceptual differences, and by the fact that loanword adaptations are more variable for consonants that do not have a very robust perceptual map. The data, however, also exhibit exceptional cases that apparently indicate effects of a historical lexicalization of individual forms, as well as of an explicit sociocultural standard. Thus, loanword adaptation in this case, though largely indicative of a perceptual base, is more than just synchronic perception.*

Keywords: loanword phonology, Korean-English borrowings, perceptual mapping, lexical variation, Korean obstruents

1. LOANWORD PHONOLOGY AND PERCEPTUAL MAPPING.

1.1. APPROACHES TO LOANWORD ADAPTATION. In recent years, there has been considerable discussion about the nature of loanword phonology. Loanword phonology is a cover term for the means by which the phonological structure of words in one language is mapped onto the phonological structure of another language, in the process of incorporating the word into the second language's lexicon. Loanword phonology, in this usage, then, indicates a process relating two phonological systems, since in many cases the actual phonological structure of the incorporated word is no different from that of other, previously existent forms in the language. However, this does not mean that the phonology of the language is not impacted by loanword phonology, since the incorporated words, even in cases where they might be considered legal forms in a categorical sense, will often be atypical in a statistical sense, leading to the development of phonological subcomponents that tend to indicate items that are borrowed from a lexifier language. Thus, another possible use for the term 'loanword phonology' is to indicate any case in which a particular subcomponent of a language's phonological system is associated with lexical items historically taken from another, lexifier language (e.g. the case of Japanese examined in Fukazawa et al. 2002). The current study examines the nature of loanword phonology in the first sense, that of loanword adaptation, indicating how the structure of words from one language gets modified in the process of incorporation into a second language.

There have been a variety of different approaches to characterizing loanword phonology. Recent ones that have garnered considerable attention have claimed that loanword mapping is essentially perceptually based (Silverman 1992, Takagi & Mann 1994, Kenstowicz 2001, 2005, Steriade 2001a,b, Peperkamp & Dupoux 2003, Iverson & Lee

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2006, Shinohara 2006, and Peperkamp et al. 2008) and does not involve extensive abstraction, but rather relies crucially on superficial phonetic similarity (Silverman 1992, Steriade 2001a,b, Kim & Curtis 2002, Peperkamp & Dupoux 2003). Among these, Peperkamp and Dupoux (2003) conceptualize loanword adaptation as being essentially the process of ordinary speech perception. For example, if adapters produce borrowed sounds with an extra, paragogic vowel, the inserted vowel would be present in the input of the adaptation process. This is because the native language of the adapters directly interferes with the phonetic perception of the borrowed sounds, resulting in a misperception with an inserted vowel (Dupoux et al. 1999, Lim 2003, Bettoni-Techio et al. 2007, Kabak & Idsardi 2007, de Jong & Park 2012). By contrast, others assume that the knowledge of phonetic perception is indirectly encoded as part of a grammar containing universal perceptibility degrees based on the acoustic properties of the sounds (Steriade 2001b). This grammar, then, integrates this acoustic similarity structure into the process of loanword adaptation.

What all of these approaches have in common, though, is that loanword adaptation is seen as a problem of perceptually matching the words of the source language with the recipient language. Consequently, low-level subphonemic acoustic properties play a role in determining the forms in borrowing. Words are borrowed into the recipient language with the sounds that are perceptually most similar to those in the source language, and this similarity is determined by the acoustic substance of the lexifier language. For example, Peperkamp and colleagues (2008) compare loanwords from French and English into Japanese and note that the French-based loanwords with a final nasal in the lexifier are more likely to exhibit a postnasal epenthetic vowel than are English-based loanwords. This difference is shown to correspond to differences in the perceptual mapping of French and English productions by Japanese listeners, and thus appears to be due to typical acoustic differences in the production of final nasal consonants in French and English that are also documented by Peperkamp and colleagues (2008).

Others have taken quite different positions on the matter. In the approach proposed by LaCharité and Paradis (2002, 2005), borrowing involves more extensive phonological abstraction; thus, subphonemic variants play little role. Here, loan adaptation is conceived of as a process primarily done by sophisticated bilinguals, who can accurately identify the source sound categories, either by means of direct phonetic perceptual skills, or by means of knowledge of the lexicon garnered through literacy (e.g. as also suggested by Iverson (2005) and Vendelin and Peperkamp (2006)) or other repositories of knowledge about the language. Thus, bilingual borrowers would execute a mapping at a categorical level (e.g. that of abstract feature counting; LaCharité & Paradis 2005) that can diverge considerably from the phonetic form of the lexifier language. Evidence cited for this approach comes from Spanish voiceless stops, which are unaspirated relative to English voiceless stops. Although English voiceless stops are more similar to Spanish voiced stops in terms of VOT, they are still adapted as Spanish voiceless stops rather than voiced (Lisker & Abramson 1964, LaCharité & Paradis 2005). This loanword mapping pattern is explained only if distinctive features like [voice] in English play a role, while noncontrasting phonetic features like graded VOT differences between Spanish and English do not, and fine acoustic differences are largely irrelevant in the borrowing process.[1]

[1] It is alternatively possible that the difference between Spanish and English involves dimensions other than VOT, and that perceptual similarity is not well characterized by VOT. Some evidence for different sensitivities has been found by Oglesbee (2008).

Between these extremes, there are a number of approaches that incorporate some degree of additional abstraction into a perceptual account, for example, by adding a general production mapping component (Boersma & Hamann 2009, Padgett 2010), by incorporating general phonological system effects into the perceptual component itself (Iverson & Lee 2006), or by simply adding abstract components to a perceptual component in a larger system that comprises the two (Yip 2002, 2006).

Overall, there is a current general consensus that loanword adaptation does not just involve a single mapping system, but likely involves multiple mapping systems. Smith (2006) shows clearly the existence of doublets, two different concurrent mappings for the same lexical item, where one form appears in situations where contact between the languages is more distant, and the other appears in situations where the contact is more direct. In her analysis, then, a more abstract, orthographically based mapping is active in the more distant case, and a more perceptually based mapping is active in the more immediate case. Even proponents of the paradigmatic examples of perceptual processing and abstract models admit the existence of the other system; Peperkamp and colleagues (2008) note the existence of orthographically based mapping, and LaCharité and Paradis (2005) note cases of apparently direct perceptual borrowings in their corpus. These positions, however, differ in the expected likelihood of forms being accounted for by the other system.

Most of the studies of loanword adaptation cite specific forms to illustrate aspects of a particular model, while several studies, most particularly those by Paradis and colleagues, have been more systematic in collecting corpora of loanwords whose forms need to be accounted for. Since the current state of the discussion hinges on claims of overall likelihood, rather than absolute existence, it is critical that models be tested against systematic corpora. The approach in the current study also collects a corpus of loanwords, but further defines a set of consonants to be examined in advance and attempts to account for all of the loanword mapping patterns in that set. Previous works tend to examine specific segments that act as illustrations of particular effects, leaving an open question of how much of the overall loanword mapping pattern can be accounted for by any model.

While several previous works of loanword phonology have been based on large corpora of loanword adaptations, a persistent weakness in the literature in its current state concerns methods for creating predictions of a perceptually based account. For example, while LaCharité and Paradis (2005) give perceptual mapping data for several specific cases (usually involving the mapping of rhotics), in other cases they cite earlier work on some aspect of the acoustics of a particular contrast (e.g. VOT or vowel formant values). The problem with this approach is that we currently do not know enough about the acoustic structure of the contrast space in languages to predict the crosslinguistic perception of speech sounds from estimates of one or two acoustic parameters. For example, while it is commonly accepted that the frequencies of the first and second formant yield a space within which vowels contrast, the relationship between these formant values and perceptual responses in large-scale perceptual mapping studies (e.g. Strange et al. 1998) is not at all straightforward. The reason for this is that other dimensions are also implicated differently in the different languages: in particular, in the case of vowels, the durational dynamics of vowel production and the exact distribution of tokens of each category in this space tend to exhibit language-specific differences. The most straightforward approach to examining a perceptual mapping model is to conduct a perceptual mapping study that parallels some part of a corpus of loanword adaptations. Thus, the current study examines, in parallel to a loanword database, perceptual maps from speakers of the target language, explicitly measuring their perceptual responses to segments from the lexifier language. Using this approach, we find a strong commonality between these perceptual maps and the loanword adaptations, though with some systematic and some idiosyncratic differences.

1.2. MODELS OF LOANWORD ADAPTATION OF CONSONANTS FROM ENGLISH INTO KOREAN. The specific case examined here is that of English borrowings into Korean. There has been much work on the loanword adaptation in the extensive variety of English loanwords in contemporary Korean. In previous work, Kang (2003) proposed an approach in which subphonemic phonetic details of the sounds of the source and recipient languages play a crucial role in loan adaptation. Specifically, vowel insertion after word-final stops is more often observed in loan adaptation when the source word ends with a voiced consonant or has a last vowel that is tense (e.g. *jeep* [tʃip]/[tʃip^{h}ɨ], *zigzag* [tʃigɨdʒægɨ]). According to Kang, these both indicate that the loanword mapping is maximizing the perceptual similarity of the words between the source and recipient languages, including the effects of nondistinctive phonetic properties in the source language. Here, voiced stops have been found in large-scale spontaneous speech corpora to be perceptibly released more often, and this nondistinctive, gradient property is being preserved in the target language. Similarly, adding an extra syllable in forms with a tense vowel is expected to increase the duration of the preceding vowel, by putting it in an open syllable. Again, the subphonemic detail in the tense vowel may be being maintained through the mapping process. Kang (2010) expands on this account by adding an explicit component of regularization, which is discussed further in §6 below.

Iverson and Lee (2006) have suggested a similar model for Korean borrowing of English lexical items, but with an explicit component of phonological abstraction. It includes in the perceptual mapping algorithm a component determined by the phonological system of the target language. Here, the inputs into the process are the phonetic representations from the source language; however, these are interpreted according to the salient perceptual categories of the recipient language. For example, in this analysis, English /f/ is realized as the aspirated bilabial stop in Korean loan adaptation because [p^{h}] closely approximates [f] in terms of the feature [spread glottis], which is a primary distinctive property of the aspirated stop series in Korean. Similarly, English /v/ is rendered as the plain bilabial stop [p] in Korean loanwords because English [v] is not articulated with [spread glottis], making [p] the best fit for the English /v/. Thus, Iverson and Lee claim that it is not the phonetic properties per se in the source language but rather the interpretation of those features in terms of their phonological status in the recipient language that determines loan adaptation.

In contrast to these approaches, Oh (1996) argues for the role of more abstraction in Korean-English borrowings. For instance, the English coronal stop /t/ in words like *tie* is rendered as the aspirated stop [t^{h}aɪ], as is expected, since initial voiceless stops are aspirated in English. The same is true, however, in words such as *stick*, which is rendered as Korean [sɨt^{h}ɪk], also with an aspirated stop. This is despite the lack of aspiration on /t/ in the source English, which is then expected to map onto the tense and unaspirated /t/. This shows that Korean speakers do seem to ignore phonetic properties that are nondistinctive in the source language, even though they are distinctive in the target language. Consequently, this case would indicate that this adaptation of English sounds is based on English phonemic categories, not on the actual acoustic substance of the English productions.

1.3. THE CURRENT STUDY. The current article examines a corpus of perceptual mapping data, collected as part of a larger project examining the acquisition of the English consonant system by Korean learners of English. The corpora examined here contain items systematically sampling a subportion of the consonant system of English, and investigate the perceptual mapping of these consonants from English onto the Korean categorical inventory. These perceptual mapping patterns, then, form a foundation for making explicit predictions about the mapping of English loanwords into Korean. The accuracy of these predictions is then determined from a loanword corpus that was collected to examine loanword mapping in general. Comparing these two corpora will determine the extent to which perceptual mapping can account for the loanword mapping, and will help isolate cases of clear divergence of loanword mapping from perceptual mapping.

Park (2008) examined the inventory of perceptual maps found in this database to determine the degree to which these perceptual maps appear in previously noted borrowing patterns in Korean, noting an extensive amount of match between perceptual patterns and the borrowing patterns noted in previous works. He also noted some apparently systematic divergences, however. For example, while place mismatches are quite common in the perceptual mapping data—for example, English dental fricatives are sometimes identified as labial stops—these place switches do not appear to occur in borrowings. These observations suggested that, while there is extensive correspondence between the perceptual and borrowing patterns, the borrowing system does appear to be selectively attentive to certain features in a way that is not predicted by on-line auditory perception.

The current work expands upon this foundation by comparing the perceptual mapping patterns with a systematic sampling of the loanword mapping patterns found in a large database of English borrowings into Korean. Here, the attempt is to quantify the degree to which the borrowing patterns conform to those predicted by auditory perception, and thence to determine areas of divergence between the two processes.

The targets of analysis are the anterior obstruents in English listed at the top of Table 1 below, as they appear in various prosodic positions. These phonological segments provide a good inventory of different types of perceptual matches and mismatches, including both segments that are very similar across the languages, and segments, such as the nonsibilant fricatives, that prove to be difficult for Koreans to categorize as Korean sounds (e.g. as quantified in Park & de Jong 2008). In addition, placing these segments in different prosodic locations—initial, final, and intervocalic (prestress and poststress)—means that they will exhibit extensive allophonic variation, both in English and in Korean. (For a typical summary of Korean prosodically triggered allophonic processes, see Kim-Renaud 1995.) English voiceless stops are aspirated in initial and intervocalic prestress positions, but not in poststress and final positions, while voiced stops are typically voiceless in initial position. In Korean, lenis stops are voiceless in initial position, but voiced and extensively reduced in intervocalic position.[2] This reduction differs from similar intervocalic processes in English, though, since stress (if it occurs at all in Korean) does not condition allophonic variation. Aspirated stops contrast with fortis and lenis in voicing lag in all but final and preconsonantal position (Kim 1965, Han & Weitzman 1970, Abramson & Lisker 1972, Kagaya 1974).

In final position, extensive neutralization rules affect all obstruents in Korean, such that all laryngeal contrasts are reduced to what is written in the Korean orthography as

[2] The presence of voicing in the reduced consonant appears to be conditioned by syllabic position, so that if the consonant is syllabified in coda position, it can be produced as voiceless. See further the discussion of variation in the word *Bethel*, discussed in §3.2 below.

ENGLISH		LABIAL		CORONAL			
PROBES		voiced	voiceless	voiced	voiceless		
	stops	/b/	/p/	/d/	/t/		
	nonsibilant fricatives	/v/	/f/	/ð/	/θ/		
	sibilant fricatives			/z/	/s/		
KOREAN		lenis	fortis	aspirated	lenis	fortis	aspirated
RESPONSES	stops	ㅂ (p)	ㅃ (p’)	ㅍ (p^h)	ㄷ (t)	ㄸ (t’)	ㅌ (t^h)
	affricates				ㅈ (tʃ)	ㅉ (tʃ’)	ㅊ (tʃ^h)
	fricatives				ㅅ (s)	ㅆ (s’)	
	other				ㄹ (l/ɾ)		ㅎ (h)

TABLE 1. Consonant inventories.

lenis, and fricatives appear as stops. These neutralizations make the prosodic effect of the coda position somewhat different from the others, since phonological models of adaptation would require the effects of the categorical neutralization to appear in the loanwords, but would not predict effects of subphonemic variation between segments in the other prosodic positions.

This corpus, then, provides a useful test bed for examining the degree to which perceptual mapping straightforwardly determines loanword adaptation. If the perceptual maps in a complicated array of consonant correspondences such as these exactly match loanword maps, a model of loanword adaptation as ordinary cross-language perception is robustly supported. Divergence of loanword maps from perceptual maps would indicate some process beyond ordinary perception. Also, with the extensive variation in the consonants across the prosodic positions in the two languages, a perceptual model would predict extensive differences in the perceptual mapping patterns for consonants in different prosodic positions, and such differences in positional mappings should also be reflected robustly in positional differences in loanword mapping. To the extent that phonological abstraction of the underlying segment ‘undoes’ the prosodic variation in the segments in loanword adaptation, we would expect relatively little variation in the loanword mapping due to prosodic location, and thus to find that loanword mapping diverges from perceptual mapping across the prosodic positions. In addition, differences between codas and noncodas in models with explicit phonological components (such as that presented in Smith 2009) would be expected to arise due to phonological aspects of the loanword adaptation, and hence should diverge even more strikingly from the perceptual maps. In what follows, we present the two databases in more detail, and analyses of their relationship. These analyses indicate a very strong relationship between the perceptual maps and the loanword adaptation patterns, with two differences. The relationship between probabilities in perceptual mapping and loanword mapping is not linear, and there are notable exceptions to the match between the two mappings.

2. PERCEPTUAL MAPPING DATA AND THE LOANWORD DATABASE. The perceptual database is described and a portion of it is analyzed in detail in Park & de Jong 2008. It includes all of the segments in Table 1 situated with the vowel /a/ as a singleton consonant in the prosodic positions indicated, yielding stimuli such as [sa, as, ása, asá] for the English consonant /s/. Productions of four American English speakers were recorded and presented to forty Korean listeners who were relatively inexperienced learners of English in Korea, and the listeners were asked to identify the consonants as Korean consonants on orthographic response forms, choosing from the thirteen options indicated at the bottom of Table 1. Since the mappings were done in the context of a larger study examining their perceptual skills in English, it is very likely that they knew that the productions were from English speakers, though they were not explicitly instructed that they were. Listeners were also given the option of indicating a 'write-in' candidate, in case they thought a different representation was more appropriate; this option was taken very few times (less than 3%) for the obstruents examined here. Listeners also indicated their estimate of the degree of similarity of the English productions to the Korean categories, but these graded estimates have not been integrated into the current analyses.

The analyzed data, then, are the probabilities of various Korean responses to the English productions of each consonant. The data used to predict the loanword adaptation patterns consist of the proportions of 160 responses (40 listeners × 4 different speech tokens) to each of the ten English consonants in each of the four prosodic locations that were a specific Korean consonant (for a total foundational corpus of 6,400 responses). Since there are ten English consonants, and thirteen target Korean responses, the data consist of 130 mapping proportions, though our analysis removes at the outset data in which neither the perceptual data nor the loanwords exhibit a particular mapping, that is, values of zero for both probabilities. For example, the four stimuli with /v/ in initial position elicited lenis-/p/ responses 65.0% of the time (104 of the 160 responses), lenis /t/ 18.1% of the time (twenty-nine of the responses), nine responses of /l/ (5.6%), three responses of fortis /s/ (1.9%), and two responses each of fortis /t/ and /h/ (1.3%). All other possible responses for /v/ elicited no mappings, and were found in no loanword adaptations.

Two aspects of the perceptual database relative to the current study bear further comment. First, the productions here are American productions, so the comparison of these responses to the loanword databases is appropriate to the extent that English loanwords have come into Korean via an American English lexifier. Given the extensive language contact over the last fifty years, this is largely true, though there are some complications to the situation that are discussed below. Second, the Korean listeners in this study represent relatively inexperienced learners of English, in that they have extensive experience with English through years of school-age instruction, but tended to have little direct face-to-face interaction with American English speakers. Analyses of these listeners' performance in identifying English consonants show a wide range of abilities, with many of the listeners performing at chance with some of the novel contrasts. Thus, the perceivers examined here are clearly not the extremely proficient bilinguals posited by LaCharité and Paradis (2002, 2005). If adaptation is primarily by such proficient bilinguals, and if perceptual maps change with experience, it would create divergence between the perceptual and loanword maps. Thus, the relatively inexperienced bilinguals provide a particularly rigorous test of a perceptual model with attenuated effects of bilingual competence in the second language.

In order to compare the patterns found in the perception study with patterns in loanwords, a loanword database has been collected. The database consists of 14,576 consonantal entries, collected from various sources. First, most of the loanword data were collected from two loanword dictionaries published in Korea: *21C: The latest loanword dictionary* from Clover Publishing (2004) and *Loanword dictionary* from Minjungseoguan (2006). In addition, this core was augmented with other published sources and with surveys of native Koreans, mostly university students enrolled in phonetics and phonology classes. The data were also checked for errors by examining cases of disagreement and comparing them with various internet sites such as the Naver portal website (http://www.naver.com) and the website of The National Institute of the Korean Language (http://www.korean.go.kr).

The database was filtered to exclude technical jargon, such as obvious chemical and medical terminology, which are not likely to be known by the general educated populace, and hence whose database pronunciation might not be representative of actual usage in the larger community. Prosodic locations of interest were ones corresponding to those in the perceptual database: initial singletons, final singletons, and intervocalic singletons. Consonants in clusters in the English lexifier were not considered (even though they often would appear as singletons in Korean borrowings with epenthesis). In addition, the intervocalic forms were divided into cases in which the English lexifier has the consonant in prestress or poststress position, and consonants between unstressed locations (e.g. the last consonant in the word *entity*) were eliminated. The database, then, consists of 4,031 loanwords that would be generally familiar to native Korean speakers. Taken together, these loanwords contain 14,576 target consonants. For each consonant, maps were generated, associating it with the corresponding consonant in the English source word and also with its prosodic location in the source language.

A general perusal of this database shows one aspect of loanword mapping that is generally not discussed in much of the earlier linguistic literature on the topic, namely, that loanword adaptations are often variable in form. That is, for a substantial minority of the corpus (27.6% of the words analyzed below), there is more than one form in circulation. For example, words with English /p/ sometimes (8.7% of the words in the database) have Korean variants with fortis and aspirated stops, for example, [p^hin]/[p'in] *pin* and [p^hap^hai]/[p'op'ai] *Popeye*. These variable forms are analyzed explicitly in a separate section below (§5), but for the purposes of generally characterizing the loanword mapping patterns, variable forms are initially resolved by splitting the proportion of such forms to the mapping for a consonant evenly between the two variable forms.

The analytic approach to relating the perceptual and loanword maps followed below has three components. The first is to correlate the probability of an input English consonant in a particular prosodic position corresponding to an output Korean consonant in the loanword database with the probability of the same outcome in the perceptual database. To the extent that the perceptual and loanword maps are the same, the correlation should be exact. Abstraction or phonological distortion of the perceptual space should appear as systematic divergences between probabilities in the two maps. Second, we examine differences in the loanword outcomes for each consonant in the different prosodic positions. Both perceptual maps and loanword maps for a consonant differ to a degree across different prosodic positions. If loanword adaptation is perceptual mapping, then these loanword map differences should be the same as the perceptual mapping differences. Finally, the loanword database has many instances of lexical items with variable mapping. If loanword mapping is perceptual mapping, then we would expect lexical variability to be related to variation in the perceptual mapping.

3. Perceptual mapping proportions and loanword adaptation patterns.

3.1. Predicting loanword adaptation from perceptual maps. The appendix presents perceptual and loanword maps for the ten target consonants, split by prosodic position. What is of interest for the current context is the degree to which the probabilities in the loanword tables match those in the perception tables. To help visualize this relationship, Figure 1 plots the relationship between the perceptual mapping proportions and loanword mapping proportions for three of the four prosodic positions. (The patterns for postvocalic final consonants were somewhat different and are addressed in §3.3.) The x-axis plots the probability that an English consonant was labeled with a particular Korean consonant, and the y-axis plots the corresponding probability for the loanword database. Each point plots each probability in the appendix, with empty cells omitted (cases of correspondence that were zero in both maps). Various special markers have been included in the figures for the purpose of reference in the text below, but analyses reported here include all of the data points regardless of marker type, unless specified otherwise.

Scanning the distribution of data points along the y-axis in Fig. 1 indicates a large number of cases in which target English consonants are borrowed with different Korean consonants, depending on the word. If the loanword adaptations were entirely consistent at the segmental level, all of the data points would lie either at 100% or 0%, the top and bottom of the scale. However, while there are many cases of 0%, where a mapping never occurs in the loanword database, there are, in fact, only eight of the forty consonant × prosodic position cases that are entirely consistent. Thus, one aspect of the data that tends to run counter to models with heavy phonological abstraction is the fact that loanword mappings tend to vary across lexical items.

What Fig. 1 also indicates is that this (y-axis) gradient structure in the mapping proportions is correlated to the perceptual mapping proportions. There is an overall relationship between the two proportions, such that a high proportion of perceptual mapping tends to correspond to a high likelihood of loanword mapping, with some exceptions that are discussed below. This overall relationship corresponds to strong correlations between the loanword and perceptual mapping probabilities (initial, $r^2 = 0.727$, prestress intervocalic, $r^2 = 0.628$, poststress intervocalic, $r^2 = 0.789$). This overall relationship indicates a strong commonality between perceptual and loanword mapping.

Closer inspection of the distribution of the points in Fig. 1, however, suggests that the relationship between loanword and perceptual mapping probability is not linear; that is, loanword and perceptual mapping probabilities are not simply equivalent. With closer inspection, one notes a range of numerous minority (less than 50%) perceptual mappings that correspond to very low probability (less than 10%) loanword mappings (e.g. English /d/ → Korean fortis /t'/ in CV). Similarly, there is a distribution of majority (greater than 50%) perceptual mappings that correspond to very high probability (greater than 80%) loanword mappings (e.g. English /d/ → Korean lenis /t/ in CV). The general pattern, then, (with some notable exceptions to be discussed below) is one in which the most probable perceptual mappings tend to show up with an even higher probability in loanword mappings. Less probable perceptual mappings tend to show up with even lower probabilities in loanword mappings.

This general pattern, then, takes the shape of an ogive. To capture this shape in the distribution, we fit the data using a logistic categorization function of a type that is often used to model perceptual responses to a graded stimulus continuum.[3] The point of using such a function is to capture the general pattern that the probabilities are more evenly graded in the perceptual data than in the loanword data; the loanword probabilities tend to cluster toward zero or one. Fitting the logistic models to the data in each panel of Fig. 1 yields an even stronger correlation in each case, in three of the prosodic positions with extremely high r^2 values, as summarized in the left column Table 2. The proportion of variance in loanword mappings accounted for by the perceptual mappings in each of the three prosodic locations discussed here is around 80%, substantially higher than the linear fits mentioned above. The goodness of these logistic fits suggests that most of these loanword mapping patterns can be neatly modeled as the perceptual mapping data, modified by increasing the probability of majority probabilities and decreasing the minority probabilities, pushing the loanword adaptation probabilities for each segment in the direction of a single, high-probability outcome.

[3] The actual equation for the logistic function used here is as follows: $y = 1/1 + \mathrm{Exp}(-(a + bx))$.

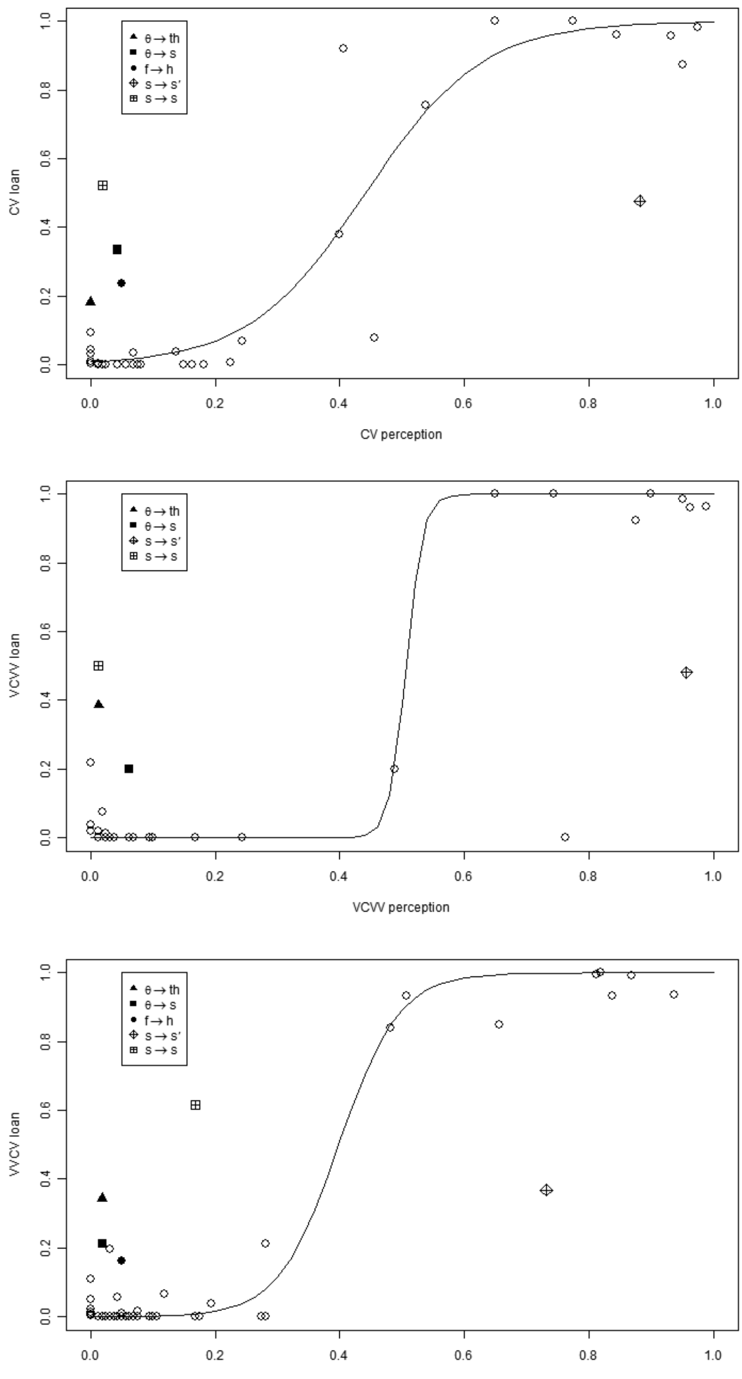

FIGURE 1. The probability of particular loanword mappings for the English consonants indicated in Table 1, plotted against the probability of that source consonant being identified as the target consonant in a perceptual identification task. Top panel: initial consonants; middle panel: intervocalic prestress consonants; bottom panel: intervocalic poststress consonants.

	ALL DATA	ALL DATA WITH MAPS > 3%	WITHOUT EXCEPTIONAL MAPPINGS
INITIAL	0.789	0.741	0.884
PRESTRESS INTERVOCALIC	0.858	0.808	0.984
POSTSTRESS INTERVOCALIC	0.831	0.798	0.976
FINAL	0.670	0.559	0.621

TABLE 2. R^2 values from regressing the probability of loanword maps against the probability of perceptual maps, using a logistic function.

One objection to this quantification, however, might be that much of the variance accounted for in the logistic fits involves not predictions about loanword mappings that occur, but rather, those that do not occur. That is to say, there are many very strange loanword mappings (e.g. /s/ → /p/) that do not occur, and perceptually these also do not occur. Thus, a different sort of interpretation of the good fits in the data might be that the perceptual data are simply filtering out loanword mappings in which the source consonant and the adapted consonant have nothing in common, and so any abstract loanword mapping model would do the same. To derive a measure of the degree to which observed loanword adaptations could be traced to observed perceptual mapping, without this component of strange, essentially unobserved mappings, all values in which the proportion of both loanword and perceptual mappings were zero (or very near zero, below 3%, such that they could easily arise as noise in the perceptual experiment) were eliminated from the data, and the correlations were recalculated, yielding the values given in the second column of Table 2. As can be seen, the variance accounted for decreases somewhat, indicating that some of the goodness of fit for the logistic regression between perceptual and loanword mapping proportions is indeed due to the large number of uncommonly realized mappings. It is also clear, however, that reductions in r^2 values are very modest, leaving behind a very robust logistic relationship between the two proportions, even without the very low-probability mappings included.

Finally, it should be noted that the degree of clustering (and hence divergence from a linear fit) differs from prosodic position to prosodic position. The prestress intervocalic consonants (middle panel of Fig. 1) cluster very strongly at 0 and 100% loanword maps, and so they fit with the most extreme logistic model of discrete categorization. That is, one might say that these data are largely consistent with a model in which all perceptual maps over 50% become completely regularized in the loanword mapping. This gives rise to a very sharp curve in the logistic fit, and to the large increase in fit from the linear to the logistic function. Data in other prosodic locations, however, exhibit more tokens in which perceptual maps with between 35% and 65% mapping exhibit loanword maps also with intermediate probability. These data suggest some more probabilistic process relating the perceptual data and the loanword outcomes.

Thus, to summarize the overall patterns in the data, there is a graded structure to the loanword mappings, involving pervasive inconsistency in the mapping of each consonant in the lexifier. These proportional inconsistencies, along with the regular loanword adaptations, are largely explained by the graded perceptual responses of relatively naive listeners of the target language to productions of the lexifier consonants. Thus, the current data conform generally to a model such as that of Peperkamp & Dupoux 2003, in which loanwords are simply perceptually mapped forms; however, these perceptual maps need to be interpreted with an added component of regularization. The loanword maps are not simply perceptual maps, but rather are the perceptual maps after having undergone a process that tends toward regularizing the maps in the direction of the most common perceptual maps (e.g. English /v/ → Korean lenis /p/). Closer inspection of the data, however, shows that there are obvious exceptions to this pattern, which are discussed in the next section.

3.2. Exceptions to the overall pattern. Examining the data in more detail reveals that the residual portions of the data, data points that lie far from the fitted logistic curve, require additional components to an overall loanword mapping model. These data points consist of two groups in Fig. 1: those lying far above the fitted curve to the left of each panel, cases in which high-probability loanword mappings do not have high-probability perceptual mappings, and those that lie below the curve to the right, cases in which high-probability perceptual mappings do not correspond to high-probability loanword mappings. These cases are highlighted in Fig. 1 by the use of different coding symbols.

These exceptions involve three types of cases. The first involves mappings with fortis /s/ in Korean. While the Korean listeners usually perceptually labeled English voiceless sibilants and dental fricatives as fortis /s/, they rarely labeled them as lenis /s/. In loanword adaptation, however, lenis /s/ is a very common outcome (e.g. [s'ebɨn]/[sebɨn] *s̲even*). This disagreement yields several of the data points in which there is a high-probability loanword adaptation with lenis /s/ corresponding to nearly zero-probability perceptual maps (to the left, above the function in each panel), and conversely very high-probability perceptual maps with fortis /s/ corresponding to loanword mapping rates between 40% and 60% (to the right, below the function). While it is possible that there is some contextual effect in the perceptual protocol that tended to discourage lenis-/s/ responses, the very low number of lenis-/s/ responses in the perceptual data suggests strongly that these loanword mappings simply do not accord with the perceptual data. These mappings might be perceptually based on lenis-/s/ perceptions of English productions of fricatives in clusters, which were not included in the perceptual experiment (cf. Kim & Curtis 2002 and Lee 2009), but this would require abstraction away from the particular context of the segment. The source of these lenis-/s/ loanword mappings might also lie in the standard orthographic conventions by the National Institute of the Korean Language (www.korean.go.kr), where English loanwords are recommended to be represented in Korean orthography using a segmentally consistent principle of one-to-one phonemic substitution. Here, unlike in the perceptual data, the conventions have adopted a lenis-/s/ mapping, apparently resulting in two forms: a perceptually motivated fortis-/s/ form, and the prescribed lenis-/s/ form.

In the second group of cases, English /f/ is borrowed as rounded /h/ (e.g. [hwail]/[p^hail] *f̲ile*). The variable borrowing of the labial fricatives as /h/ versus a labial stop has been noted by previous scholars (Lee & Cho 2006, Kang et al. 2008, Cho & Lee 2010; cf. Ito et al. 2006), who have pointed out that these /h/ loanword mappings usually involve English words that were borrowed in the earlier half of the twentieth century. During this period, the English contact with Korean was heavily mediated by speakers of Japanese, who traditionally map English /f/ onto Japanese [ɸ], a form of Japanese /h/ in the core Japanese vocabulary. Thus, the /f/ → /h/ loanword mapping either could involve abstraction based on the Japanese system, or it is possible that it was based on Korean perception of Japanese-accented productions of the English forms.

Regardless of the exact mechanism involved here, these exceptional forms indicate two further aspects of the borrowing process that need to be accounted for. First, borrowings involve an amount of time depth that distinguishes them from the synchronic perceptual mapping, since current adaptations may reflect contact conditions that no longer obtain. Current forms may reflect the second language perceptual maps of ancestors of the current speakers of the target language, rather than the current users. Second, the undoubted influence of third languages in the mapping process can lead to systematic mismatches between bilingual perceptual maps and loanword maps. These complexities would be particularly likely in balanced and partially integrated multilingual communities—for example, in Singapore with Malay, Tamil, Chinese, and English—and would seem to be less likely in cases such as that currently investigated, where the contact between English and Korean is (currently) direct and not persistently entangled with third language mediators.

The third group of cases in which loanword maps do not have corresponding high-probability perceptual maps involves the mapping of the voiceless dental fricative onto Korean aspirated /t/. While the perceptual mapping for /θ/ would generally predict a strong preponderance of (fortis-)/s/ loanword mappings, there are many more loanword mappings with aspirated /t/ than are expected. This division between /t/ and /s/ loanword adaptation for /θ/ has been noted as a feature differentiating languages in previous work (Brannen 2002, Ahn 2003). For example, previous literature has noted /s/ (production) mapping for Parisian French, but /t/ mapping for Canadian French (Brannen 2002). Lombardi (2003) also reported that in second language acquisition, English /θ/ was substituted with [t] by Russian speakers but with [s] by Japanese speakers. In the current case, however, speakers of the same language exhibit both outcomes. An examination of the individual loanwords exhibiting the different mappings indicates some lexical regularity, in that the words with a /t/ mapping are scholarly forms of either Greek or Hebrew origin ([t^{h}ema] *theme*, [k^{h}at^{h}olliʃidʒɨm] *Catholicism*, [p^{h}it^{h}agoɾas'ɨ]/[p^{h}idagoɾasɨ] *Pythagoras*, [et^{h}osɨ] *ethos*, [pedel]/[petel] *Bethel*) and may also be similar to a larger lexical class of chemical jargon that were removed from the database as being very unlikely to be known by speakers outside of the field of jargon (e.g. [t^{h}oɾium] *thorium*).

The particular case of *Bethel* is striking in this regard. The two variants in this case are quite different from the others in that the variants are allophonically related, and the variation, [pe.del] in the spelling <pe.tel> vs. [pet.el] in the spelling <pet.el>, is one of syllabification of the medial lenis stop. The two variants are different in spelling and can also be in pronunciation, although in casual and fast speech [pe.del] is a likely outcome for both spellings, since the medial lenis stop usually is resyllabified with the following vowel. The nonresyllabified spelling is what would be typical in cases where there is a morphological break after the consonant. It seems that *Bethel* was borrowed when Christianity was first introduced in Korea (which was more than 200 years ago) and the adapters would be scholars or experts in western religion knowing that *Bethel* is bimorphemic: *Beth* = house (as in also *Bethlehem*), and *El* = (lowercase) 'god': *Bethel* = 'House of God'. *Bethlehem* (= 'House of Bread') also exhibits the same unusual variation. According to the Naver portal site (www.naver.com), Bethlehem has variant forms [pet.le.hem] <pes.le.hem> and [pet.ne.hem] <pes.ne.hem> mostly from Gospel songs, along with [pe.dɨl.le.hem] <pe.tɨl.le.hem> in our database. (Korean nouns generally do not end with /t/ but with /s/ or /t^{h}/, which are neutralized as unreleased [t] in coda due to coda neutralization (Davis & Cho 2006). Also, native Korean tends to avoid /l/ in onset, and Korean disallows consonant clusters, so they are often broken by inserting a vowel.) The unusual coda-syllabified forms [pet.le.hem] <pes.le.hem> and [pet.ne.hem] <pes.ne.hem> seem to occur because the original adapters treated *Beth* as a separate morpheme, and this usage is preserved in cultural artifacts (even modern artifacts) such as songs, regardless of the current awareness of the morphological structure of the original form.

It is not the case that all classical origin forms, however, exhibit stop loanword mapping, since similar scholarly terms can exhibit /s/ mapping or even variable mappings (cf. /s/ mapping: [misosɨ]/[mis'os'ɨ] *mythos*; /t/ mapping: [et^{h}osɨ] *ethos*; variable mapping: [p^{h}eisosɨ]/[p^{h}eis'os'ɨ]/[p^{h}at^{h}osɨ] *pathos*, [t^{h}erap^{h}i]/[serap^{h}i]/[s'erap^{h}i] *therapy*).[4] Nonscholarly Germanic loanwords, however, always exhibit /s/ mapping. What this pattern suggests is a sensitivity in the loanword adaptation to how original forms with stops may have entered into the language, either by means of Korean scholars of the classical languages, or perhaps through orthographic transmission, and these have been in competition with the perceptually based fricative forms in more recent years. In addition to indicating a potential effect of a different source language (i.e. here, Greek or Hebrew vs. English), these localized patterns in the current data point out that loanword adaptation can exhibit lexical clustering (e.g. similar to the clustering found in morphologically determined allomorphy), and so these will not be amenable to a perceptually based explanation.

The overall pattern in the data, however, is not characterized by these exceptions, but rather these might be considered localized exceptions to the overall pattern. In the context of the overall database, if we remove the exceptional maps just discussed from the data set (leaving just the maps encoded in Fig. 1 with hollow circles), the r^2 measures for the onset and two intervocalic prosodic positions become very high, accounting for well over 90% of the variance in loanword mapping probabilities. The values for each prosodic position are given in the right column in Table 2. This suggests strongly that overall loanword mapping in the Korean situation can be accounted for as perceptual mapping, as it gets regularized through the process of common usage. This process of usage, however, extends over a long period of time, and thus can outlive the productive period of borrowing, and therefore can obscure effects of a third language on the process. These data also indicate that the process of loanword adaptation, at least in literate cultures, is susceptible to explicit cultural stipulations in particular corners of the segmental system, which can be at variance with the basic perceptual pattern, the use of lenis /s/ in this case.

3.3. CODA CONSONANTS. Turning to the analysis of the postvocalic final consonants, we must account for an additional complication. Because of the neutralization pattern in Korean, the identity of the consonant in the loanword is contingent on the adaptation of the prosodic structure as well. Phonological models would predict, on the loanword side, that final consonants either get borrowed as plain stops, or, if borrowed as fricatives or fortis or aspirated stops, they must get borrowed with a following paragogic vowel to put the consonant in a noncoda position. This pattern is, in fact, maintained without exception in the loanword database; Korean borrowings of English words do not exhibit exceptions to the general Korean pattern. Rates of paragoge, however, differ radically from segment to segment, as summarized in Table 3, ranging from 100% for English words ending in /s/, /z/, and /v/, to 25% for words in ending in /p/, with an average per segment of approximately 80%. What this means for consonant adaptation is that nonparagogic forms, due to the phonological system of Korean, will exhibit plain stops, regardless of the perceptual mapping of the segment.

[4] As one referee notes, additionally suggesting this sort of explanation is the covarying vowel mapping that accompanies the /s/–/t/ difference in *pathos*. The /s/-mapped forms additionally show the fronting and raising of the first vowel, which is expected in English productions of the Greek-origin word, while the /t/-mapped form retains the original low vowel.

	PROBABILITY IN LOANWORDS	PROBABILITY IN PERCEPTUAL DATA
/p/	0.250	0.038
/b/	0.354	0.275
/f/	0.893	0.438
/v/	1.000	0.450
/θ/	0.864	0.562
/ð/	1.000	0.462
/t/	0.577	0.375
/d/	0.973	0.375
/s/	1.000	0.684
/z/	1.000	0.625
MEAN	0.791	0.428

TABLE 3. Proportion of loanword forms with a paragogic vowel and proportion of perceptual responses with a paragogic vowel in de Jong & Park 2012.

Figure 2 plots the proportions of loanword maps for each consonant against the corresponding proportion of matching perceptual responses for that same consonant. R^2 values for the logistic fits, even after suppressing the potentially troublesome cases discussed above, never rise over 70% (Table 2). In Fig. 2, it is also immediately apparent that final-consonant loanword mapping is, if anything, less regular than that in the other prosodic positions. Apparently, the presence of position-specific neutralization rules in the target language is affecting the loanword mapping, and the general effect is to create many more segmental loanword maps than in other prosodic positions, and these loanword maps do not correspond very well to the perceptual maps.

As would be expected by the phonological neutralization patterns, the most obvious examples of divergence from the perceptual data in the loanword data involve mapping to plain stops; these are coded with various hollow symbols in Fig. 2. Three data points, coded with larger triangles and squares below 10% on the x-axis along the y-axis of the figure, are ones in which coronal consonants /ð/, /θ/, and /t/ are mapped onto a plain /t/ in the Korean form. If we examine the loanword mappings for the voiceless stops, we find the mapping for the English /t/ as the lenis final stop to be 42.3%, also much higher than the 1.9% perceptual responses. This corresponds to an overprediction of the aspirated loanword response: 55.4% loanword mapping corresponding to 73.1% perceptual mapping responses. With the labial consonants, we find the same pattern, lenis-/p/ loanword mapping appearing in 75% of the words, while perceptual lenis-/p/ responses are obtained in only 30% of the trials. Thus, some of the variability in the loanword maps here is due to the effect of variable paragoge.

However, neutralization patterns in final position do not completely explain the poor fits found here. If we remove loanwords that did not have an inserted vowel after the coda and rerun the correlation analysis, we still get very poor fits of the loanword adaptation probabilities to the perceptual maps (for maps > 0.03, logistic $r^2 = 0.348$, linear $r^2 = 0.332$), and again, loanword mapping to plain stops tends still to be more common than predicted from the perceptual data, even with the word-final (nonparagogic) cases suppressed.

In addition, more careful examination of the patterns shows that, even with the mapping to plain stops, there is a pervasive effect of perception mapping probability on the loanword maps. This shows up in two ways. First, the preponderance of plain (lenis) stop mappings is gradient, such that less likely perceptual responses of a plain stop correspond to less likely loanword mapping to a plain stop. For example, /ð/ and /t/ are very rarely labeled as plain stops in the perceptual data, and equivalent loanword maps to plain stops

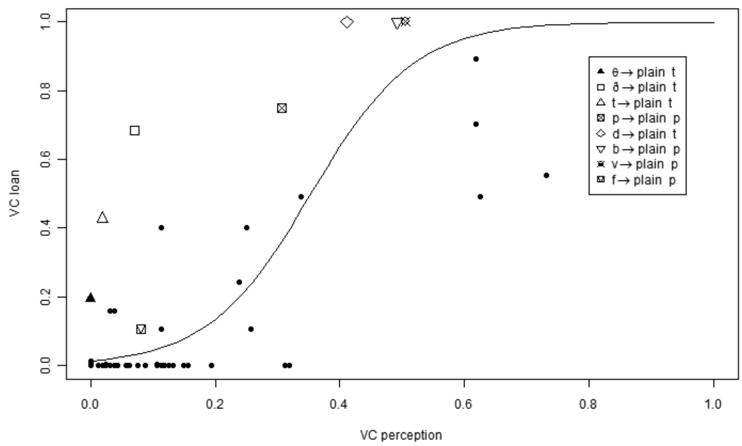

FIGURE 2. Same as Fig. 1, but for consonants in word-final position.

are less than 75%; however, /v/ and /b/ are more commonly perceptually labeled as plain stops, and exhibit loanword maps to plain stops that are exceptionless. Between these two is /p/, which is intermediate in both the loanword and the perceptual data.

Second, the rate of paragogic vowels for each consonant in the loanword adaptation is also related to the probability of perceptual paragoge. As part of the larger study from which the perceptual data are drawn, Korean listeners were also asked to count the number of syllables in each stimulus. Each of the stimuli with a final consonant exhibited an audible release, which tended to support the perception of an additional syllable head (more details of these data can be found in de Jong & Park 2012). Just as with loanword adaptation, however, the perception of an additional vowel also varied by consonant, as summarized in Table 3, and the rate of loanword paragoge is correlated with the rate of perceptual paragoge ($r^2 = 0.389$). The general pattern of relationship, as with the segmental maps, is that the two maps are similar but not identical; the loanword adaptation rates tend to cluster more heavily in the extremes.

Pursuing the perceptual account of the variability in coda mappings, we note further that the perceptual responses, like the loanword mappings, tend to be much more variable. While the exact reason for this perceptual effect is unclear, it appears to be related to an overall lack of attention in the Korean listeners to cues that reside in the offset of the vocalic region, and a corresponding increase in confusions between consonants whose distinctions rely on such cues (cf. Silbert & de Jong 2007, de Jong et al. 2009). What this means is that, among the various alternatives for each consonant, there tend not to be any responses that stand out as being much more perceptually likely than the alternatives, and hence there tend to be fewer data points in the upper right end of the logistic function in Fig. 2. The data points tend to all reside in the left half of the figure, suggesting that the process of regularization does not have obvious mapping candidates to regularize to. In the case of each fricative, the perceptual maps are extremely varied, with the modal response to final /ð/ being 31.3% of the responses as lenis /p/, and the modal response to /θ/ being 31.9% of the responses as aspirated /p/. Thus, these cases of loanword mapping to plain, lenis /t/ appear to be the most extreme cases of inconsistent mapping in the perceptual data.

What these patterns suggest is that there is a tendency to regularize loanword maps in the direction of plain stops particularly in the absence of a very strong perceptual propensity to other responses. The fact that noisy coronals tend to resist this default loanword mapping would, then, reside in the fact that noise generated with coronals tends to be more salient than that in labials (for reasons discussed further in Stevens 2000:389–402 and de Jong & Park 2012), and this noise would distinguish the productions from Korean final plain stops, which are unreleased. In the absence of strong information otherwise, then, the loanword map to the plain stops represents something of a minimal construal of the input. The fact that this default manner and laryngeal specification is acoustically minimal would mean that this map would be the least dissimilar from a perceived version of the input as not containing much acoustic substance-bearing phonological information. That is, this loanword mapping effect could be indicating a tendency for the reduction of dissimilarity from inputs—in this case, inputs with little in the way of phonologically relevant information.

One further note of interest relative to previous work on loanword mapping concerns the next most overrepresented cases of loanword mapping in the final-consonant data, the mapping of /θ/ forms of Korean /s/. In both of these cases, the proportions of perceptual responses are 11% and 25%, while the loanword mapping proportions are over 40%. The same overrepresentation is apparent in the voiced counterpart, but not in the alveolar stop cases. Cases of mapping to /s/ of final consonants have been discussed in Davis & Cho 2006 as indicating the phonological effect of undoing the neutralization of Korean fricatives in final position. In this account, they discuss the fact that surface plain stops in final position in Korean can be indicators of an underlying /s/, and such underlying forms can surface in loanwords as well.

4. Variation across prosodic positions. Our analysis in §3 simply treats the prosodic positions as different test cases for examining the obstruent mapping. As noted above, however, we can also compare the loanword patterns across the prosodic positions to examine the degree to which the mapping patterns are sensitive to the position-specific differences in perceptual mapping. A perceptual model would predict that any differences in loanword mapping across prosodic positions should correspond to perceptual mapping differences. As noted above, however, a segmental or feature-based model such as that of LaCharité & Paradis 2005 would, in its simplest form, predict no variation across the prosodic positions, except where explicit phonological constraints associate particular prosodic positions with particular segmental outcomes. Such models would predict very strong correlations between the probabilities of various maps across the positions, but only where specified allophonic variation is involved.

Examining the maps, one finds that the patterns of loanword and perceptual mapping for each consonant are quite similar across the prosodic positions; a consonant tends to be adapted and perceived similarly across the prosodic positions. A measure of this similarity is given in Table 4. Table 4 gives r^2 values for regressing the probability of each loanword map (left half of cell) and perceptual map (right half of cell) for the prosodic position in the row against the maps for the prosodic position in the column. Correlations are at 70% or above for the nonfinal positions, and somewhat lower between final position and the other positions (right column). Thus, loanword and perceptual patterns are somewhat different in final position from other prosodic positions, in both maps.

	INITIAL	PRESTRESS INTERVOCALIC	POSTSTRESS INTERVOCALIC	FINAL
INITIAL	1.000/1.000	0.689/0.872	0.950/0.787	0.419/0.511
PRESTRESS INTERVOCALIC		1.000/1.000	0.788/0.913	0.574/0.505
POSTSTRESS INTERVOCALIC			1.000/1.000	0.428/0.698
FINAL				1.000/1.000

Table 4. R^2 values from regressing loanword and perceptual maps across prosodic positions. Loanword map/perceptual map. Mappings of < 0.03 are not included.

Though the patterns of loanword adaptation are similar across the (nonfinal) prosodic positions, they are not identical; thus we can test to see if this difference across the loanword maps corresponds to differences across the perceptual maps. We take the deviation in the probability of a loanword map (e.g. /p/ → /p'/) in one prosodic position from another prosodic position, and then correlate it with the deviation of the probabilities of these maps in the perceptual data across the same two prosodic positions. Since there are four prosodic locations, there are six pair-wise combinations of the locations that can be examined. Figure 3 plots all of the pair-wise comparisons for each map against the matched prosodically triggered differences in the perception data.

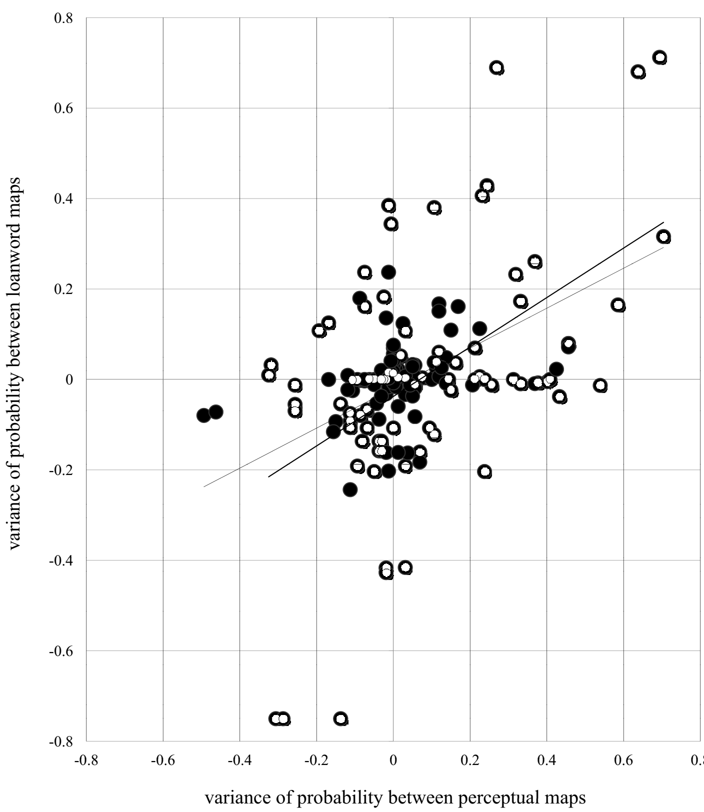

FIGURE 3. The variance between the probability of particular loanword mappings across prosodic positions plotted against the difference in the probability of that mapping in the perceptual responses to consonants. Hollow symbols indicate comparisons between coda position and other positions; filled symbols indicate comparisons between noncoda positions.

There is a clear and significant positive correlation ($r^2 = 0.209$, $t(273) = 6.76$, $p < 0.01$) between the perceptual differences and the loanword differences. For example, some of the extreme values come from voiceless stops, particularly labial stops, where the loanword mapping in most conditions is to an aspirated stop, while final stops tend to be mapped onto plain stops. Highlighted here is the fact that the same increased tendency toward a plain stop outcome appears in the perceptual data. Such effects are not restricted to stops, though. Another clear example is that of the loanword mapping of /z/. /z/ in coda position is more likely to be mapped onto a fricative, while in other positions it is more likely to map onto a (plain) affricate. This is true of the perceptual data as well.

Models of loanword adaptation that rely on segmental differences abstracted from the prosodic location do not rule out variation in the perceptual maps, since many factors can affect the outcome of the loanword adaptation process. Such models do not, however, lead one to expect variation across prosodic position that is systematically related to perceptual variation. But such models might lead one to expect systematic differences between final and nonfinal maps. These may be due to phonological effects that are not specifically perceptual; one might not expect these differences to correlate with perceptual differences. This, however, is not the case. If we only examine prosodic differences between codas and noncodas (which are coded with hollow symbols in Fig. 3), the correlation is even stronger than the general correlation ($r^2 = 0.255$, $t(89) = 4.76$, $p < 0.01$). Thus, we cannot rule out perceptual motivation for these differences. Also, if we remove the coda differences from the analysis, and look only at the smaller differences between the other positions, even here with these smaller differences, a positive correlation is evident (and significant, though weaker; $r^2 = 0.101$, $t(82) = 3.04$, $p < 0.01$). Thus this perceptual relationship pervades the differences found across prosodic positions in the loanword mapping data.

5. VARIABLE FORMS. This section closes the data analysis, returning to a point noted above, that loanword maps are variable not only across lexical items (the target of our quantitative analyses in the previous two sections) but also within lexical items. This within-lexical-item variation is not rare, being evident in more than a quarter of the lexical items. This variation does not just indicate indiscriminate noise in the loanword process, with respect to the various consonants, but is strongly dependent on the particular consonant, as is tabulated in Table 5.

SOURCE CONSONANT	INITIAL	FINAL	PRESTRESS INTERVOCALIC	POSTSTRESS INTERVOCALIC	TOTAL
/p/	8.7% (22/252)	13.1% (11/84)	15.1% (8/53)	13.3% (13/98)	11.1% (54/487)
/b/	15.9% (42/264)	12.5% (3/24)	0% (0/28)	1.5% (1/66)	12.0% (46/382)
/t/	3.5% (5/145)	24.9% (56/223)	5.2% (4/76)	12.0% (21/175)	13.9% (86/619)
/d/	7.6% (14/185)	1.1% (1/91)	2.6% (1/38)	0.9% (1/107)	4.0% (17/421)
all stops	9.8% (83/846)	16.6% (70/422)	6.7% (13/195)	8.1% (36/446)	10.6% (202/1909)
/f/	47.5% (74/156)	14.3% (4/28)	0% (0/28)	32.3% (10/31)	36.2% (88/243)
/v/	0% (0/76)	0% (0/31)	0% (0/34)	0% (0/74)	0.0% (0/215)
/θ/	87.0% (20/23)	87.0% (15/17)	87.5% (14/16)	86.4% (19/22)	87.2% (68/78)
/ð/	0% (0/2)	50% (1/2)	0% (0/0)	14.2% (2/14)	16.7% (3/18)
/s/	97% (224/231)	98.3% (183/186)	96.1% (50/52)	74.2% (46/62)	94.7% (503/531)
/z/	6.3% (1/16)	21.3% (10/47)	0% (0/27)	6.5% (7/107)	9.1% (18/197)
all fricatives	63.3% (319/504)	68.5% (213/311)	40.8% (64/157)	27.1% (84/310)	53.4% (680/1282)
TOTAL	29.8% (402/1350)	38.6% (283/733)	21.9% (77/352)	15.9% (120/756)	27.6% (882/3191)

TABLE 5. Proportion of lexical items per consonant and prosodic position that exhibit more than one mapping.

There is a pattern to this dependency; it tends to track the degree to which there is a dominant category in the perceptual mapping. Developing the general perceptual account suggested so far would lead one to expect a decreasing relationship between the probability of one dominant perceptual map and the proportion of forms that are variable.[5] To illustrate, if a loanword were adapted based on perceptual responses on the fly (Peperkamp and colleagues' model), more variable perceptual responses would yield different outcomes more often. If loanword maps are simply partially regularized perceptual maps, then different outcomes of the perceptual mapping process are least likely to occur in cases where one perceptual map predominates. As the most prominent perceptual map becomes less probable, the likelihood of obtaining different loanword maps increases to a point where variable outcomes to the process are virtually guaranteed. We can quantify this effect by plotting, for each consonant in each prosodic position, the proportion of lexical items that are variable against the probability of the most likely perceptual map for that consonant.

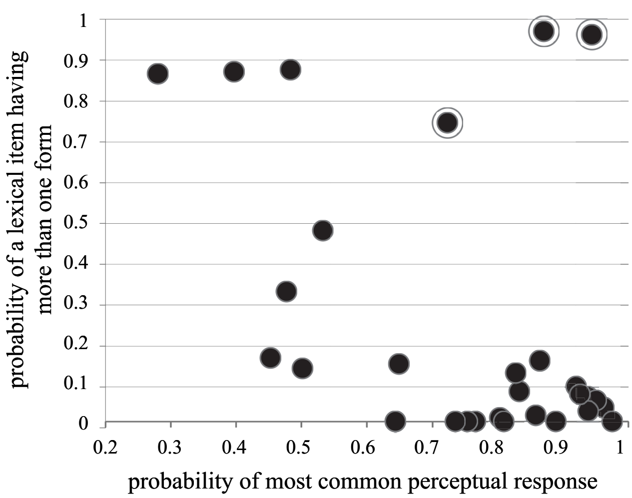

FIGURE 4. Probability of lexical items with a particular consonant in a particular prosodic position having multiple loanwords plotted against the probability of the most likely perceptual map for that consonant in that prosodic position.

Figure 4 does this, excluding consonants in final position. (Final-position patterns are similar, but shifted to the left.) The graph shows the expected relationship; increased probabilities of one single perceptual map mean reduced likelihood of having lexical items with multiple forms. (There are, again, some exceptions, indicated with circled markers in Fig. 4.) If the most common perceptual response receives less than 60% of the perceptual responses (symbols in the left half of the figure), the likelihood of variable adaptation rises (to nearly 90% in three of the cases). As the likelihood of one common perceptual response climbs over 60% (symbols to the right half of the figure), variability rates fall to less than 20%. What this pattern indicates is that most of the

[5] During review, the question arose of whether having a second viable perceptual map encourages more variation than would happen in a case in which there are numerous alternatives to the dominant category. The current data do not include enough variety to tell for sure, but it is the case that /b/ in onset position is a clear case in which there are two dominant mapping responses (lenis and fortis /p/), both with roughly the same proportion. In this case, loanword variation is low, at less than 20%.

loanword patterns are constrained strongly by perceptual mapping, and ones that are not tightly constrained by a dominant perceptual mapping tend to exhibit variable forms. What do not occur here are data points downward and to the left, which would indicate cases in which there are no dominant perceptual responses, but there is nevertheless relatively little variation in lexical forms.

There are, however, three data points where there are variable forms in the face of strongly consistent perceptual maps (circled markers upward and to the right). Each of these data points concerns variable loanword mapping between fortis and lenis /s/ in the three prosodic locations. As noted above, we believe that this variation is associated with explicitly standardized norms that run counter to the perceptual data. Thus, one of the exceptions to the perceptual mapping analysis in §3 also proves exceptional in the within-lexical-item variation analysis here.

6. Summary of current results and discussion. The current results largely provide evidence of a strong relationship between perceptual mapping and loanword adaptation. As noted informally by Peperkamp and Dupoux (2003), perceptual mapping patterns also generally appear in the loanword mapping data. More than just indicating a general parallel pattern between the two types of mapping, however, there is also an evident relationship between the variation in perceptual mapping and the variation in loanword mapping. This relationship is evident in the variation in mapping across lexical items and within lexical items. Across lexical items, the general pattern is that minority loanword mappings correspond to appreciable proportions of perceptual responses with the same outcome. Within lexical items, the general pattern is that variable lexical forms are much more likely in cases in which there is no predominant perceptual response.

These observations suggest an account of English-Korean loanword adaptation that begins in the perceptual mapping of English productions onto Korean categories, but then proceeds beyond the synchronic perceptual mapping through a process of usage in which perceptual response patterns, which are variable in nature, tend to become regularized in the direction of a single segmental pattern in the loanword mapping data. This is true both across lexical items and within lexical items. Thus, loanword mapping is not the same as perceptual mapping; it is more consistent, and thus might be considered to be more abstracted from specific speech events than are experimentally derived perceptual maps. A very similar conclusion is reached by Kang (2010), examining diachronic variation in the expression of secondary rounding in Korean borrowings of English words. She argues for a model in which loanword maps arise out of perceptual maps over time as a corpus of borrowings from English becomes large enough and salient enough for users to develop a standardized borrowing pattern. This model is quite similar to that proposed by Haugen, in his classic *Language* article on borrowing (1950, and an extensive empirical study supporting it, Haugen 1953). Here, early borrowing patterns are more chaotic, and become regularized as more individuals and more bilingually sophisticated individuals become involved in the borrowing process.

This difference between perception and adaptation may explain the difference between the maps noted by Park (2008). Park (2008) noted that, while place-of-articulation changes occur in perceptual maps, they do not appear in Korean loanwords. This pattern is also obtained in the current data, but is not noted above because it is part of the much larger pattern of logistical correlation between the two maps. While place switches are more common than chance in the perceptual mapping data, none of these mappings are of sufficient probability to lead one to expect large numbers of loanwords to reflect them. Thus, the feature-specific treatment suggested by Park (2008) does not seem to be necessary. Running counter to this conclusion, however, is the fact that the loanword database does not include ANY example of a place switch. Thus, since we are dealing with predicted low-probability events, we cannot be sure at this time that there is no place-specific loanword mapping constraint, even though it does not appear necessary to capture the overall patterns in the current data.

Further evidence for a regularized perception account is found in the mapping data for final consonants. The first effect is that the addition of a paragogic vowel is more likely with consonants that are more likely to induce perceptual paragoge. As with the segmental data, the instances of paragoge tend to be more all-or-nothing than the perceptual data, hence suggesting again a process of regularization. With respect to consonant mapping, the overwhelming effect in the data is that consonants appearing in postvocalic coda positions, the targets of neutralization rules in the Korean system, exhibit much more variable loanword mapping patterns. This messy mapping pattern corresponds to very weak perceptual maps, as is evident in the large amount of variation in the perceptual mapping patterns examined here, as well as in other aspects of the perceptual data, including the increased failure to find any Korean correspondent to the English productions, and very low goodness estimates (de Jong & Park 2012). Thus, the final-consonant data here illustrate the effect of lack of robust perceptual input into the loanword mapping process, yielding more chaotic loanword mapping results.

Interestingly, in this position we also begin to find effects that would be traditionally ascribed to the phonological system: a tendency toward an underspecified segment in the current data, and in other studies, the presence of morphologically induced /s/ default (Davis & Cho 2006). The current data also indicate overrepresentation of the loanword /s/ outcome in the dental stop cases, but not in the dental fricative cases. Overall, then, the final-consonant results suggest that loanword adaptation patterns can and do diverge from perceptual mapping in that they also proceed in the absence of strong perceptual input. It may be that in these situations, overall phonological and morphophonemic system effects are most likely to be detected.

The current data also indicate other ways in which loanword adaptation in the Korean case is not perceptually based. We find examples in which loanword mappings apparently reflect the effects of a third language in the mapping process, and cases in which the apparent source of the loanword mapping effect is nearly a century distant from the current perceptual maps. Thus, another difference between segmental perception and loanword adaptation lies in the fact that loanword mapping is strongly lexical. Lexical items, once incorporated into the target language, take on their own histories, which may then diverge from the perceptual behavior of later generations.

Such divergence in the loanword maps raises the question of the mechanism for regularization. Models such as those in Haugen 1950 and Kang 2010, as well as a hybrid model presented in Smith 2009, all seem to require not only that loanword users have access to the source forms, but also that the loanword forms are part of a coherent system of known correspondences between the two languages. Smith (2009) is most explicit about this, positing first a role of perceptual and orthographic (and other) information in constructing the source form of the loanword, and then a phonological system of correspondences between the source and the actual loanword form. These correspondences are particular to the loanword phonology, thus providing a mechanism for loanword adaptations to develop their own phonological system (as in the Japanese case analyzed in Fukazawa et al. 2002). In the current case, we do find evidence of an effect of explicit standardization in the current data, but not the usual effect of standardization. Here, in the case of /s/ loanword mapping, we find an effect of explicit standardization creating variability in cases in which the standard loanword map runs counter to a strong perceptual map.

This raises the general question of whether such standardization, either in the construction of a loanword-specific grammar in the individual or explicitly in the culture, is really necessary to get the regularization effects noted here. As suggested by Davidson (2007), it might not be. The variable perceptual mapping could be regularized by the process of repetitive usage. That is, using Haugen's (1950) approach, a borrower who has contact with the source language uses the lexical item in the context of the borrowing language. From here, monolingual and bilingual recipients alike can repeat the form, encouraging the use of the most common form, contributing toward lexical regularization. Similarly across lexical items, the same segment in different lexical items will have similar perceptual roots, and so the regularization process will tend to proceed toward the same outcome.

The account suggested by the current data, then, would be one in which perceptual mapping provides an enormous and persistent input into the loanword process, overwhelmingly determining the loanword phonology. This input, however, in situations where perceptual performance by speakers of the target language is very poor, is attenuated, yielding more variable loanword maps with possibly evident effects of phonological and morphophonemic default mapping. However, this regularized perceptual mapping does not account for all of the data; various cases indicate historical specificity to individual lexical items far outweighing the perceptual effects, and also there is some evidence in the Korean case for an effect (albeit not very effective) of explicit standardization on the language.

7. Conclusion. The current study examined a corpus of perceptual and loanword data and has attempted to account for the entire content of a subset of the loanword database in terms of the perceptual data, finding a strikingly clear logistic relationship between the two. This pattern lends support to previously proposed perceptual mapping accounts, but also finds historical, lexical, and sociocultural effects, showing that, while perceptual mapping may be a major determinant of the structure of consonants in English loanwords into Korean, loanword phonology is not just perceptual processing. Loanword phonology is part of a larger process of lexical development over time in a language community in which individual perceptions are fed into the development of a larger linguistic system by repeated usage. This conclusion, however, does not negate the fact that loanword maps in the Korean-English case conform strikingly to perceptual maps.

As noted above, however, these outcomes may be restricted to the particular Korean-English cultural relationship, one in which third language mediaries (currently) do not predominate in the contact relationship, one in which the number of nearly native bilinguals is still relatively low, and one in which the lexical flow into the target language is, nevertheless, very high. A pressing next step is to examine other contact situations, ones with a larger proportion of proficient bilinguals, ones with a more complex third language entanglement, and ones in which lexical borrowing is less common. By examining a range of situations, both with explicit perceptual maps and larger loanword samples and systematic sampling of the phonological system, we should be able to determine the extent to which loanword mapping is an extension of individual perceptual mapping in these other contact situations.

Appendix: Probabilities of an English consonant (columns) being perceived or adapted as a particular Korean consonant (rows), categorized by prosodic position and corpus.

Perception English consonants

Korean	/p/	/b/	/f/	/v/	/θ/	/ð/	/t/	/d/	/s/	/z/
/p/		0.406	0.081	0.650		0.150				
/p’/		0.456	0.225		0.069					
/p^h/	0.931	0.075	0.538		0.163	0.013				
/t/		0.013		0.181	0.069	0.775		0.844		0.019
/t’/					0.244	0.013		0.138	0.013	
/t^h/	0.013						0.975			
/l/				0.056						
/s/					0.044				0.019	
/s’/			0.044	0.019	0.400				0.881	
/tʃ/							0.013		0.056	0.950
/tʃ’/									0.019	0.025
/tʃ^h/										
/h/	0.013	0.019	0.050	0.013		0.013				

Loanword English consonants

Korean	/p/	/b/	/f/	/v/	/θ/	/ð/	/t/	/d/	/s/	/z/
/p/		0.920		1.000						
/p’/	0.044	0.080	0.006							
/p^h/	0.956		0.756							
/t/					0.035	1.000	0.010	0.962		
/t’/					0.070		0.003	0.038		
/t^h/					0.183		0.983			
/l/										
/s/					0.335				0.522	0.094
/s’/					0.378				0.478	0.031
/tʃ/							0.003			0.875
/tʃ’/										
/tʃ^h/										
/h/			0.237							

Table A1. Initial position (CV).

Perception English consonants

Korean	/p/	/b/	/f/	/v/	/θ/	/ð/	/t/	/d/	/s/	/z/
/p/		0.900	0.013	0.744		0.100				
/p’/	0.019		0.169	0.031	0.069					
/p^h/	0.875	0.013	0.650	0.063	0.063					
/t/		0.038		0.069		0.763		0.950		
/t’/			0.025	0.013	0.244		0.013	0.025		
/t^h/	0.031				0.013		0.963			
/l/				0.025		0.094				
/s/					0.063				0.013	
/s’/			0.063	0.013	0.488				0.956	
/tʃ/						0.013				0.988
/tʃ’/										0.013
/tʃ^h/										
/h/	0.031		0.063	0.013	0.038					

Loanword English consonants

Korean	/p/	/b/	/f/	/v/	/θ/	/ð/[a]	/t/	/d/	/s/	/z/
/p/		1.000		1.000						
/p’/	0.075									
/p^h/	0.925		1.000							

(Table A2. *Continues*)

Loanword

KOREAN	/p/	/b/	/f/	/v/	/θ/	/ð/[a]	/t/	/d/	/s/	/z/
					ENGLISH CONSONANTS					
/t/					0.217		0.020	0.987		
/t’/							0.961	0.013		
/t^h/					0.385		0.020			
/l/										
/s/					0.199				0.500	0.037
/s’/					0.199				0.481	
/tʃ/									0.019	0.963
/tʃ’/										
/$tʃ^h$/										
/h/										

[a] There were no lexical borrowings with this consonant in this prosodic position.

TABLE A2. Prestress intervocalic position (VCV).

Perception

KOREAN	/p/	/b/	/f/	/v/	/θ/	/ð/	/t/	/d/	/s/	/z/
					ENGLISH CONSONANTS					
/p/	0.169	0.869	0.175	0.819	0.063	0.275		0.100		
/p’/	0.119		0.106	0.013	0.094					
/p^h/	0.506		0.481	0.031	0.281					
/t/	0.019	0.050	0.025	0.044	0.031	0.656	0.050	0.813		0.044
/t’/	0.013		0.038		0.194		0.044	0.031		
/t^h/	0.031		0.013		0.019		0.838			
/l/		0.031		0.056		0.019		0.025		
/s/	0.013		0.031		0.019		0.013		0.169	
/s’/	0.050		0.075		0.281		0.013		0.731	
/tʃ/							0.025		0.075	0.938
/tʃ’/									0.013	
/$tʃ^h$/										
/h/	0.069	0.013	0.050		0.013					

Loanword

KOREAN	/p/	/b/	/f/	/v/	/θ/	/ð/	/t/	/d/	/s/	/z/
					ENGLISH CONSONANTS					
/p/		0.992		1.000						
/p’/	0.066	0.008								
/p^h/	0.934		0.839							
/t/					0.197	0.849	0.011	0.995		
/t’/					0.037		0.057			
/t^h/					0.344		0.934			
/l/										
/s/					0.211	0.022			0.616	0.051
/s’/					0.211	0.022			0.368	0.014
/tʃ/						0.108		0.005	0.016	0.935
/tʃ’/										
/$tʃ^h$/										
/h/			0.161							

TABLE A3. Poststress intervocalic position (VCV).

Perception

KOREAN	/p/	/b/	/f/	/v/	/θ/	/ð/	/t/	/d/	/s/	/z/
					ENGLISH CONSONANTS					
/p/	0.306	0.492	0.081	0.506	0.044	0.313	0.031	0.106		
/p’/					0.031					
/p^h/	0.238	0.063	0.619	0.113	0.319	0.088		0.019	0.013	

(TABLE A4. *Continues*)

Perception

KOREAN	ENGLISH CONSONANTS /p/	/b/	/f/	/v/	/θ/	/ð/	/t/	/d/	/s/	/z/
/t/		0.063	0.013	0.031		0.071	0.019	0.411		
/t'/					0.031		0.025	0.025		
/tʰ/	0.031	0.013		0.025	0.025	0.019	0.731	0.088		
/l/	0.013	0.038		0.044		0.194		0.038		
/s/	0.075	0.056	0.056	0.038	0.113	0.038	0.106	0.156	0.338	0.256
/s'/	0.013	0.013	0.044		0.250	0.031	0.031	0.013	0.625	0.113
/tʃ/										0.619
/tʃ'/										
/tʃʰ/										
/h/	0.075	0.119	0.125	0.150	0.131	0.150	0.025	0.031		

Loanword

KOREAN	ENGLISH CONSONANTS /p/	/b/	/f/	/v/	/θ/	/ð/	/t/	/d/	/s/	/z/
/p˺/[a]	0.750	0.646	0.107							
/p/		0.354		1.000						
/p'/	0.006									
/pʰ/	0.244		0.893							
/t˺/[a]					0.136		0.423	0.027		
/t/					0.059	0.684	0.004	0.962		
/t'/							0.004			
/tʰ/							0.554			
/l/										
/s/					0.402	0.158	0.002		0.490	0.106
/s'/					0.402	0.158	0.001		0.490	0.106
/tʃ/									0.012	0.702
/tʃ'/										
/tʃʰ/							0.001			
/h/										

[a] Vowel paragoge occurs in all consonants except the cases marked as /p˺/ and /t˺/.

TABLE A4. Final position (VC).

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