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Speaking Outside the Box: Learning of Non-native Phonotactic Constraints is Revealed in Speech Errors

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Abstract

Phonological speech errors reflect the linguistic knowledge of the speaker. For example, in English, a misplaced [ŋ] will always end up as a syllable coda, in agreement with the phonotactic constraint that [ŋ] segments must be codas. Two experiments showed that phonotactic knowledge and its influence on speech errors can be easily changed. Participants were taught to produce [ŋ] in syllable onset position, and as a result produced errors reflecting this new knowledge.

Introduction

Phonotactic rules (or constraints) govern which sounds can or cannot combine in a given language. An English speaker, for example, could easily decide, without much thought, that "*blong"* is a possible English word, and that "*ngob"* is not. This is because the segment [ŋ], which is common in syllable coda position in English, such as in *sing*, is not available as a word onset for English speakers, though it is acceptable in other languages, such as Burmese. In this study, we trained English speakers to produce syllables with [ŋ] onsets. After training, not only did the speakers then produce these syllables, but strikingly, their phonological speech errors included instances in which intended [ŋ]'s (both onsets and codas) slipped to erroneous onset positions, demonstrating some flexibility to the new learning.

Knowledge of phonotactic constraints arises from early experience during infancy (e.g. Jusczyk et al., 1993), but continues to affect language processing throughout life. Moreover, such knowledge is at least temporarily malleable. In syllable input-processing tasks, both adults (e.g. Onishi, Chambers & Fisher, 2002) and infants (Chambers, Onishi, & Fisher, 2003) quickly acquire sensitivity to artificial phonotactic constraints introduced in experimental materials, such as a constraint that [f] only occurs as an onset during the experiment. Sensitivity to phonotactics in output is demonstrated by studies of phonological speech errors. Such errors exhibit the phonotactic regularity effect: Speech errors follow the phonotactic constraints of the language of the speaker (Fromkin 1971). For example, a slip such as "tlime line" for "time line" or "nging" for "king" would not occur because initial [tl]'s or [ŋ]'s violate English phonotactics.

The sensitivity of slips to the sound distributions in one's language can be changed by recent experience. Dell et al. (2000) explored the implicit learning of new arbitrary phonotactic constraints and demonstrated that slip patterns reflect the experimentally induced constraints. In a syllable production task, participants recited syllables that contained artificial (but legal in English) phonotactic constraints (e.g. [f] is always onset, [s] is always coda). An analysis of speech errors showed that participants were able to learn these new constraints, as they were significantly more likely to produce errors that obeyed the new constraints than errors that violated them. These results have been replicated and extended by Goldrick (2004), Taylor and Houghton (2005) and Warker and Dell (2006). It is important to note that, in all of these studies, the artificial language is actually *more* restricted than English, the participants' native language. For example, in Warker and Dell's (2006) artificial language, the consonants [k], [g], [m], and [n] were restricted to either onset or coda position, whereas these consonants can appear in either environment in English. While the participants readily learn these new phonotactic constraints, they are learning by excluding, rather than adding, sequences. This state of affairs is illustrated in the left half of Figure 1, in which the artificial phonology allows a subset of what is allowed by English.

If the implicit learning that occurs during these experiments is a product of a powerful acquisition process, it should have some ability to step outside of the phonological system of the speaker and learn new constraints, rather than simply prime a subset of the existing system. That is, it should be able to learn constraints that define genuinely new sequences (right half of Figure 1). The present study provides evidence of this.

The first experiment examined whether participants were able to learn a phonological constraint that is illegal in their native language ([ŋ]-onsets). In this experiment, the only [ŋ]-segments participants were exposed to occurred in syllable onset position. The second experiment allowed [ŋ] segments to occur at both onset and coda positions, and examined whether participants were able to learn [ŋ] as a possible onset, even when presented with [ŋ] codas (which, in English, always occur in syllable coda position).

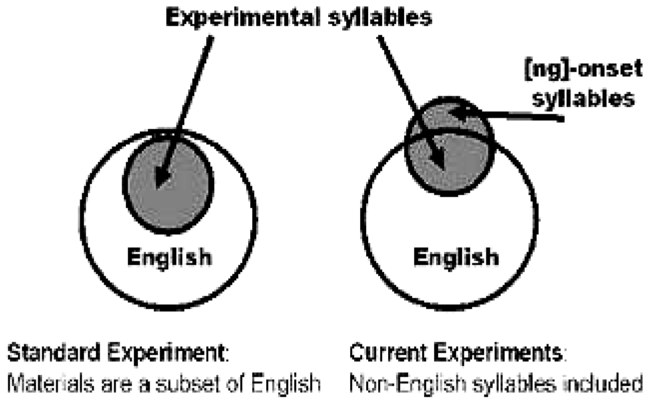

Figure 1: Experimental syllables.

The key question for both experiments is whether participants' experience producing [ŋ] onsets will lead to speech errors in which [ŋ] slips to onset position. Previously, in studies in which [ŋ] was not trained as an onset (e.g. Dell et al., 2000), it never slipped to onset position. The presence of [ŋ] onsets in the present study would support an approach to linguistic knowledge that recognizes the role of recent experience in shaping that knowledge.

Experiment 1

Participants repeated 4-syllable CVC sequences in time to a metronome. Metronome pacing was chosen to promote the production of errors without forcing an abnormally fast speech rate. The syllables were made up of eight consonants ([h], [ŋ], [f], [s], [k], [g], [m], [n]) and the vowel [E] (as in bed). [k], [g], [f], [s], [m], and [n] could appear either as onset or coda in any sequence. Following the phonotactic constraints of English, [h] only appeared as onset. However, [ŋ] which in English always appears in coda position, was restricted to onset position, creating sequences such as "hem, gef, ŋes, nek." As in previous studies, we expect slips such as "hem gef → hem hef." [h] should always maintain its onset position when it slips because [h] is always an onset both in English and in this experiment. We would also expect slips such as "hem gef" → "gem gef" in which the unrestricted consonant [g] moves from onset to onset, and that these would be somewhat more likely than slips such as "hem gef" → "heg gef", in which [g] moves from onset to coda. But such cross-positional or "illegal" movement should occur for unrestricted consonants because these occur as both onsets and codas in the experiment.

The critical data in the experiment involve slips in which [ŋ]'s move. Will they move only to coda position, as dictated by English phonotactics? Or will there be some movement to onset, for example, "gef → ŋef"?

Participants

Six students of the University of Illinois at Urbana-Champaign were compensated for participating in the experiment. Each was a native speaker of English who had studied a foreign language at high school age or later (excluding languages that permit [ŋ]-onsets). The data from two participants were not analyzed (one was unable to keep rhythm with the metronome, the other unable to produce [ŋ]-onsets).

Training

To prepare participants for producing [ŋ] onsets in the main experiment, a training procedure was developed. There were five steps, using flash cards, in the training. In the first step, participants were asked to recite one-syllable words with [ŋ] codas (hang, long, ring, wing). In the second step, they recited two-syllable words with a medial [ŋ] (hanging, longing, ringing, winged). Next, the words presented to the participants for recitation were separated into their syllables (hang-ing, long-ing, ring-ing, wing-ed). In the next step, these were separated before the coda of the first syllable, making [ŋ] the first sound of the second syllable (ha-nging, lo-nging, ri-nging, wi-nged). Finally, participants performed drills, producing syllables with [ŋ] onsets and vowel codas (nga, nga, nga, ngo, ngo, ngo, ngi, ngi, ngi). At all steps, the experimenter demonstrated [ŋ] onsets and provided more training trials at the request of participants. Because the sound [ŋ] is always spelled "ng" in English, all written materials expressed the sound using the English spelling.

Materials

For each participant, a set of 96 four-syllable sequences was randomly generated, subject to the constraints described above. Each consonant appeared exactly once in each sequence.

Each set of sequences was printed in 16-point bold Ariel lowercase font one sequence per line and 16 lines per page (6 pages per participant, total), and presented on paper. A window over the page was used to present only one sequence at a time.

Procedure

After completion of the training set, participants were presented with the sequences to recite. Participants spoke into a microphone in a soundproof room, and were recorded using a Kay Elemetrics recorder, and analyzed using Cool Edit software. Each sequence was read a total of four times. To ensure that participants were familiar with each sequence before each trial, each sequence was first recited once at a rate of 1 beat per second (speaking in time with the beats of a metronome). Next, each sequence was recited three times at a rate of 2.53 beats per second. To familiarize them with the speeded recitation task, participants were each first given four sequences to recite (not recorded), using the same protocol as in the recorded trials.

Results and discussion

Recordings of the participants' recitations were analyzed for errors by the experimenter. A syllable was judged to contain an error if a participant replaced one consonant with another from the sequence. Sequences in which a participant began a syllable with an incorrect consonant and self-corrected (e.g. hem → k-hem) were also coded as errors. Vowel errors were not counted, nor were those containing a consonant from outside the experiment. 212 consonant movement errors were identified.

The coding reliability was acceptable. A second coder, unaware of the experimental conditions, listened to the recordings of a subset of the produced syllables (2304 syllables). The coders agreed on 98% of the codes. As most of these were agreements regarding the absence of an error, it is useful to note that there were 45 syllables where both coders agreed that an error was present. Of these, they agreed on *what* the error was for 42 syllables. The coding reliability of [ŋ] targets and errors, in particular, was also acceptable. On the 288 [ŋ] targets in this sample, the coders agreed on 96% of the codes, and there were no mispronounced [ŋ] targets or other consonants mispronounced as [ŋ] where the two coders assigned different errors. (There were 5 cases, though, where the second coder labeled as correct what was initially coded as some other consonant slipping to [ŋ]).

Although the number and types of errors produced by each participant varied, all participants produced [ŋ] onsets. In a comparison of *correctly produced* onsets, it was found that, overall, participants correctly produced [ŋ] onsets at about the same rate as they produced any other onset. Overall, [ŋ] onsets were produced correctly 97.2% of the time, which was nearly the same as that for other onsets which were correct 96.8% of the time ($t = 0.54$). Figure 2 shows a spectrogram of a correctly produced onset [ŋ]. There is a clear nasal onset in conjunction with formant transitions indicative of a velar place of articulation.

Next, the probability of [ŋ] movement errors was considered, that is, cases where some other consonant was replaced by [ŋ]. Across the 4 participants, there were 32 cases of [ŋ] movement. Crucially, 50% of that movement was to onset position, and all four participants produced at least one such error. Figure 3 shows the spectrogram for an utterance in which the onset is incorrectly replaced by an [ŋ]. Again, the [ŋ] appears to be well formed. Given that 0% of the [ŋ] movement errors in Dell et al. (2000) or Warker and Dell (2006) were to onset position, it is safe to conclude that these [ŋ]-onset errors reflect the current participants' recent experience producing [ŋ]-onsets. Interestingly, of all syllable onsets produced correctly, those with [ŋ] onsets were found to be significantly more likely to have errors in coda position than syllables with any other correctly produced onset (2.8% vs. 1.2% of syllables respectively, $t = 3.26$, $p < .05$). Perhaps extra attention directed to the production of an [ŋ] onset led to these additional coda errors.

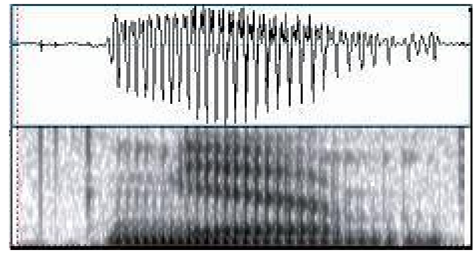

Figure 2: The syllable "ŋem" produced in earnest.

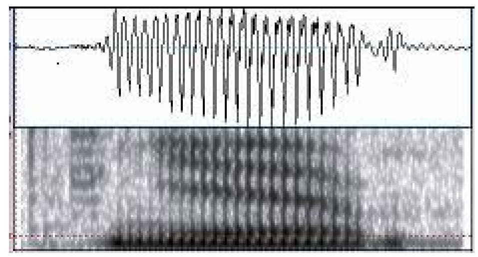

Figure 3: The syllable "ŋem" produced in error.

The results suggest that native speakers of English learned something akin to the constraint: *[ŋ] can be an onset during this experiment*. Evidence of such learning comes from the fact that participants produced [ŋ] onsets when they intended to produce another onset. Specifically, [ŋ]'s slipped to onset position 50% of the time. Without experience with [ŋ] onsets, [ŋ]'s invariably slip to coda position. But this experience within the experiment does not make the production of [ŋ]'s easy. The participants' lifelong experience of nothing but [ŋ]-codas prior to the experiment is seen in the findings that [ŋ] errors emerged as onsets to a lesser extent than other consonants did, and correctly produced [ŋ] onsets caused coda errors. Experiment 1 showed that participants produced [ŋ] onset slips when [ŋ] was restricted to onset position. Experiment 2 tested whether participants would still produce [ŋ] onset slips if the stimuli included [ŋ] codas.

Experiment 2

Method

The method used was the same as in Experiment 1, except that instead of being restricted to onset position, [ŋ] was left unrestricted, and appeared equally frequently in onset and coda position. Five new participants from the same population as those in Experiment 1 were trained on onset-[ŋ] pronunciation and then performed the sequence recitation task. The data of one participant was not analyzed, due to an inability to perform the task.

Results and discussion.

Recordings of the participants' recitations were analyzed as they were in Experiment 1. 208 consonant errors were recorded. Coding reliability (based on 2304 syllables—288 with [ŋ] onsets-- listened to by a second coder) was similar to that of the first experiment. There was 98% agreement on codes both for all syllables and target [ŋ]-onsets and there were no cases involving [ŋ]-onsets as targets or errors in which the two coders assigned different errors. There were 4 cases, though, where the second coder labeled as correct what was initially coded as some other consonant slipping to [ŋ], and 3 cases of the reverse.

As in Experiment 1, all participants produced target [ŋ] onsets correctly for the most part (95% correct). In an analysis of the 54 [ŋ] movement errors, [ŋ] onsets slipped to onset, as opposed to coda position, 42% of the time. This can be contrasted with the fact that [ŋ] codas slipped to coda, as opposed to onset, position 75% of the time. The other unrestricted consonants, ([f], [s], [m], [n], [k], and [g]) maintained their positions when they slipped, 68% of the time for onsets and 73% for codas. [h], which was restricted to onset position, never slipped to coda position. The much larger tendency for [ŋ] to slip from coda to coda than onset to onset is likely the result of the participants' lifetime of experience with English

These results reinforce those of the first experiment. Both experiments found many instances in which [ŋ]-onsets moved to other onset positions. The second experiment, though, found 7 instances in which [ŋ]-*codas* moved to onset position. Three of the four scored participants produced errors that resulted in unintended [ŋ]-onsets, and two of them produced [ŋ]-onsets in which the source of the error was an an [ŋ]-coda. The presence of other [ŋ]-onsets in the stimulus materials apparently licensed the onset position for [ŋ], setting the stage for the coda-to-onset slips. Note that, in natural speech-error collections and in previous experiments with [ŋ] restricted to the coda slot, no coda-to-onset errors have been observed.

General Discussion

In two experiments, participants learned a phonotactic pattern that is contrary to the linguistic information they have been exposed to over their lifetimes. The learning was revealed in their production of errors. Errors that form [ŋ]-onset syllables do not occur in natural studies of speech errors and in experimental studies that do not expose the speakers to [ŋ]-onsets. Here, when [ŋ]-onsets were required to be spoken, [ŋ]-onsets also emerged in their slips.

The results are particularly important because findings from previous studies of implicit learning of artificial phonotactic constraints in production (e.g. Dell et al., 2000) can be attributed to a "local tuning of an already learned syllabic structure" (Taylor & Houghton, 2005, p. 1415). That is, the previous studies do not definitively show that recent experience can actually change the core of the phonological processing system, a core that is based on the constraints that define the legal and illegal sequences for the speaker's language. They may only demonstrate that known syllables and syllable types can be primed by exposure. Our results challenge this limited view of the learning process.

The data presented here thus offer evidence of a powerful acquisition process that allows new information to be integrated into the existing phonological processing system. More generally, they suggest that language learning never stops. The processing system adapts to recent experience, while continuing to reflect the accumulated experience of a lifetime of speaking and listening.

Acknowledgments

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