The tongue slips into (recently learned) patterns [*]

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Abstract

Speech errors reflect linguistic knowledge. For example, phonological errors follow language-wide phonotactic constraints such as the fact that [h] must be an onset in English. We review five experimental studies that demonstrate that errors adhere to artificial experiment-wide constraints (e.g. [f] must be an onset during this experiment) as well as language-wide constraints. These studies show that the language production system adapts to its recent experience with phonological patterns.

1 Introduction

Speech errors, or slips of the tongue, are an important source of data in psycholinguistics. It is not uncommon for textbooks in the field to devote entire chapters to them and their implications for theories of speech production (e.g. Carroll, 1999). The prominence of slips in the field, however, is a recent phenomenon. When psycholinguistics was in its infancy during the 1960's, speech errors were dismissed, both by linguists who were simply not interested in performance data and by experimental psychologists who saw their study as a suspect relic of Freudian theory.

Nooteboom was among the first to see the potential of speech errors as data for production theory. His article (Nooteboom, 1969, "The tongue slips into patterns") antedated the influential error analyses of Fromkin (1971) and Garrett (1975) and went beyond the classic study of Meringer & Mayer (1895) by linking errors to the information processing requirements of speaking as well as to the properties of spoken language. For example, he argued that one must consider the limited nature of short-term memory when explaining the distance that misplaced speech sounds move in errors (e.g. example 1).

(1) everything you hear → *everyhing you hear*

We (and just about everyone else nowadays) agree with Nooteboom that error patterns can be explained through cognitive and perceptual mechanisms acting on linguistic knowledge. Here, though, we put forth a more specific claim: Errors reflect recent experience with linguistic regularities as well as long-term linguistic knowledge. In other words, the tongue slips into recently learned patterns as well as those acquired through a lifetime of speaking.

2 The syllable-position and phonotactic-regularity effects

Consider error example (1) again. The [h] in *hear* moves to the onset of the nearby syllable *thing*, replacing the [Θ]. Why does it move specifically to the *onset* of this syllable rather than some other spot? One explanation, termed the *syllable-position effect*, is that speech

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sounds may have a tendency to preserve their position when they move in an error. The consonant [h] was an onset in *hear* and so it emerges as an onset in *hing*. An alternative explanation appeals to the fact that [h] is *always* an onset in English syllables. That is, the principles of English sound combinations, its *phonotactic* constraints, license [h] for onset position, but not for syllable-final (coda) position. More generally, we may explain the movement of [h] to an onset rather than a coda slot by hypothesizing a *phonotactic regularity effect* on errors: Errors do not create phonotactically illegal sequences.

The syllable-position and the phonotactic-regularity effects are both genuine influences on error patterns. The syllable-position effect has been observed in analyses of error collections in several languages (e.g. Garcia-Albea, del Viso, & Igoa, 1989; MacKay, 1970; Nooteboom, 1969; Stemberger, 1983). There is a clear tendency for onsets to move to onset positions and codas to move to coda position. Thus, *napkin* might slip to *kapkin* ([k]-onset moves to an onset position) but would be less likely to be mispronounced as *papkin* (movement of [p]-coda to onset position). The syllable-position effect is a bit difficult to disentangle from confounded influences of word position because word-initial sounds have a strong tendency to slip to other word-initial locations (Shattuck-Hufnagel, 1983). But when word-onset influences are removed from the data, a syllable-position effect remains. For example, in one analysis of English slips, 77% of English non-word-initial consonant movements retained their syllable positions (Vousden, Brown, & Harley, 2000).

The phonotactic regularity effect is even stronger than the syllable-position effect. The claim that phonological speech errors create only legal sound sequences was originally made by Meringer & Mayer (1895) and was called as the “first law” of speech errors by Wells (1951). Although this effect is often characterized as exceptionless, illegal slips do occur. For example, Stemberger (1983) collected 37 slips that violated the phonotactic-regularity effect, e.g. (2) below. These violations, however, were from a large collection of phonological slips, over 99% of which were phonotactically legal.

(2) first floor dorm → *first floor dlorm* (onset [dl] is illegal)

The standard view of the syllable-position and phonotactic-regularity effects is that they are separate influences on the form of speech errors. The syllable-position effect derives from a process of inserting consonants labeled as either onset or coda into labeled slots in a syllable structure or “frame”. Each slot only takes appropriately labeled consonants (e.g. Shattuck-Hufnagel, 1979). So, the [k] in *napkin* is [k]-onset, not just [k]. If it slips to the first syllable of *napkin*, it must be inserted into that syllable frame’s onset slot, creating the erroneous syllable [kæp]. The phonotactic-regularity effect is assumed to have a different mechanism. It reflects a set of phonotactic rules (e.g. *[h] must be an onset*) that are acquired early in life. If a potential slip violates a rule (e.g. an [l] is about to be inserted into *dorm* to create *dlorm*) some unspecified process either prevents the error or corrects it so that it is no longer illegal (Fromkin, 1971). Consequently, errors that violate the rules do not occur.

Our contention is that the syllable-position and phonotactic-regularity effects are not the result of distinct mechanisms. Rather they reflect closely related constraints on phonological sequences. The only difference is that the syllable-position effect arises from what we call *local constraints* and the phonotactic-regularity effect is a consequence of *language-wide constraints*. To illustrate, consider the target phrase, *king of hearts*. To produce this phrase, one must retrieve its constituent speech sounds and assign them to syllables and syllable positions (Levelt, Roelofs, & Meyer, 1999). In particular, one must retrieve and assign [k] to the onset of the first syllable, [ɪ] to its vowel slot, [ŋ] to its coda slot, and so on. These processes are subject to constraints. Some of these constraints apply only in specific situations; for example, *[k] is onset | KING*. (The symbol "|" should be read as "in the context of"). Thus, this constraint would be active when *king* is spoken. Other constraints are more general, even language-wide; for example *[ŋ] is coda | all of English*. That is, English phonotactics require that [ŋ] be a coda. We assume that these constraints, local and general, are invoked during production and that they bias the assignment of speech sounds to syllable positions. The actual mechanisms of this bias are not important here. But it is worth noting that spreading activation through the network is a psychologically plausible way to represent constraints and their satisfaction, and that many models of production employ such mechanisms (e.g. Berg & Schade, 1992; Dell, 1986; Harley, 1984; Levelt et al., 1999; Stemberger, 1985).

An error that obeys the syllable-position effect, such as *king of karts* for *king of hearts*, is facilitated by the relevant local constraint, *[k] is onset | KING*. The erroneous [k] sticks close to *king* and it maintains it status as onset. However, as we mentioned before, the syllable-position effect is often violated (23% of the time in Vousden et al.'s, 2000, analysis of English word-internal errors). There are a couple of reasons for the frequency of these violations from our constraint perspective. First, the location of the error itself is outside of the relevant context; [k] should be an onset when saying *king*, not when saying *hearts*. Second, there are other local constraints that could work against the relevant constraint, constraints such as *[k] is coda | JACK* or *[k] is coda | HARK*. If any of these opposing constraints were to become active, they would counteract *[k] is onset.* Perhaps thinking about the king of hearts calls to mind other playing cards, such as the jack of hearts. Or possibly, planning the word *heart* activates the phonologically similar word *hark*. Speech-error studies (including Nooteboom's original paper) suggest that preparing to say a word leads to the activation of its semantic and phonological neighbors. All things considered, there are good reasons to expect local constraints such as *[k] is onset | KING* to have only limited influence and, hence, to expect violations of the syllable-position effect to be common.

Language-wide constraints such as *[h] is onset | all of English* or *[ŋ] is coda | all of English* are inherently more powerful than the local constraints. Because they are true for all words of the language, there are no opposing constraints. For example, there is no *[ŋ] is onse...* constraint to stimulate the error *king of ngearts*. Moreover, their influence is not limited to the context of a particular word. Their context is all of English. These properties of language-wide constraints help us understand why phonotactic regularity is a much stronger influence on errors than the syllable-position effect.

In summary, the syllable-position and phonotactic-regularity effects are both products of constraints on how speech sounds are positioned in syllables. The syllable-position effect results from errors adhering to a local constraint in the vicinity of a particular word. Adherence to language-wide phonotactics is due to more general constraints. In this way, the two error effects can be thought of as two ends of a continuum of breadth of constraint, with the syllable-position effect at the narrow end and the phonotactic regularity effect at the wide end.

3 The role of experience in speech errors: Where do the constraints come from?

Language-wide and local constraints must be learned. We are not born knowing that [k] is an onset in the word *king*, or that [ŋ] must always be a coda. Undoubtedly, much of this learning occurs early in life (e.g. Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993). We contend, though, that learning about the positions of sounds in syllables does not stop after childhood. On the contrary, language learning never stops. Language users continually adjust their knowledge of constraints based on their experience with phonological forms. This learning is implicit and serves to adapt the production and recognition systems to the current situation.

We have carried out several experiments demonstrating that recent experience can affect knowledge of constraints and thus change speech error patterns (Dell, Reed, Adams, & Meyer, 2000; Warker & Dell, in preparation). In particular, we tested the idea that experience can strengthen the syllable-position effect, turning it into a kind of phonotactic regularity effect. In these studies, English speakers recited syllables whose consonants were artificially restricted to particular syllable positions. For example, throughout the first experiment described below, [f] only occurred as an onset and [s] only occurred as a coda. Hence, [f] and [s] exhibited what we call *experiment-wide constraints*. Experiment-wide constraints (e.g. *[f] is onset | this experiment*) are a kind of middle ground between local constraints (e.g. *[k] is onset | KING*) and language-wide constraints (e.g. *[h] is onset | all of English*). The data of interest were the extent to which errors adhered to the constraints. We expected that errors would adhere to language-wide constraints nearly all of the time (the phonotactic-regularity effect). So, any slip of an [h], for example, should be to an onset position. We also expected that slips would adhere to local constraints (the syllable- position effect) around 70-80% of the time. Onset-[k]'s should tend to slip to onset positions, but there would be a fair number of exceptions. What about [f] and [s], the sounds subject to experiment-wide constraints? If learning occurs, slips of [f] and [s] should come to obey these constraints. For example, onset-[f]'s should move to onset, rather than coda, positions at a greater rate than consonants not subject to experiment-wide restrictions.

4 Learning experiment-wide constraints: First-order effects

4.1 Methods

Eight English-speaking participants recited four-syllable sequences in time with a metronome (e.g. example 3). They repeated 96 of these sequences four times in a row in an experimental session. Moreover, each participant did four separate sessions on separate days.

(3) *feng keg hem nes*

Each sequence contained one each of eight consonants, [h, ŋ, f, s, k, g, m, n], and the vowel was always [ɛ]. The consonants fell into three groups: language-restricted [h, ŋ], experiment-restricted [f, s], and unrestricted [k, g, m, n]. Within each sequence, [h] was always an onset and [ŋ] was always a coda, respecting English phonotactics. The consonants in the unrestricted group could be either onsets or codas. In one sequence, [k] might appear as an onset (as in 3 above), but in the next, it could be a coda. Experiment-restricted consonants maintained their target syllable positions throughout the four sessions for the experiment. Half of the participants experienced [f] only as an onset and [s] only as a coda, and half experienced the reverse assignment. In total, 384 such sequences were prepared for each participant, divided into four sets of 96.

Each sequence was presented visually one at a time. The participant first repeated it slowly (1 syllable/sec) and then three times without pause at a faster rate (2.53 syllables/sec). Half of the participants were informed about the experiment-wide constraints at the beginning of each session ("when you see an 'f' it will be at the beginning of a syllable and when you see an 's' it will be at the end of a syllable"), and half were told nothing about these constraints. This manipulation was designed to test whether explicit knowledge of the experiment-wide constraints influences the extent to which errors adhere to them.

A second experiment used [k] and [g] as the experiment-restricted consonants; [f] and [s] were then put along with [m] and [n] in the unrestricted group. Another group of eight English speakers participated. In all other respects, this [k-g] version of the study was the same as the [f-s] version.

4.2 Results

The data of interest were slips in which consonants moved from one location to another. When such movement occurred did the consonants maintain their syllable positions? Table 1 shows the percentage of slips that did so, as a function of consonant group, for both the [f-s] and [k-g] experiments. First, consider slips of the unrestricted consonants. These maintained their syllable positions 68% of the time in the [f-s] experiment and 77% of the time in the [k-g] experiment. This clear syllable-position effect provided a baseline against which to compare effects for restricted consonants. Next, consider the language-restricted consonants. In both experiments, movements of [h] and [ŋ] kept their positions 100% of the time, demonstrating the robustness of the phonotactic-regularity effect. The key findings came from the experiment-restricted consonants. Slips of these maintained their positions at a greater rate than did the unrestricted consonants. In fact, these slips nearly always kept their positions (98% and 95% of the time), much like those of language-restricted consonants, which always stayed in position.

Table 1. Percentage of consonant movement errors that maintained syllable positions (from Dell et al., 2000)

	Unrestricted	Language-restricted	Experiment-restricted
Experiment 1	68% (*n*=1941)	100% (*n*= 640)	98% (*n*= 484)
	[k, g, m, n]	[h, ŋ]	[f, s]
Experiment 2	77% (*n*=1850)	100% (*n*=1016)	95% (*n*= 718)
	[f, s, m, n]	[h, ŋ]	[k, g]

Our interpretation of these results is that speakers learned something about the distribution of the experiment-restricted consonants and this knowledge affected their errors. The effect of this learning was strong in a number of respects. It developed on the very first day of testing in both experiments; 98% for [f-s] and 93% for [k-g] of the experiment-restricted consonants kept their positions on first-day slips. The effect also appeared regardless of how the consonants were restricted (whether [f] was always an onset or whether [f] always was a coda). In fact, all 16 subjects exhibited high rates of position maintenance for the restricted consonants, including those who had not been explicitly informed about their distribution (see Dell et al., 2000, for detailed analysis of the data).

4.3 Discussion

We have suggested that speakers may be learning a new constraint, something like *[f] is onset | this experiment*. This constraint has a wider influence than local constraints and, in some ways, can be thought of as an experimentally induced analogue of language-wide phonotactic constraints. An alternative interpretation of the data is that previously existing constraints are being affected. One possibility is that particular local constraints are being strengthened. Perhaps every time that one says the syllable *fen*, the constraint *[f] is onset | FEN* grows stronger. If we then assume that stronger local constraints exert greater influence on errors in their vicinity, we can perhaps explain why slips of experiment-restricted consonants kept to their positions more than those of unrestricted consonants. Another possibility is that existing *general* constraints are subject to learning. For consonants that distribute freely across onsets and codas in the language such as [f], we hypothesized the existence of local constraints, only. But suppose that in addition to these local constraints, there exist general constraints of the form *[f] is onset* and *[f] is coda*. If the general constraints are affected by experience, our speakers who only get [f] in onset position may have their general [f]-onset constraint strengthened. The corresponding general constraint promoting [f] as a coda would not be strengthened or may even weaken. Thus, slips of [f] would show an enhanced tendency to stick to onset positions.

The data in Table 1 do not allow us to discriminate among these interpretations. What is required is a systematic investigation of the kinds of constraints that can and cannot be acquired and the conditions that promote their acquisition. As an initial step in this investigation, we have tested the learning of “second-order” experiment-wide constraints (Warker & Dell, in preparation). The constraint *[f] is onset | this experiment* is first-order; a particular consonant is associated with a particular syllable position. A second-order constraint is one in which the position that a consonant is associated with is conditioned on another property of the context. In the next section, we describe three experiments in which the experiment-wide constraint is a second-order vowel contingency. For example, in Experiment 3, some participants experienced syllables in which [f] must be an onset and [s] must be a coda, if the vowel is [ɪ], but [f] must be a coda and [s] must be an onset if the vowel is [æ]. This kind of experiment-wide constraint allows us to test whether the speech production system is capable of acquiring new arbitrary relations. Recall that one interpretation of the first-order findings is that existing general positional constraints (e.g. *[f] is onset*) are strengthened. If that is the only kind of learning that happens in these experiments, a second-order vowel-contingent constraint could not influence the error pattern. Experiment-restricted consonants such as [f] and [s] occur both as onsets and codas in this kind of second-order study and, hence, there is no overall correlation between consonants and particular syllable positions. If there is a tendency for slips of the restricted consonants to stick to their positions beyond that of the unrestricted consonants, this tendency could not be attributed to strengthening an existing general constraint.

5 Learning experiment-wide constraints: Second-order effects

5.1 Methods

Eight English-speaking participants recited four-syllable sequences, such as those in Example (4), in time with a metronome on four separate days, producing 96 four-syllable sequences a day.

(4) *han fak mas gang*
sim ghin kif hing

As in Experiment 1 and 2, each sequence had 8 consonants, which fell into three groups: language-restricted [h, ŋ], experiment-restricted [f, s], and unrestricted [k, g, m, n]. The vowels in each sequence were either all [æ]'s, or all [ɪ]'s. Throughout the four sessions of the experiment, the experiment-restricted consonants adhered to the following constraints: *[f] is onset, [s] is coda* | *[æ]* and [s] *is onset, [f] is coda* | *[I]*. Half of the participants received the reverse constraints. Also, as before, half of the participants were informed of the constraints at the beginning of the experiment and half were not informed. The procedure was identical to that of Experiment 1 and 2.

An additional experiment used [k] and [g] as the experiment-restricted consonants, and a third one used [m] and [n]. These experiments were similar to the [f-s] version except that only four speakers participated in each.

5.2 Results

Errors where consonants moved from one location to another in a given sequence were analyzed to see if slips involving the experiment-restricted consonants would maintain their syllable position more often than slips involving the unrestricted consonants. In all three experiments, slips of [h] and [ŋ] followed the language-wide constraint and kept to their respective positions 100%. Unrestricted consonants maintained their position 77% in the [f-s] version, 74% in the [k-g] version, and 77% in the [m-n] version. However, the main findings concern errors involving the experiment-restricted consonants. On the first day of testing, slips of these consonants only maintained their syllable position about as often as slips of the unrestricted consonants: 86% in the [f-s] version, 72% in the [k-g] version, and 81% in the [m-n] version. But for the later testing sessions, day two through day four, experiment-restricted consonants kept their syllable position more often than the unrestricted consonants: 93% in the [f-s] version, 84 % in the [k-g] version, and 96% in the [m-n] version. Figure 1 shows the breakdown of percentages by day and by experiment.

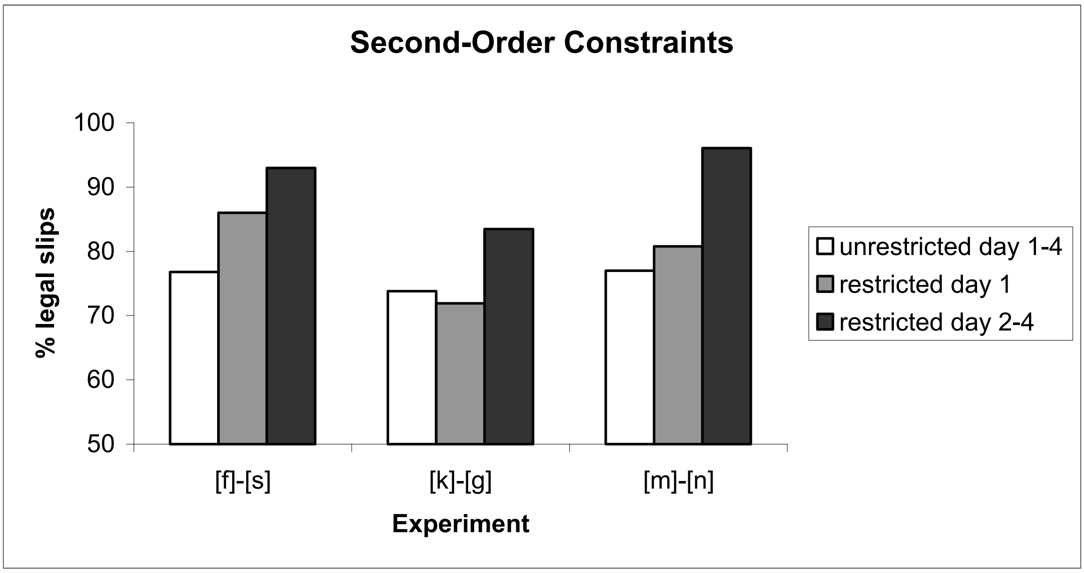

Figure 1. Percentage of experiment-restricted consonant movement errors that maintained syllable position.

The interpretation of these results is that participants learned something about the positions of the experiment-restricted consonants with regard to the identity of the vowel and, in turn, this learning influenced their speech errors. However, the pattern of learning differed from that found in Experiment 1 and 2. In the first-order constraint experiments, learning was found on the first day of testing. But in the second-order constraint experiments, it took until the second day of testing for participants' errors to adhere to the constraint. This pattern surfaced regardless of whether participants were explicitly informed of the constraints beforehand.

5.3 Discussion

Our results suggest that people can learn vowel-consonant dependencies and that these second-order constraints take longer to acquire than first-order constraints. This may occur because the second-order constraint is more complex and thus, harder to learn. As a result, people require more exposure to the constraint before being able to implicitly assimilate the rules. The learning of a second-order rule also indicates that people are not simply strengthening existing constraints, such as *[f] is onset*, since the experiment-restricted consonants occurred as both onsets and codas throughout the experiment. Rather, the results imply that the participants are adding a new constraint to their existing collection.

6 General Discussion

Our experiments show that speech errors respect the patterns present in an experiment as well as those that are true for the entire language. Participants acquired sensitivity to both first- and second-order constraints on the positions of consonants within syllables, although the second-order constraints were learned more slowly. We suggest that experience in producing syllables changes the speech production system, adapting it to its current circumstances.

The learned constraints have been described in terms of particular phonological categories—onsets, codas, and phonological segments. In a recent speech-error experiment, Goldrick (2004) demonstrated that features must be represented as well. Goldrick restricted a consonant to a particular position (e.g. *[f] is onset | this experiment*), but included a similar unrestricted consonant (e.g. [v]) in the study. The presence of the unrestricted [v] weakened the tendency for [f] slips to be onsets. Furthermore, slips of [v] exhibited an increased tendency to be onsets, even though [v]'s were equally likely to be codas and onsets. These findings point to the acquisition of constraints about features such as *labial* or *fricative*, as well as constraints about entire segments.

Changes in speech-error patterns point to changes in production mechanisms. What about speech perception? Can the perceptual system rapidly acquire new constraints? Onishi, Chambers, and Fisher (2002) showed that it can. Their participants listened to CVC syllables that exhibited the same kinds of experiment-wide constraints that were tested in our production experiments. Then they presented participants with novel test syllables that followed the constraints and found that they could respond to these more quickly in an auditory naming task than novel syllables that violated the constraints. Both first-order and second-order vowel-contingent constraints could be learned.

Onishi et al. (2002) also identified a second-order constraint that could not be learned in their perceptual study. The constraint involved a speaker-voice contingency rather than a vowel contingency, for example, [b] is an onset if spoken by speaker A and [b] is a coda if spoken by speaker B. Onishi et al. hypothesized that constraints can only be rapidly learned if their elements are internal to the phonological system. Vowels and consonants are both internal to this system, and languages commonly exhibit phonotactic constraints in which consonants and vowels are dependent (e.g. in American English, the diphthong [iu] follows a restricted set of onsets, such as [k] or [m]). Speaker identity, though, would not normally be considered part of the phonological system. We are currently investigating this hypothesis in production by testing whether speech errors can become sensitive to a second-order constraint involving consonant position and a factor that can be argued to be extra-phonological, speech rate.

A final issue concerns language acquisition. We have been characterizing these experiments as learning experiments, inviting the conclusion that adult participants are learning artificial phonological constraints in much the same way that children acquire the phonotactics of their native language. We cannot assert this conclusion with confidence. We note, though, that 16-month olds learn first-order consonant-position constraints from listening to CVC syllables about as quickly as adults do (Chambers, Onishi, & Fisher, 2003). Studies with second-order constraints in children's perception are ongoing (K. Chambers, personal communication). Our speech-error results suggest that children will learn the second-order constraints, but perhaps more slowly than they do the first-order constraints.

7 Conclusions

Back in 1969, Nooteboom predicted that speech errors "may be of some use for the future construction of an explicit theory of language use" (p. 132), and proceeded to demonstrate just how this could be done. Nooteboom's understated prediction has been fully realized. Not only are speech errors profoundly important to theories of language production, but also, as we have seen, error patterns suggest useful avenues of exploration in perception and acquisition, in short, in all of psycholinguistics.

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