An onset is an onset: Evidence from abstraction of newly-learned phonotactic constraints

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ABSTRACT

Phonotactic constraints are language-specific patterns in the sequencing of speech sounds. Are these constraints represented at the syllable level (*ng* cannot begin syllables in English) or at the word level (*ng* cannot begin words)? In a continuous recognition-memory task, participants more often falsely recognized novel test items that followed than violated the training constraints, whether training and test items matched in word structure (one or two syllables) or position of restricted consonants (word-edge or word-medial position). E.g., learning that *p*s are onsets and *f*s codas, participants generalized from **p**e**f** (one syllable) to **p**utvi**f** (two syllables), and from **p**utvi**f** (word-edge positions) to bu**f**pak (word-medial positions). These results suggest that newly-learned phonotactic constraints are represented at the syllable level. The syllable is a representational unit available and spontaneously used when learning speech-sound constraints. In the current experiments, an onset is an onset and a coda a coda, regardless of word structure or word position.

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Introduction

Languages vary in the sound sequences they allow (phonotactics) and language users make use of this information; phonotactic knowledge affects online speech processing and facilitates word learning (e.g., McQueen, 1998; Storkel, 2001). For instance, when learning labels for new objects, even 12-month-old English-learning infants preferentially accept word forms that are phonotactically legal in English (e.g., **pl**ok) over those that are phonotactically illegal (e.g., **pt**ak; MacKenzie, Curtin, & Graham, 2012). Thus, constraints are learned early. But what is the linguistic unit over which these phonotactic constraints are represented? Is *plok* a better label because *pl* starts other words of similar structure (i.e., one-syllable words such as **pl**um), because *pl* starts other words of varied structures (e.g., words such as **pl**um, **pl**enty, **pl**asticine), or because *pl*

starts other syllables regardless of their position in the word (e.g., **pl**um, com**pl**ain, du**pl**icate)? The representations underlying phonotactic learning will have consequences for later generalization. For example, if what matters is the position within the word, then learning at a word edge (as in **pl**enty) should not generalize to word medial positions (as in com**pl**ain). If what matters is position within a syllable, then learning at word edge should transfer to word medial positions as long as position in the syllable (e.g., syllable initial) remains the same (e.g., **pl**enty and com**pl**ain but not di**pl**omat, where *pl* crosses a syllable boundary).

Just as listeners have access to multiple structural units during speech perception (e.g., phoneme, syllable; Goldinger & Azuma, 2003), it may be that listeners also have access to multiple structural units for representing phonotactic knowledge. Listeners may represent and generalize phonotactic patterns at the level of the syllable, where a syllable can be thought of as having initial (onset) and final (coda) positions. Thus, a constraint such as '*f* is an onset' would be represented as a generalizable fact about

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syllables (i.e., *f* can start syllables) regardless of the word position and independent of the structure of the word (e.g., word-initial constraints, such as '*f* is an onset' in **f**action, should readily generalize to word-medial position, as in con**f**er, as long as syllable position is maintained). Alternatively, phonotactic patterns may be represented at the level of words (e.g., Steriade, 1999). If so, a constraint such as '*f* is word-initial' would be represented as a generalizable fact about words (i.e., *f* can start words), and may not generalize to other word positions (e.g., the pattern learned from **f**action provides no direct information about con**f**er), though it might generalize to other word structures as long as word position was maintained (e.g., **f**og, **f**urniture).

For phonotactic constraints to be represented at the level of the syllable, the syllable must be a structural unit available to the learner. The following sections review (1) evidence in support of the syllable as a unit of representation, (2) evidence suggesting the need for other units of representation, and (3) evidence suggesting words as one possible alternative unit of representation, then present the current experiments in which generalization of newly-learned phonotactic constraints was used to explore whether underlying representations seem to be syllable-based, word-based, or seem to depend on both levels.

Evidence in support of the syllable as a unit of representation

Several lines of work support the view that syllables are useful units of representation. First, syllable-level representation of phonotactics would be in accord with linguistic accounts that aim to describe the possible words of a language as legal combinations of the possible syllables of that language, thus treating syllables as one of the structural units of sound patterns (see Goldsmith, 2011, for a review). Indeed, although restrictions on the consonant clusters that can occur in word-final and word-initial positions are often redundant with restrictions on the consonants that can cross within-word syllable boundaries, syllable-level representations carry more information. For instance, knowing *pk* cannot end and *km* cannot start a *syllable* tells us that *pkm* cannot occur crossing a syllable boundary within a word (e.g., neither *pupk.min*, with a syllable boundary after the *k*, nor *pup.kmin*, with a syllable boundary before the *k*, would be permissible; e.g., Ewen & van der Hulst, 2001), and it also tells us that neither *pupk* (with word final *pk*) nor *kmin* (with word-initial *km*) would be possible words. In contrast, knowing that *pk* cannot end and *km* cannot start *words* provides no information about whether the sequence *pkm* can occur at a syllable boundary that is not at word edge (i.e., crossing a syllable boundary within a word), and accounting for this fact would require an additional word-level restriction (e.g., *pkm* cannot occur within words). Syllable-rather than word-level representation would thus be more parsimonious.

Second, the syllable seems to be a unit available to language users; naturally occurring language games (e.g., Ubby Dubby in English, in which *ub* is added before each vowel; Patel & Patterson, 1982) and other linguistic phenomena (e.g., reduplication) apply at the level of the syllable (e.g., Blevins, 1995). Further indirect evidence for the syllable as a structural unit arises from experiments with multisyllabic words. For instance, when three-syllable nonwords were presented dichotically, participants erroneously reported hearing words that resulted from the movement of a whole syllable more often than words that resulted from the movement of only parts of syllables such as the vowel (e.g., Mattys & Melhorn, 2005).

Third, adult language users have been shown to be sensitive to syllable structure. In a speeded production task, they were faster to repeat a two-syllable word when its first syllable shared the structure of the one-syllable word that preceded it (e.g., participants were faster to repeat *til.-fer* when it followed *tem* than when it followed *temp*; Sevald, Dell, & Cole, 1995). Thus, several pieces of evidence suggest that the syllable is a unit readily used when learning about and processing speech sounds.

Evidence suggesting the need for other units of representation

However, there is also evidence which suggests that syllable-based representations may not be sufficient or even required for phonotactic learning, and which points to the utility of alternative units of representation. First, speakers may not use syllables when identifying words (Cutler, Mehler, Norris, & Segui, 1986), and when asked to divide words into syllables, speakers are not necessarily consistent with one another (e.g., Treiman & Zukowski, 1990). Moreover, speakers' syllable divisions do not always agree with the divisions suggested by phonotactic patterns; for example, although most would agree that *melon* contains 2 syllables, there is disagreement as to whether the syllabification is *me.lon*, *mel.on,* or *mel.lon* (e.g., Treiman & Danis, 1988). These issues raise questions about the usefulness of syllables as representational units (e.g., Treiman & Danis, 1988; Treiman & Zukowski, 1990).

Second, natural-language phonotactics cannot be fully characterized at the level of the syllable; the description of some naturally-occurring phonotactic constraints seems to require reference to morphemes and word boundaries, or to sequences that cross syllable boundaries. For example, Korean restricts consonant contact across syllable boundaries and native listeners are sensitive to these constraints, which cannot be reduced to restrictions on syllable codas and onsets (e.g., Kabak & Idsardi, 2007), implying a structural unit other than the syllable. If phonotactic constraints were solely represented at the level of the syllable, no information should be available regarding permissible consonant sequences across syllable boundaries, yet speakers show sensitivity to word-internal, cross-syllable information (e.g., Hay, Pierrehumbert, & Beckman, 2004; Mattys, Jusczyk, Luce, & Morgan, 1999; Richtsmeier, Gerken, & Ohala, 2009). For example, after being familiarized with two-syllable nonwords containing adjacent consonants that in English, were more (e.g., *k.t* in *bok.tem*) or less frequent (e.g., *p.k* in *bop.kem*) across the internal syllable boundary, children were more accurate at repeating words containing the frequent than the infrequent clusters (Richtsmeier et al., 2009).

Third, novel sound-sequence learning cannot always be easily explained using syllable-level representations alone. For instance, English-speaking adults can learn a