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Speech errors reflect the phonotactic constraints in recently spoken syllables, but not in recently heard syllables

Jill A. Warker *, Ye Xu, Gary S. Dell, Cynthia Fisher

Beckman Institute, University of Illinois, 405 N. Mathews Ave., Urbana, IL 61801, United States

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ABSTRACT

Adults rapidly learn phonotactic constraints from brief production or perception experience. Three experiments asked whether this learning is modality-specific, occurring separately in production and perception, or whether perception transfers to production. Participant pairs took turns repeating syllables in which particular consonants were restricted to particular syllable positions. Speakers' errors reflected learning of the constraints present in the sequences they produced, regardless of whether their partner produced syllables with the same constraints, or opposing constraints. Although partial transfer could be induced (Experiment 3), simply hearing and encoding syllables produced by others did not affect speech production to the extent that error patterns were altered. Learning of new phonotactic constraints was predominantly restricted to the modality in which those constraints were experienced.

1. Introduction

When native English speakers hear the word "ngungseh" (/ŋʌŋsɛ/), they immediately suspect that it is foreign. The word violates the phonotactic constraint in English that /ŋ/ only appears in syllable-final (coda) position. Phonotactic constraints like this one are language-specific. In fact, the example given above is a word in Cantonese, which permits /ŋ/ in syllable-initial (onset) position.

How do we learn language-specific phonotactic constraints? Obviously, we learn from experience. But linguistic experience with word forms comes from two sources, what we hear (perception) and what we say (production). The experiments presented in this paper investigate the roles that perception and production play in constructing phonotactic knowledge, and their potential interactions with one another during that construction.

Sensitivity to phonotactics begins early in life. Infants as young as 9 months old discriminate between sound sequences that are legal or illegal in their native language (e.g., Jusczyk, Friederici, Wessels, & Svenkerud, 1993). Among legal sound sequences, they discriminate between those that are of high and low phonotactic probability (Jusczyk, Luce, & Charles-Luce, 1994). The influence of this knowledge is felt throughout life in both perception (e.g., Dupoux, Kakehi, Hirose, Pallier, & Mehler, 1999; Massaro & Cohen, 1983; McQueen, 1998; Redford, 2008) and production (e.g., Fromkin, 1971; Redford, 2008). In this paper, we will be particularly concerned with the expression of phonotactic knowledge in production performance, and specifically with how phonotactics shape speech errors.

Although phonotactic learning begins early in life, recent evidence suggests that the resulting knowledge is far from static in adulthood. It is the guiding hypothesis of the present research that although adults already possess rich phonotactic knowledge, they can still learn new phonotactic-like constraints from ongoing experience. Dell, Reed, Adams, and Meyer (2000) provided the first demonstration of adults' learning of new consonant-position constraints by requiring participants to produce many syllables exhibiting those constraints. The participants recited sequences of four consonant-vowel-consonant (CVC) syllables, such as "kes feng heg men". The critical

* Corresponding author.
E-mail addresses: warker@uiuc.edu, warker@cyrus.psych.uiuc.edu (J.A. Warker).

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manipulation involved the artificial restriction of particular consonants to particular syllable positions. For example, half of the participants experienced /f/ always as an onset and /s/ always as a coda, and half experienced the reverse assignment. As a result, the syllables to be recited reflected multiple levels of constraints on consonant positions: /h/ and /ŋ/ were restricted by *language-wide constraints*. As required by English phonotactics, /h/ only appeared in onset position, and /ŋ/ only appeared in coda position. /f/ and /s/ were subject to the artificially-imposed *experiment-wide constraint*. The other consonants (/k/, /g/, /m/, /n/) were *unrestricted* and appeared in both onset and coda positions. Learning was measured by whether the experiment-wide constraint pattern emerged in participants' speech errors over the course of four testing sessions, each session occurring on a separate day. The unrestricted consonants served as a baseline for comparison with the consonants subject to the experiment-wide constraints.

Participants' speech errors in this task reflected the constraints present in the materials. Errors involving /h/ and /ŋ/ never violated the language-wide constraints. That is, even in errors, /h/ only surfaced as an onset and /ŋ/ only as a coda. The key results concerned the consonants subject to the experiment-wide constraints: Errors involving the constrained consonants (/f/ and /s/) were overwhelmingly likely to be "legal" errors, which means that, when these consonants slipped to a new syllable, they preserved their original status as an onset or a coda (98% and 95% legal in Experiments 1 and 2, respectively). These percentages were much larger than their respective unrestricted baselines (68% and 77% legal). This suggests that participants implicitly picked up the experiment-wide constraint from reciting the syllables and that this learning caused the experimentally restricted consonants to preserve their syllabic position to a greater extent than the unrestricted consonants.

The new consonant-position constraints were learned very rapidly. Even though participants had four sessions of training, Dell et al. (2000) found evidence of learning in the first session. The time course of learning consonant-position constraints was probed in more detail by Taylor and Houghton (2005). They revised the procedure of Dell et al. by introducing a reversal of the consonant position constraint in the middle of the experiment (e.g., */f/ always an onset, /s/ always a coda* switched to */s/ always an onset, /f/ always a coda*). Participants' speech errors reflected this new constraint within 9 trials, further supporting the rapid learning of constraints that depend only on consonant position within a syllable. Goldrick (2004) further modified the materials so that constraints defined at the level of the segment (*/f/ is always an onset*) and constraints defined at the level of phonetic features (*the feature "bilabial" can occur in the coda*) were simultaneously present, and found speech errors to be sensitive to both kinds of constraints. Other studies using this paradigm have demonstrated the learning of probabilistic (Goldrick & Larson, 2008) and context-dependent (Warker & Dell, 2006; Warker, Dell, Whalen, & Gereg, 2008) constraints on consonant position.

Another indispensable source of phonotactic information comes from perception experience. Listening to others speak is the first step in learning a language. Information about the organization of the sound patterns in a language is certainly available to perceivers, but is listening experience alone enough for learning phonotactic constraints? Onishi, Chambers, and Fisher (2002) found that it was. They instructed adult participants first simply to listen to a set of CVC syllables, in which one group of consonants was restricted to onset position (e.g., /b/, /k/, /m/, /t/) and another group of consonants was restricted to coda position (e.g., /p/, /g/, /n/, /č/). During a subsequent test phase, the participants shadowed (repeated immediately upon hearing) both studied and unstudied syllables. Each unstudied syllable was legal or illegal, depending on the consonant-position constraints present in the familiarization materials. Shadowing latencies were shorter for legal than for illegal syllables, suggesting that the participants learned the new phonotactic constraints and applied them to new syllables in the test. Since the participants only experienced the constraints in the familiarization materials, they must have learned the experimental constraints from listening experience.

Infants can also learn new phonotactic constraints from brief perception experience. Chambers, Onishi, and Fisher (2003) examined 16.5-month-old infants' ability to learn consonant-position constraints using the head-turn preference procedure. Infants heard sets of CVC syllables containing artificially imposed consonant-position constraints, and were then tested on legal and illegal unstudied items. Infants preferred to listen to illegal items relative to legal items, showing that they discriminated the two types of items and were more interested in those that displayed a different pattern from the syllables in the study phase. Further studies showed that 9- and 10-month-old infants succeeded in similar tasks (Chambers, 2004; Saffran & Thiessen, 2003; Seidl & Buckley, 2005).

To sum up, previous research has showed that both infants and adults can learn new phonotactic-like constraints. This can occur in production, where repeated recitation of constrained syllables affects speech errors, and in perception, where listening to constrained syllables affects performance in subsequent perceptual tests.

2. Relationship between perception and production

The current study investigated whether perception and production experience interact with one another during phonotactic learning, a question inspired by the previous studies. The relationship between perception and production has always been controversial. A common intuition is that perception and production processes must access the same linguistic representation systems (phonology, semantics, etc.), since we speak the same language that we hear and understand. However, other phenomena suggest that the relationship between perception and production is not so straightforward. Perception and production development are not synchronized in early language acquisition, with children typically exhibiting perception abilities that may not be expressed in their production (e.g., Clark & Hecht, 1983; Menn, 1983). This unbalanced relationship between perception and production persists