Supporting Information

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SI Text

Auxiliary analyses were conducted to test various alternative explanations for the effect of sonority distance. One possibility is that the effect of sonority distance reflects not universal grammatical preferences but proficiency with second languages that allow certain types of onset clusters. Another class of explanations attributes the observed pattern of results to the phonetic and phonological properties of Korean. As described below, the results are inconsistent with both of these explanations.

Contribution of Second-Language Proficiency. We first address the possibility that the pattern of results reflects phonological knowledge of languages other than Korean. To this end, we asked participants to indicate all second languages they know and to report their level of proficiency (see Table S1). Of the various second languages spoken by the participants, English was most frequent and was the one in which most participants self-reported to have attained the highest proficiency. To determine whether the sensitivity to onset structure is due to English proficiency, we assessed the effect of onset cluster type for early vs. late learners of English (those learning English before or after the age of 11—the mean age of English acquisition in the sample). Because we were specifically interested in factors affecting perceptual repair, we focused on the one-syllable targets in syllable judgment, and the nonidentity condition in the identity judgment task. The results are presented in Table S2. A 2 age × 4 onset type ANOVA showed no evidence that proficiency modulated the effect of onset type (F <1.63 for the interactions).

Contribution of Knowledge from Korean. A second class of explanations attributes the results to knowledge concerning the specific phonetic and phonological properties of Korean. Consider first the contribution of phonetic knowledge concerning consonant release. Korean is known to systematically constrain the release of stop consonants in the syllable: Stop consonants manifest a release burst before a vowel. Accordingly, Korean speakers might interpret the presence of a release burst as a cue for the presence of a vowel (1, 2). If release bursts are more salient in stop-initial clusters with more ill-formed small sonority-distances *(bdif)* relative to more well formed ones with large distances (e.g., *blif*), then the perceptual repair of ill-formed clusters could be due to this phonetic property of the stimuli, not their sonority-distances. This concern cannot fully account for the findings (e.g., it offers no explanation for the effect of a cluster's sonority-distance on the perception of its disyllabic counterpart), but we nonetheless evaluated this possibility. To that end, we inspected all wave forms of items with stop-initial clusters (i.e., those with large sonority rises, small rises and plateaus) for the presence of a release burst and measured its duration and intensity. The results are presented in Table S3. Without exception, every stop-initial item had a release burst, and its duration did not differ significantly across the three types of onset [$F2$ (2, 58) < 1, MSE = 11.33]. Although the three onset types differed on the intensity of the burst [$F2$ (2, 58) = 3.48, MSE = 19.11, P < 0.04], this pattern was not monotonically related to sonority distance nor did it reliably correlate with performance in either syllable judgment [r (88) = −0.17 and r (88) = 0.01 for response accuracy and response time, respectively] or identity judgment [r (88) = −0.06 and r (88) = 0.06 for response accuracy and response time, respectively; all P values > 0.05].

We next turned to examine various relevant phonological properties of Korean. One such property concerns consonant voicing. Previous research on loanword adaptation (1) has observed higher rate of repair for voiced compared with voiceless stops. Because stop-initial materials (large rises, small rises, and plateaus) were matched for their initial consonant, this factor cannot explain the perceptual repair of onsets with small sonority distances. Likewise, most items were matched to their quartet members on their rhyme, and consequently, the misperception of items with small sonority-distances as disyllabic cannot be attributed to the repair of ill-formed codas (*lbif* → *lbife*).

We next turned to assess distributional phonological properties of Korean syllables. Korean is known to constrain the distribution within syllables of [l] and [ɾ], the allophones of the abstract phoneme /L/; [l] is typically restricted to codas (the only occurrence of *l* between vowels is in geminates), whereas [ɾ] occurs only in onsets (1–3). If Korean speakers consider coda allophones as markers of syllable boundary and interpret the Russian r-trill as a tap [ɾ], then *l*-initial onsets may be more likely to undergo repair than *r*-initial ones*. The greater misperception of onsets with small sonority distances in our experiments might thus reflect knowledge concerning the distribution of Korean allophones, not universal grammatical principles. To test this possibility, we compared responses to rises (both large and small) and falls including *l* and *r* by means of a 2 (*l*/*r*) × 2 (rise/fall) ANOVA. To protect this comparison from the effect of voicing of the obstruent stop (e.g., *pl* vs. *bl*), we only considered onsets including voiceless stops (which are less likely to trigger repair, and occur in both onsets and codas in Korean). The ANOVA did not yield a reliable interaction in either syllable count [$F2$ (1, 23) = 2.79, MSE = 0.010, P < 0.11 and $F2$ (1, 23) = 3.05, MSE = 29,923, P < 0.10 for accuracy and response time, respectively] or identity judgment [accuracy: $F2$ (1, 23) = 3.15, MSE = 0.037, P < 0.09; response time: $F2$ (1, 23) < 1, MSE = 3,763]. Ill-formed onsets of falling sonority yielded lower accuracy compared with well formed onsets of rising sonority for both *l*- and *r*-initial items (Table S4).

We also examined the possibility that the better performance with large rises is due to a handful of test items with a consonant-glide sequence, a sequence occurring in Korean (but not a true CC syllable onset, as the glide is associated with the following vowel rather than the preceding consonant: see footnote†† in the main text). An ANOVA comparing quartets whose large rise is a familiar consonant-glide sequence to quartets with other large rises (2 familiarity × 4 types) yielded no evidence of an interaction in either syllable judgment (F < 1.1 in accuracy and response time) or identity judgment [accuracy: $F2$ (3, 84) = 1.58, MSE = 0.04, P < 0.21; response time; F2 (3, 84) = 1.66, MSE = 11,408, P < 0.19], and the results with unfamiliar large rises closely followed the omnibus pattern (Table S5).

On yet another explanation, the familiarity with initial consonant-glide combinations could have affected performance indirectly, by prompting Korean speakers to acquire the sonority

*To maintain the position of *l* in the coda, such repair must insert a schwa before the *l* (e.g., *lbif* → *elbif*), rather than after it (e.g., *lbif* → *lebif*). The insertion of a schwa after C1 is expected to increase the misperception of l-initial onsets as disyllabic in syllable judgment, but it is not entirely clear why it would lead to the misperception of CCVC items as identical to their CeCCVC counterparts in identity judgment.

hierarchy from experience with such sequences. There are several reasons to doubt this explanation. First, existing computational simulations have shown that exposure to such clusters alone is insufficient to trigger knowledge of the sonority-hierarchy[†]. Although this simulation did learn sonority-sequencing preferences of the sort demonstrated by our Korean participants given a language containing only consonant-vowel and consonant-glide-vowel words, such learning was possible only when the simulation was equipped with learning bias to use sonority as the basis of well-formedness generalizations. Moreover, the simulated learner did have active knowledge of sonority sequencing; it did not evaluate the well-formedness of nonnative consonant sequences merely by "analogy" to native words. These outcomes are fully in line with our hypothesis. Indeed, we are not citing the reported experiments as evidence that sonority sequencing cannot be learned by Korean speakers, but simply as evidence that these speakers do have this knowledge—not just knowledge of the Korean vocabulary.

Such learning, however, might be particularly challenging given the specific phonological properties of Korean. A generalization from consonant-glide sequences to onset clusters hinges on the representation of such sequences as two consonants. However, the glides in question do not pattern with other Korean consonants; e.g., they escape cooccurrence restrictions that apply to word-medial consonant clusters (4). Rather, they behave like vowels with respect to assimilation (4, 5), cooccurrence restrictions (5), reduplication (4), speech errors (6), and their representation by the orthography (5)—which leads many accounts of Korean to view such glides as member of the syllable's nucleus rather than two-consonant members of the onset. A learner treating consonant-glide sequences as two consonants runs the risk of incorrectly generalizing the properties of consonant-glide sequences to other consonant-sequences. To the extent the interpretation of consonant-glide sequences as two consonants could support any useful inferences regarding the universal sonority hierarchy, such gains might come at the price of a failure to acquire the phonology of Korean altogether.

Finally, we examined the possibility that the effect of repair might reflect experience with syllable contacts—the cooccurrence of consonants across Korean syllables (e.g., [cap.**k**'o], "catches and," where "." represents a syllable boundary). The effects of such experience are difficult to predict. Sequences C_1C_2 familiar from syllable contact might be recognized more accurately. Conversely, C_1C_2 sequences familiar as markers of syllable boundary before C_2 in Korean could encourage postulation in the experiments of a syllable boundary before C_2 by means of epenthetic repair (*pk* → *pe.ka*). Either way, it is important to ensure that the effect of sonority distance is not confounded with familiarity. To this end, we compared responses to sequences attested across syllables (e.g., *p.k*; for discussion, see refs. 7 and 8) to those that are unattested (e.g., *b.d*; see Table S6). Because Korean has no obstruent-sonorant sequences in syllable contact (i.e., sequences with rising sonority), our analysis was limited to onsets with plateaus and falls. A 2 (attested vs. unattested clusters) × 2 (plateaus vs. falls) ANOVA yielded a significant interaction in both syllable judgment [accuracy: $F2\ (1, 56) = 8.55$, MSE = 0.015, $P < 0.006$; response time: $F2\ (1, 56) < 1$, MSE = 24,255] and identity judgment [accuracy: $F2\ (1, 56) = 8.54$, MSE = 0.035, $P < 0.006$; response time: $F2\ (1, 56) = 8.77$, MSE = 14,689, $P < 0.005$]. Although familiar sequences were processed more accurately, familiarity does not explain the effect of sonority distance. Specifically, syllable judgment yielded higher accuracy for sonority plateaus relative to sonority falls whether or not the sequences were familiar. Likewise, identity judgment yielded faster and more accurate responses to sonority plateaus even when the sequences of level rising vs. falling sonority were both attested [accuracy: $F2\ (1, 29) = 8.18$, $P < 0.08$; response time: $F2\ (1, 29) = 13.70$, $P < 0.001$; a small reverse effect for unattested items was not significant, $F < 1.3$ in accuracy and response time]. The Materials are listed in Table S7.

In conclusion, these analyses lend no support to the attribution of sonority-distance effects to the specific phonetic and phonological properties of Korean nor to second languages spoken by our Korean participants.

[†]Hayes B, 38th Meeting of the North East Linguistic Society, October 26–28, 2007, Ottawa, ON, Canada.

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Table S1. Self-reports (no.) of second language proficiency

Second language	Proficiency			
	A few words	Hearing only	Hearing and speaking only	Fully comfortable
English	31	34	5	0
Chinese	18	1	1	1
French	4	0	0	0
Japanese	8	1	0	0

Numbers indicate the number of participants at given proficiency level. These levels were ″I only speak a few words″; ″I am only comfortable hearing the language″; ″I am comfortable with both hearing and speaking the language″; ″I am fully comfortable hearing, speaking and writing in the language″.

Table S2. The effect of onset cluster type for early vs. late learners of English

Sonority profile	Syllable judgment		Identity judgment	
	Accuracy	Response time, ms	Accuracy	Response time, ms
Early English acquisition				
Large rises	0.72	1,222	0.73	1,090
Small rises	0.66	1,323	0.68	1,078
Plateaus	0.64	1,359	0.51	1,127
Falls	0.50	1,381	0.39	1,231
Late English acquisition				
Large rises	0.70	1,288	0.66	1,045
Small rises	0.68	1,335	0.62	1,054
Plateaus	0.59	1,355	0.40	1,109
Falls	0.47	1,404	0.28	1,232

Table S3. The mean duration and mean intensity of the release burst in stop-initial items

Item	Duration, ms	Intensity, dB
Large rise	10.11	60.49
Small rise	9.58	59.07
Plateau	10.28	62.04

Table S4. Mean response accuracy and response time (ms) to onsets of rising and falling sonority including *l* vs. *r* sonorants

	Syllable judgment (one syllable)				Identity judgment (nonidentity trials)			
	Accuracy		Response time, ms		Accuracy		Response time, ms	
Sonority profile	*l* onsets	*r* onsets	*l* onsets	*r* onsets	*l* onsets	*r* onsets	*l* onsets	*r* onsets
Rises	0.76	0.70	1,393	1,258	0.85	0.83	1,017	1,051
Falls	0.56	0.37	1,379	1,488	0.56	0.27	1,193	1,268

Table S5. Mean response accuracy and response time (ms) to quartets whose large-rise member has a familiar consonant-glide cluster relative to unfamiliar clusters

	Syllable judgment (one syllable)				Identity judgment (nonidentity trials)			
	Accuracy		Response time, ms		Accuracy		Response time, ms	
Onset type	Familiar	Unfamiliar	Familiar	Unfamiliar	Familiar	Unfamiliar	Familiar	Unfamiliar
Large rise	0.69	0.72	1,152	1,272	0.62	0.70	1,088	1,106
Small rise	0.66	0.67	1,339	1,313	0.66	0.62	1,049	1,091
Plateau	0.60	0.63	1,330	1,373	0.45	0.41	1,095	1,213
Fall	0.49	0.49	1,452	1,424	0.20	0.37	1,247	1,231

Table S6. Mean response time and response accuracy to consonant sequences with sonority plateaus or falling sonority that are either attested (existent) or unattested (nonexistent) across syllables in Korean

	Syllable judgment (one syllable)				Identity judgment (nonidentity trials)			
	Accuracy		Response time, ms		Accuracy		Response time, ms	
Sonority profile	Unattested	Attested	Unattested	Attested	Unattested	Attested	Unattested	Attested
Plateau	0.63	0.61	1,398	1,333	0.22	0.58	1,289	1,097
Fall	0.41	0.58	1,445	1,416	0.29	0.36	1,236	1,231

Table S7. Materials used in Experiments 1 and 2.

Large rise	Small rise	Plateau	Fall
blif	bwif	bdif	lbif
brɑp	bnɑp	bdɑp	rgɑp
klim	knim	kpim	lpim
krɛk	knɛk	ktɛg	rtɛk
drif	dlif	dbif	rdif
drɑf	dlɑf	dgɑf	rdɑf
dwip	dmip	dgip	mdip
dwʊp	dmʊp	dgʊp	mdʊp
drʊp	dnʊp	dbʊp	rdʊp
driʃ	dniʃ	dgiʃ	rbiʃ
glɛp	gmɛp	gdɛp	lgɛp
glɑn	gmɑn	gbɑn	lfɑn
grɛf	gmɛf	gbɛf	rgɛf
gwit	gmit	gbit	mgit
klɛf	kmɛf	ktɛf	lkɛf
kræf	kmæf	kpæf	rgæf
krik	knik	ktig	rkik
kwʊg	knʊk	kpɑk	mkʊk
klɑp	kmʊp	ktɑp	ltɑp
krɛp	kmɛp	ktɛp	rkɛp
plik	pnik	pkik	ltik
præf	pnæf	ptæf	rpæf
trʊf	tlʊf	tkʊf	rtʊf
twɛp	tlɛp	tkɛp	mtɛp
trɑk	tnɑk	tkɑk	rtɑk
twæf	tmæf	tpæf	mtæf
trɛf	tnɛf	tpif	rtɛf
twʊk	tnʊk	tgʊk	mgʊk
træp	tmæp	tpæp	rpæp
twɑg	tmɑk	tpɑk	mtɑk