The Role of Abstraction in Constructing Phonological Structure

Yongeun Lee (yelee@cau.ac.kr)
Department of English Language and Literature, Chung-Ang University, 221 Heukseok-Dong
Dongjak-Gu, Seoul KOREA

Matthew Goldrick (matt-goldrick@northwestern.edu)
Department of Linguistics, Northwestern University, 2016 Sheridan Rd.
Evanston, IL 60208 USA

Abstract

In many languages, speakers group together certain segments within a syllable to form subsyllabic constituents. We propose that learners construct these representational structures; they postulate constituents to account for patterns that cannot be attributed to other properties of the linguistic system. To support this perspective, we first review data from English and Korean showing (a) these languages contain robust statistical cues to subsyllabic constituents and (b) speakers are sensitive to these cues (Lee & Goldrick, 2008). We then present new analyses of the Korean lexicon suggesting that when inferring subsyllabic constituents learners abstract away from general phonological alternations (specifically, coda neutralization).

Keywords: subsyllabic structure; acquisition; rime; body; neutralization; English; Korean; speech errors

The Origins of Subsyllabic Structure

Syllables play a critical role in many domains of language processing, including speech perception (Álvarez, Carreiras, & Perea, 2004), production (Cholin, Levelt, & Schiller, 2006; Laganaro & Alario, 2006) and short-term memory (Nimmo & Roodenrys, 2002). In this work, we focus on the internal structure of syllabic units.

We review evidence that subsyllabic structure varies cross-linguistically. English and other Indo-European languages group together vowels and codas into a unit ('rime') distinct from the onset (Kessler & Treiman, 1997). For example, the English syllable for 'cat' /kæt/ is argued to be composed of onset /k/ and rime /æt/. In contrast, Korean (Yoon & Derwing, 2001) and Japanese (Katada, 1990) group onsets and vowels into a unit ('body') distinct from the coda (such that the Korean syllable for 'feather' /kis/ is decomposed as body /ki/ vs. coda /s/).

In this work, we argue that speakers construct these structures to account for associations between segments that are not attributable to other, more general, phonological patterns. We first review research showing that in both Korean and English the distribution of segments provides robust statistical cues to their contrasting subsyllabic structures; furthermore, speakers are sensitive to these statistical cues (Lee & Goldrick, 2008). We then present an analysis of a new, larger lexicon of Korean. This shows that robust cues to subsyllabic structure are not found when considering representations that incorporate the influence of more general phonological patterns. This is consistent with the claim that learners postulate subsyllabic structures only after correcting for other potential sources of phonological patterns.

Crosslinguistic Variation in Subsyllabic Structure

A variety of types of behavioral data suggest that subsyllabic structures differ across languages. We focus on two prominent subtypes involving alternate groupings of the nucleus and margin positions: onset-rime (dividing a CVC syllable into C-VC) vs. body-coda (CV-C).

Subsyllabic Structure in Indo-European Languages

Indo-European languages—specifically, both Germanic (Dutch, English, German) and Romance (French)—have been argued to group together the nucleus and coda into a unit (rime) to the exclusion of the onset. The presence of this rime unit has been used to account for the greater prevalence of phonotactic restrictions governing vowel-coda vs. onset-vowel sequences (e.g., Dutch: Martensen, Maris, & Dijkstra, 2000; English: Kessler & Treiman, 1997; French: Perruchet & Peereman, 2004). In metalinguistic tasks, English speakers judge syllables sharing the vowel and coda (but not onset) to be more similar than syllables sharing the onset and vowel (but not coda; Yoon & Derwing, 1994). Finally, spontaneously occurring speech errors (e.g., MacKay, 1972) as well as those produced in short-term memory tasks (e.g., Treiman & Danis, 1988) are more likely to involve the simultaneous misordering of the vowel and coda (i.e., the rime unit) vs. the onset and vowel.

Subsyllabic Structure in Korean and Japanese

Similar evidence has been used to argue that Korean and Japanese have a different subsyllabic structure, grouping the vowel and onset together to the exclusion of the coda. With respect to metalinguistic tasks, Katada (1990) documents a Japanese language game that involves reuse of onset-vowel sequences, excluding any following codas. Yoon & Derwing (2001) show that in contrast to the English pattern discussed above Korean speakers judge syllables sharing the onset and vowel (but not coda) to be more similar than those sharing only the vowel and coda. Kureta, Fushimi, & Tastumi (2006) find that Japanese speakers use onset-vowel sequences to prepare responses in an implicit priming paradigm (in contrast, Dutch speakers can rely on singleton

onsets; Meyer, 1991). As discussed in more detail below, Korean speech errors are more likely to involve simultaneous misorderings of onsets and vowels than vowels and codas (Lee & Goldrick, 2008).

Sensitivity to Contrasting Subsyllabic Patterns

Building on our previous work (Lee & Goldrick, 2008), we propose that speakers postulate subsyllabic structures to account for associations between segments that are not attributable to other, more general, phonological patterns. This learning mechanism can account for the contrasting subsyllabic structures of English and Korean. There are not only significant differences in the statistical patterns of English and Korean; learners are sensitive to these statistical patterns. We claim that this sensitivity is what leads these speakers to acquire distinct subsyllabic structures.

Contrasting Subsyllabic Patterns

To document the contrasting structure of English and Korean, Lee & Goldrick (2008) examined the type frequency distributions of segments in consonant-vowel-consonant (CVC) forms. Subsyllabic patterns were indexed by $r\phi$ (Pearson's r for dichotomous data; Perruchet & Peereman, 2004). This provides an index of the degree to which the presence vs. absence of one segment across lexical items is correlated with the presence vs. absence of another. As shown in Figure 1, we replicated previous findings for English (Kessler & Treiman, 1997); vowel-coda (VC) sequences are significantly more strongly associated than onset-vowel (CV) sequences. Korean shows the complementary pattern—providing a statistical basis for their contrasting subsyllabic structures.

Note that Berg & Koops (2010) failed to find a significant difference in CV vs. VC dependencies in Korean forms. This likely reflects a lack of power; they applied a large series of weak, non-parametric tests of association to each CV and VC sequence independently.

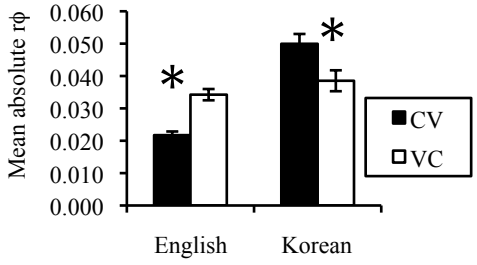

Figure 1: Subsyllabic patterns in English and Korean underlying forms. Error bars = standard error.

Sensitivity to Subsyllabic Patterns

Speech errors show that English and Korean speakers are sensitive to these subsyllabic patterns. Lee & Goldrick (2008) induced speech errors using a short-term memory task. The to-be-remembered materials were CVC syllables where the association strength of the onset-vowel and vowel-coda were varied. As shown in Figure 2, when one of these subsyllabic sequences was more strongly associated than the other, participants' errors tended to simultaneously misorder the more vs. less strongly associated sequence. However, when the two sequences were equated in association strength, speakers relied on the overall patterns of their languages—revealing sensitivity to subsyllabic structure.

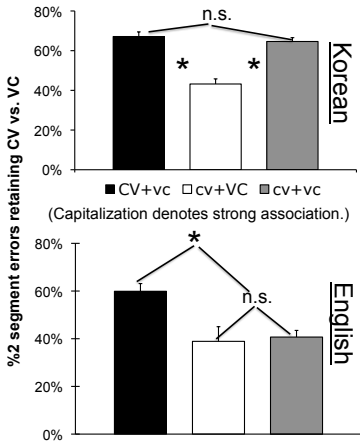

Figure 2. Proportion of speech errors involving simultaneous misordering of onset and vowel (CV) vs. vowel and coda (VC). Stimuli had strongly associated onset and vowel (CV+vc), strongly associated vowel and coda (cv+VC) or equal, weak association between onset-vowel vs. vowel-coda (cv+vc). Error bars = standard error.

These results show that speakers are sensitive not only to the association of specific consonants and vowels but also the more general patterns of association in their language. Speakers clearly can access the necessary statistics; this allows them to acquire the contrasting subsyllabic structures of English and Korean.

The Nature of Subsyllabic Patterns

What motivates the language processing system to construct subsyllabic structures? We claim that it is driven by the need to account for the otherwise unexplained patterns of association between particular segments (as shown in Figure 1). Critical to this claim is that such patterns be *unexplained*; that is, they are not attributable to other sources of phonological patterns. To examine this more closely, we examined how these subsyllabic patterns interact with other phonological patterns in Korean.

Neutralization

Across languages, the same morpheme can appear with different sounds depending on the context in which that morpheme is spoken. For example, the plural morpheme in English can be [s] (*cats*) vs. [z] (*dogs*) vs. [ɪz] (*buses*). In cases of *neutralization*, morphemes that have contrasting sounds in one context have the same sound in another. For example, English distinguishes [t] and [d] word finally (e.g.,

bet vs. *bed*); this contrast disappears almost entirely in intervocalic, post-stress position (e.g., *betting* vs. *bedding*).

In generative phonology (Chomsky & Halle, 1968), such patterns are accounted for by assuming at some abstract level (e.g., 'underlyingly' in the lexicon), the distinction between these two sounds is present; it is then eliminated by phonological "processes" (e.g., the phonological grammar).

Neutralization in Korean Korean has extensive neutralization in syllable-final (coda) position (Kim & Jongman, 1996). The three way distinction between lax (lightly aspirated) /p/, heavily aspirated /pʰ/ and reinforced (ejective glottalized) consonants /p'/ is eliminated in coda position (all are produced as unreleased lax in coda). For example, 'straw' and 'house' are homophones in citation form [tʃip]. In nominative case, however, the consonants that appear finally in the citation form are produced with distinct forms ('straw': [tʃipʰi]; 'house': [tʃibi]). Additionally, fricatives (/s, s',h/) and palatals /tʃ, tʃʰ/ are neutralized to [t] in coda.

In Lee & Goldrick (2008), we examined statistical patterns found in the abstract, lexical form of CVC words. These encode as distinct segments that are neutralized in citation forms. Are the same robust statistical cues found when we consider surface forms—which necessarily include the influence of the general neutralization pattern?

Patterns in Abstract vs. Surface Forms

Method

A new corpus of CVC Korean words was developed by extracting forms from an online dictionary (http://krdic.naver.com). Dialect-specific and North Korean words, surnames, abbreviations, archaic words, and bound morphemes were excluded. Including homophones as distinct lexical items yielded a total of 2,101 word types. For this analysis, we excluded words with glide onsets due to disagreement regarding their association to the onset vs. nucleus of syllables (Kang, 2003; Lee, 1994). The coda neutralization processes discussed above were applied across-the-board to each underlying form to generate surface forms.

A Monte Carlo permutation test was used to assess the reliability of differences in association strength. The distribution of differences expected to occur by chance was estimated by repeated, random re-shufflings of the observed $r\phi$ values into two groups. For example, for onset-vowel vs. vowel-coda, the $r\phi$ values for the two types of sequences were collapsed and randomly divided into two groups (equal in size to the observed sets). The difference in mean $r\phi$ values for these two random groups was then calculated. This process was repeated 10,000 times to estimate the chance distribution of $r\phi$ differences between two groups. The location of the observed difference in this distribution provides an estimate of the probability it occurred by chance.

Results

As shown in Figure 3, the results for abstract, underlying forms match those of Lee & Goldrick (2008). Onset-vowel sequences are more strongly associated than vowel-coda sequences ($p < .03$). In contrast, the surface forms do not contain robust cues to subsyllabic structure. There was no significant difference between the association strength of onset-vowel vs. vowel-coda sequences ($p > .30$). This was due to a significant increase in the association strength of VC forms in surface vs. underlying forms ($p < .02$).

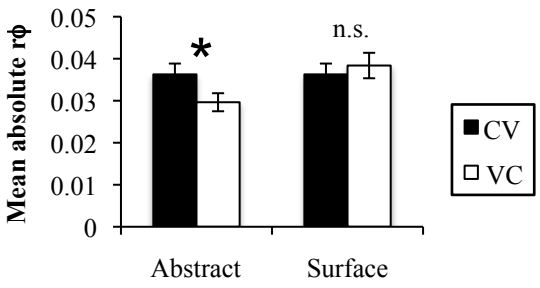

Figure 3. Subsyllabic patterns for Korean abstract and surface forms. Error bars = standard error.

VC Associations in Abstract vs. Surface Forms

The increase in association strength for VC forms reflects the elimination of weakly associated VC sequences. Abstract VC sequences where the final consonant was not found in surface citations forms (e.g., /s/) had a mean absolute $r\phi$ of 0.021, compared to 0.040 for sequences where the final consonant does appear in surface forms (e.g., /t/). It is unclear what gives rise to this difference. It is possible that weak association triggers neutralization processes. Alternatively, it may be that since neutralized sequences are not present in surface forms they are not subject to articulatory or perceptual constraints that give rise to dependencies between consonants and vowels. Future research will be required to address these possibilities.

Discussion

We have argued that speakers possess the means, opportunity and motive to construct varying subsyllabic structures across languages. The results of Lee & Goldrick (2008) show that speakers have the means; they are sensitive to subsyllabic association patterns. Our lexical analyses show that such association patterns provide speakers with the opportunity to acquire distinct subsyllabic structures. Our current analyses of abstract vs. surface forms suggest that speakers' motivation for constructing such structures lies in accounting for patterns of association that cannot be attributed to other phonological patterns.

Future work should examine the novel predictions of this framework for other languages. Our approach predicts that if the linguistic environment fails to provide the opportunity, speakers will fail to construct subsyllabic constituents. Grimes (2010) provides evidence consistent

with this prediction. Hungarian fails to show strong asymmetries in the association of onset-vowel and vowel-coda sequences. Consistent with a lack of subsyllabic constituent structure, Grimes argues that Hungarian exhibits neither body- nor rime-based phonotactic patterns.

The finding that speakers rely on abstract representations to acquire subsyllabic structure is consistent with other results from the phonotactic processing literature. Abstract underlying representations are typically assumed to be stored in the lexicon. Other research suggests that other types of probabilistic phonotactic constraints are associated with properties of lexical representations. Specifically, probabilistic phonotactic patterns have been argued to reflect type, not token, frequency of phonological structures (Buchwald, 2005; Pierrehumbert, 2003). This suggests that many phonological patterns may be intimately connected to abstract, lexical phonological representations.

More broadly, research such as this suggest that the learners' construction of linguistic structure critically relies on generalizations at multiple levels of abstraction (Pierrehumbert, 2006)—not simply the 'surface' distributional properties of linguistic forms.

Acknowledgments

This research was supported in part by National Science Foundation Grant BCS-0846147 to MG. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We thank the Phonatics Discussion Group at Northwestern University for helpful comments.

References

Álvarez, C. J., Carreiras, M., & Perea, M. (2004). Are syllables phonological units in visual word recognition? *Language and Cognitive Processes*, *19*, 427-52.

Berg, T., & Koops, C. (2010). The interplay of left- and right-branching effects: A phonotactic analysis of Korean syllable structure. *Lingua*, *120*, 35-49.

Buchwald, A. (2005). *Representation, repair, and well-formedness: Grammar in spoken language production*. Unpublished doctoral dissertation, Johns Hopkins University, Baltimore, MD.

Cholin, J., Levelt, W. J. M., & Schiller, N. O. (2006). Effects of syllable frequency in speech production. *Cognition*, *99*, 205-235.

Chomsky, N., & Halle, M. (1968). *The sound pattern of English*. New York: Harper & Row.

Grimes, S. M. (2010). *Quantitative investigations of Hungarian phonotactics and syllable structure*. Unpublished doctoral dissertation, Indiana University, Bloomington, IN.

Kang, K. (2003). The status of onglides in Korean: Evidence from speech errors. *Studies in Phonetics, Phonology, and Morphology*, *9*, 1-15.

Katada, F. (1990). On the representation of moras: Evidence from a language game. *Linguistic Inquiry*, *21*, 641-646.

Kessler, B., & Treiman, R. (1997). Syllable structure and the distribution of phonemes in English syllables. *Journal of Memory and Language*, *37*, 295-311.

Kim, H., & Jongmann, A. (1996). Acoustic and perceptual evidence for complete neutralization of manner of articulation in Korean. *Journal of Phonetics*, *24*, 295-312.

Kureta, Y., Fushimi, T., & Tatsumi, I. F. (2006). The functional unit in phonological encoding: Evidence for moraic representation in native Japanese speakers. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 1102-1119.

Laganaro, M., & Alario, F.-X. (2006). On the locus of the syllable frequency effect in language production. *Journal of Memory and Language*, *55*, 178-196.

Lee, Y. (1994). Onset analysis of Korean on-glides. In Y. K. Kim-Renaud (Ed.), *Theoretical issues in Korean linguistics*.

Lee, Y., & Goldrick, M. (2008). The emergence of sub-syllabic representations. *Journal of Memory and Language*, *59*, 155-168.

MacKay, D. G. (1972). The structure of words and syllables: Evidence from errors in speech. *Cognitive Psychology*, *3*, 210-227.

Martensen, H.E., Maris, E., & Dijkstra, A.F.J. (2000). When does inconsistency hurt? On the relation between phonological consistency effects and the reliability of sublexical units. *Memory and Cognition*, *28*, 648-656.

Meyer, A. S. (1991). The time course of phonological encoding in language production: Phonological encoding inside a syllable. *Journal of Memory and Language*, *30*, 69–89.

Nimmo, L., & Roodenrys, S. (2002). Syllable frequency effects on phonological short-term memory tasks. *Applied Psycholinguistics*, *23*, 643-659.

Perruchet, P., & Peereman, R. (2004). The exploitation of distributional information in syllable processing. *Journal of Neurolinguistics*, *17*, 97-119.

Pierrehumbert, J. B. (2003). Probabilistic phonology: Discrimination and robustness. In R. Bod, J. Hay and S. Jannedy (Eds.) *Probability theory in linguistics*. Cambridge, MA: MIT Press.

Pierrehumbert, J. B. (2006). The next toolkit. *Journal of Phonetics*, *34*, 516-530.

Treiman, R., & Danis, C. (1988). Short-term memory errors for spoken syllables are affected by the linguistic structure of the syllables. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*, 145–152.

Yoon, Y. B., & Derwing, B. (1994). Sound similarity judgments for Korean words by Korean and English speakers. In P. Koskinen (Ed.), *Proceedings of the 1994 Annual Conference of the Canadian Linguistic Association*. Toronto: Linguistic Graduate Course Union.

Yoon, Y. B., & Derwing, B. (2001). A language without a rhyme: Syllable structure experiments in Korean. *Canadian Journal of Linguistics*, *46*, 187-237.