

Sept 12, 2018

Atelier de Phonologie

**Phonological regularity,
perceptual biases, and the role of
phonotactics in speech error analysis**

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Speech errors tend to respect grammar

“First law” of tongue slips (due to Wells 1951)

Speech errors respect phonotactic constraints, only produce legal phonological combinations (Boomer & Laver 1968, Nootboom 1967, Garrett 1980)

Phonological constraints active in repairs (Fromkin 1971: 41)

play the victor → *flay the pictor* (exchange of *p* and *v*, *vl* → *fl*)

Syntactic regularity in speech errors (Garrett 1980, Bock 2011)

- Category constraint (word substitutions respect part of speech labels), producing licit but unintended sentences.
- Sentence blends, role mis-assignments, and spurious agreement relations tend to respect grammar too.

Bock 2011: 332

“The most striking thing about attested syntactic errors is that, like other kinds of speech errors, they occur within a structural matrix that resists modification.”

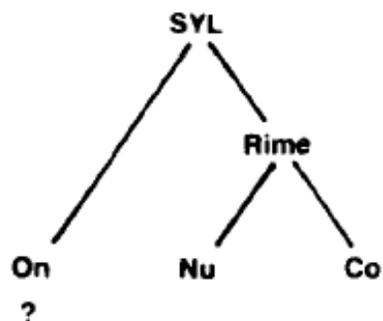
Regularity as a hard constraint

Early models: grammatical regularity not really explained, but the result of a built-in “structural matrix”

Spreading-interactive model of Dell 1986

- Mental lexicon: activation dynamics for selecting valid linguistic units
- Tactic frames: productive capacity for language (simple sentence trees, word trees, and syllables. (a.k.a. ‘structural matrix’)

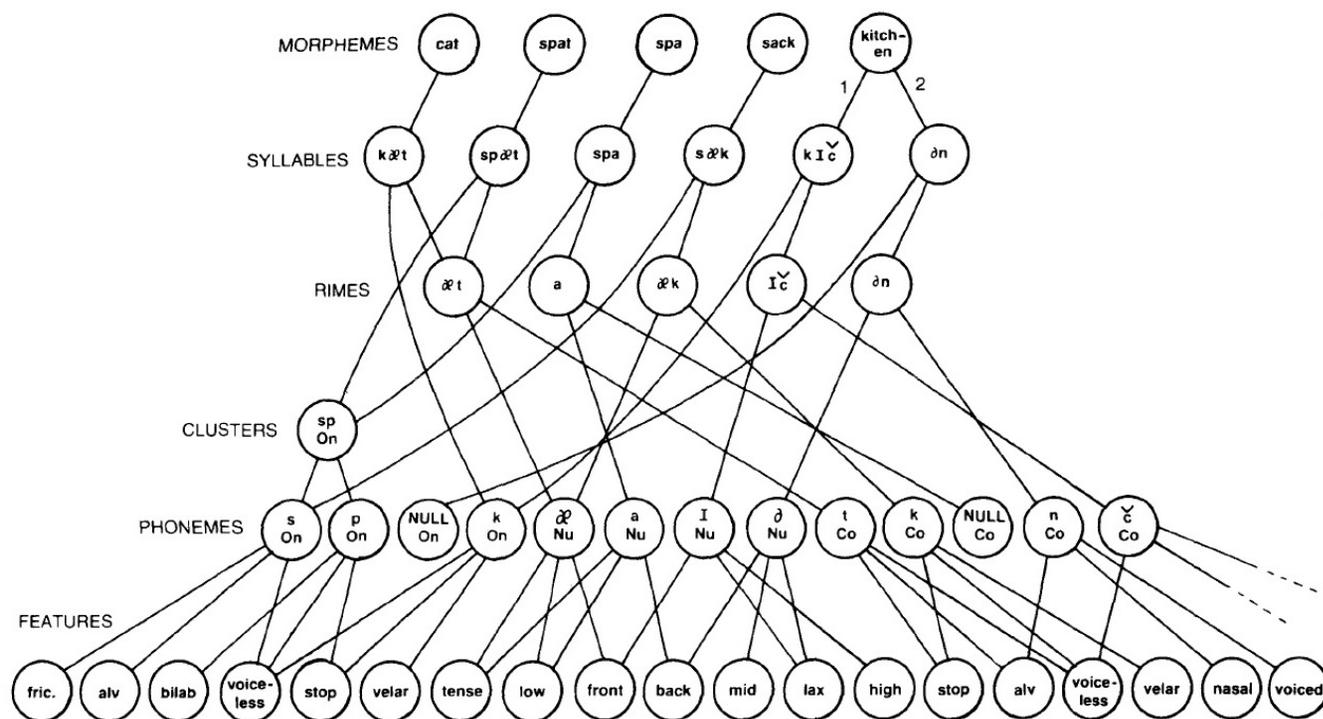
Tactic frame



Result: *v/* is not a valid onset for intended word *play* because [*v/*, Onset] is not a node in the mental lexicon.

Clear role for grammar!

Mental lexicon (fragment)



But regularity is not a hard constraint

Stemberger 1983: phonological regularity is very high, but speech errors do violate English phonotactics, approx. 1% of the time (37 violations/6,300 examples); standard of 99% phonological regularity

... in the first floor /**dl**orm — dorm room

I /**sth**ough— thought I said ‘moff’

... knowledge of the cooperative /**rp**in— principle

Problem: need a model that can produce phonotactic violations (but rarely); not possible if regularity is a hard constraint.

Theoretical issue (due to Stemberger): the dominance of phonological regularity in speech errors does not entail that speech errors are controlled directly by phonotactic constraints—other independently need mechanisms sensitive to frequency could be at work.

Dell et al. 1993: regularity without tactic frames

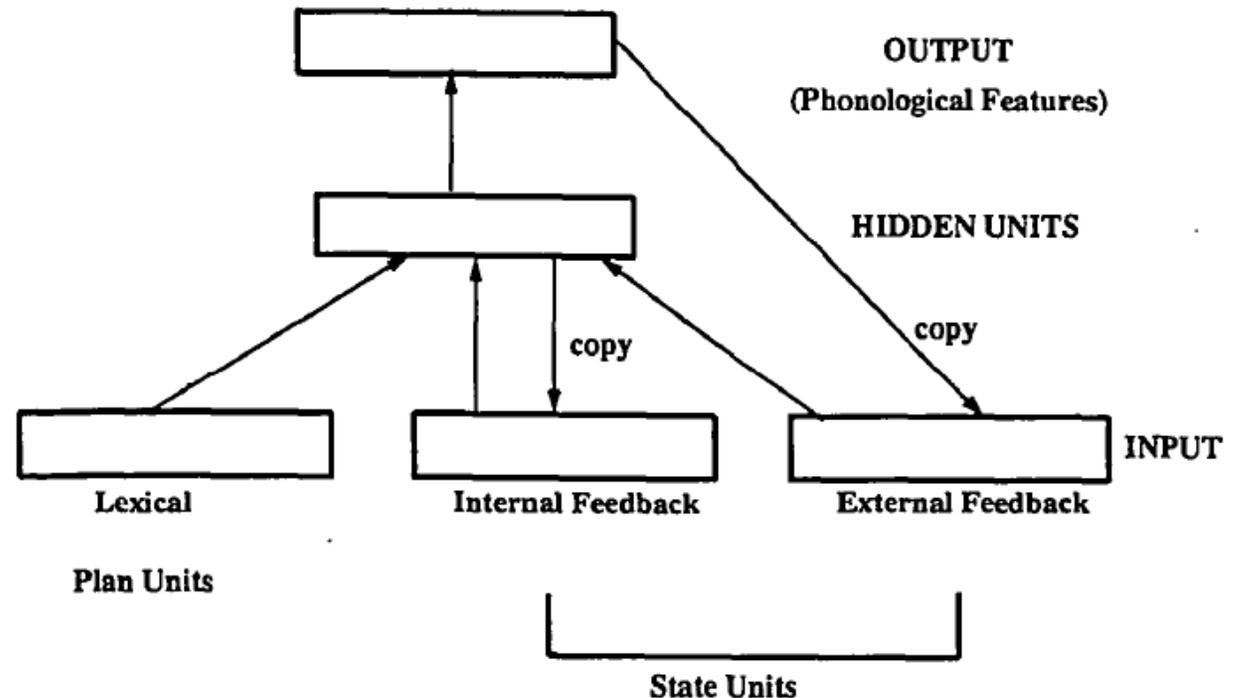
Dell et al. (1993): simple recurrent network proposed as a model of phonological encoding. Trained on a sample of English words and tested against a set of phonological benchmarks characteristic of speech error patterns (i.e., phonological regularity, CV substitutions, syllabic constituent effect, word-onset asymmetry)

Network features:

Sequential: outputs a single segment, then another, in sequence

Recurrent: current segment processed in tandem with knowledge of past segments

Distributed representations: segments are represented as a vector of feature values (cf. distinctive features)



Result: given certain parameters (trained on frequent vocabulary, internal and external input), the model produces errors that are **phonotactically regular about 96.3% of the time**

Clear role for mechanisms intrinsic to language production processes.

Leading question: is phonological regularity due to phonological grammar, or due to mechanisms intrinsic to theories of speaking? (Or both?)

Formal grammars

Prosodic phonology, Optimality Theory, Harmonic Grammar, Government Phonology, SPE Phonology

=Symbolic computational models of linguistic competence
→ phonological regularity could result from applying system of phonotactics to output of speaking.

Psycholinguistic Theories of Speaking

Two-step interactive model (Dell et al. 1997),
WEAVER++ (Levelt et al. 1999), Gradient symbol processing (Smolensky et al. 2014)

=Activation dynamics for production processes
→ Phonological regularity could arise from the way frequency and other features are encoded in memory

Focus and approach

SFUSED (=Simon Fraser University Speech Error Database):

principal dataset for today's presentation

Describe a methodology for collecting speech errors and demonstrate that it has an impact on the characterization of regularity

Re-assess phonological regularity in English speech errors

Just how phonologically regular are speech errors? (How common are phonotactic violations?)

Examine model implications: does the overwhelming fact of phonological regularity (with violations) require grammar, an activation dynamics, or combination of both?

Part 2 tomorrow (Diderot talk, Wed Sept. 13)

Examine a host of dimensions of cross-linguistic markedness

to see if it has a major impact on the structure of speech errors

SFU Speech Error Database (SFUSED)



Current languages

SFUSED English (10,104 errors)

SFUSED Cantonese (2,549 errors)

Goals

- Build a multi-purpose database based on audio recordings that supports many types of language production research
- Linguistically sophisticated coding of errors
- Explicit processing assumptions and fields that support probing of psycho-linguistic biases
- Examine how the structure of non-Indo-European languages impacts language production processes

Methods: data from audio recordings

Natural conversations in audio recordings

- errors collected from unscripted speech in podcast episodes
- scripted speech ignored, not counted in time metrics
- viewed as waveform in speech analysis software
- “offline” data collection vs. “online” data collection (most prior studies)

Podcasts

- mix of genres: lifestyle, entertainment, science, technology
- selection criteria: high production quality, long segments of unscripted speech, talkers no media professionals, balance of male and female speakers
- nine podcasts, roughly 50 hours of each, about 1000 errors

Dialects and idiolectal features

- “Standard American English”, i.e., some variety of Midlands dialect
- idiolectal features: e.g., intrusive velar [mʌktʃ] ‘much’; habitual so not an error
- podcast notes: non-standard dialects, idiolectal features, used as reference material for assessing errors

Definition of speech error (Dell 1986)

“unintended non-habitual deviation from the speech plan”

Methods: data collectors and training

Multiple data collectors

- total of 13 data collectors (currently)
- data collector part of the record (can be examined for skewed distributions)
- cf.: 1 or 2 experts studies, or large number of untrained data collectors

Training

- undergraduate students with introduction to formal linguistics
- given phonetic training in transcription and tested for transcription accuracy
- introduction to speech errors, definition and illustration of all types
- training through listening tests: assigned pre-screened recordings, asked to find errors; given feedback

Target for training

- MPE (minutes per error) of 3.0 or less
- less than 25% false positives

Methods: verification and classification

Verification

- data submissions batch imported, verified by data analyst
- checked against reference material on casual speech patterns
- checked for slips of ear, change of speech plan, false starts, errors of ignorance
- podcast notes checked for idiolectal features (habitual, not an error)
- approximate 25% of submitted errors are removed, not true errors

Classification separate from data collection

- data analyst classifies each error with variables from standard taxonomies
- major class: unit, type of operation (e.g., substitution, deletion, etc.), direction
- ambiguity resolved with Occam's Razor (though alternatives retained as part of record)

SFUSED English interface



Record ID no.
Last Modified
Total Completed

Major Class Fields

Master Type
Altern. MType
Level
Type
Direction
Contextual? Y N
Right Lexeme? Y N NotAppl
Form Rule Violation? Y N

Specific Class Fields

Obvious Malapropism Y N NotAppl
Phonotactic Violation
Gradient Type
Prosody Type
Form Rules Type
Morpho Cats
Onsetless Syllable Source? Y N
Onset CC Source? Y N
Two Term Intervener
Transformation Type

Complex Processes-check all appropriate:
 Sub Del Stress Exch
 Add Shift Grad Blend

Example Fields

A: I don't allow my dog to get blood transfusions. B: Did you xxx oh //[sw]eaking of ah, /C[w]ist, Christ and science, there's a show on the history channel ...

	Intended	Error
Orthographic:	<input type="text" value="speaking"/>	<input type="text" value="[sw]eaking"/>
Phonetic:	<input type="text" value="'spikɪŋ"/>	<input type="text" value="'swikɪŋ"/>
Word Bounded?	<input type="radio"/> Y <input checked="" type="radio"/> N	Clipped? <input type="radio"/> Y <input checked="" type="radio"/> N
Source Different Talker?	<input type="radio"/> Y <input type="radio"/> N	Corrected? <input type="text"/>

Word Fields

POS:
Open/Closed
Regular/Irregular
Lexical Word?
NotAppl
Error-Intended Semantic Relationship
Error-Intended Morphological Relationship

Sound Fields

	Supplanted Intended:	Intruder:	Source Sound
CV Structure:	<input type="text" value="C"/>	<input type="text" value="C"/>	
Syllabic Role:	<input type="text" value="Onset"/>	<input type="text" value="Onset"/>	<input type="text" value="NotAppl"/>
Word Position:	<input type="text" value="Medial"/>	<input type="text" value="Medial"/>	<input type="text" value="NotAppl"/>
Whole Syllable:	<input type="text" value="spi"/>	<input type="text" value="swi"/>	
Error action is in:	<input type="text" value="Onset"/>		

Given Record Fields

Researcher
Found Date
File
Podcast
Time stamp
Online/offline
Talker Self?
Speaker Sex
Spreadsheet
Confidence Intended
Confidence Transcript.
Personal Info? Y N
Record Complete? Y N
Record Confirmed By:
 ja ak ld on

Identical Neighboring Seg? Y N
Syllable with error has:
 Main Stress Second. Stress No Stre
Phonologically Legal? Y N
Triggers Resyllabification? Y N

Markedness Measures

Onset (Initial) Satisfaction Violation No Change
NoHiatus Satisfaction Violation No Change
NoComplexOnset Satisfaction Violation No Change
NoComplexCoda Satisfaction Violation No Change
NoCoda Satisfaction Violation No Change
NoDiphthong Satisfaction Violation No Change

Advantages

Alderete & Davies 2018, Language and Speech

Reliability and data quality

- audio recording supports data collection separate from verification by another researcher
- with different collectors, can minimize collector bias and measure it if it exists
- audio recordings help in spotting idiolectal features and phonetic structures

Metrics

- audio recordings have a duration, with allows measures that are not possible with online collection, e.g., collection metrics
- supports much better estimates of speech error frequency
- using capture-recapture methods, we find that speech errors are much more frequent than reported in prior work (an error at least every 48.5 seconds, likely more frequent)

Data discovery

- audio recordings allow acoustic analysis, probe fine-grained phonetic detail
- can address frequent cry for “more context” (can be recovered)
- with a time metric, can investigate time-based effects like speech rate

Better sample of true population of speech errors

- sample has much higher coverage, likely three to four times better
- less ‘easy to hear’ and more ‘hard to hear’ speech errors
- collect more errors that occur in fast speech

Sample coverage: less 'easy to hear' errors

Online collection: direct observation, requires high degree of confidence
(Early stage in data collection had 1,100 errors collected online)

Offline collection: from audio recordings, can replay and listen to slow speech

Exchanges (swap of two elements, very easy to hear)

Ex. *We can just wrap mine in a **/torn /korkilla** (corn tortilla, 1495)*

	Offline	Online
Morphemes		6
Phrases		1
Sounds	1	25
Words	1	15
Totals	2 (0.38% of 533)	47 (5.6% of 839)

% Exchanges elsewhere:

Stemberger 1982/85: ~6%

Pérez et al. 2007: 35%

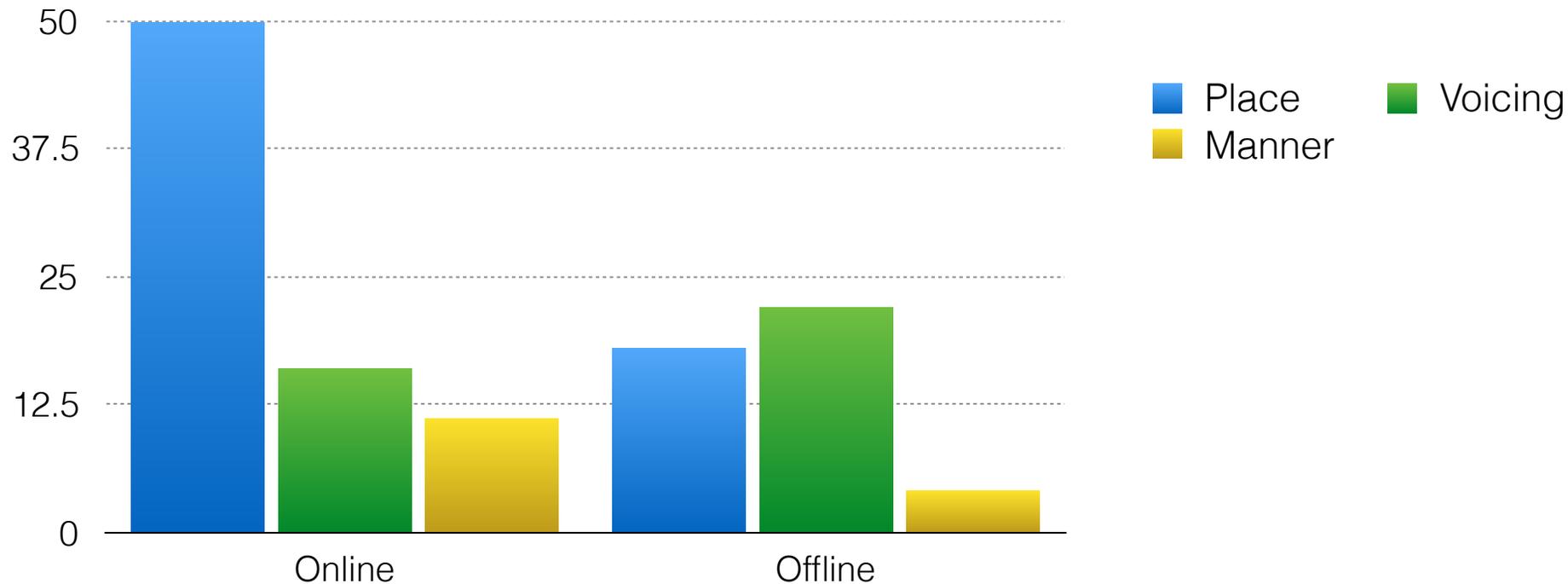
Dell and Reich 1981: 54%

Sample coverage: more 'hard to hear' errors

Finding: errors in mis-pronunciation are easier to detect in place of articulation than voicing (Cole et al. 1978).

Online: counts reflect this perceptual bias

Offline: counts don't reflect this bias; more voicing errors detected than place.



Summary of differences

*Alderete & Davies 2018
Language and Speech*

Sound errors

- Online errors have more corrected errors than offline errors.
- Online has a stronger repeated phoneme effect than offline errors.*
- Online errors have a stronger lexical bias than offline errors. (*)
- Online errors have a weaker word-onset effect than offline errors.*
- Online errors are more likely to be contextual than offline errors.*
- Online errors have more perseverations and exchanges than offline errors.*
- Online sound substitutions are more symmetric and more concentrated in a small number of substitutions than offline errors, which are more diffuse and asymmetrical.*

Word errors

- Online errors have less additions and deletions and more blends than offline errors.*
- Online word substitutions are much more likely to be in nouns than offline errors, which are more diffuse across lexical and function categories.*
- Online errors tend to respect the category constraint more than offline errors.

* = significant association from chi square test

How does methodology affect data composition?

How phonologically regular are speech errors in SFUSED English?

English phonotactics

Guiding assumption: a word is phonotactically licit if it can be syllabified within a well-formed syllable of English (Kahn 1976, Giegerich 1993, Jensen 1993)

Onset	Peak	Coda
(s)(C1)(C2)	X4 (X5)	(C6)(C7)(C8)(C9)

Conditions:

All C positions are optional.

Banned C1: *ŋ ʒ*, Banned Codas: *h, j, w*.

Onset clusters: obstruent + sonorant

Appendix + C, C always a voiceless stop, *sf* rare/loans

Banned onset clusters: vd fric/affricate + sonorant, labial + *w*, coronal nonstrident + *l*,
θw fjV fw fl sr sh gw stw skl

Onglide *j*: part of peak because of limited distribution, but cannot occur in *CCju* cluster.

Coda clusters X5+C6: falling sonority (r > l > nasals > obstruents) and *s + p t k*; *lg* is banned.

C7-9 are appendices limited to coronal obstruents

Nasal + obstruent clusters agree in place and the obstruent is voiceless.

Tense vowels and diphthongs are bimoraic (fill X4 and X5), lax vowels are short fill X4.

Stressed and final syllables are bimoraic (lax vowels occur in closed syllables) and all syllables maximally trimoraic (syllables tense vowels only have simple codas)

Results: illustrations of phonotactic violations

Alderete & Tupper 2018
WIREs Cognitive Science

Substitutions

Illicit onsets/appendices

1500 ... by the maps at the ^selection /**[ʃkrin]** (screen)

5739 ... they shoot, /**[ʒu]** shoot The Thick of It ... (you)

Illicit codas/rimes

1245 ... Their HOV /**[laɪŋ]** xxx lane is like one driver (lane)

5898 Vin Diesel got kicked off of /**Rei[ŋ]**deer Games ... (reindeer)

Nonnative sounds

5964 ... first of all, Katrina /**[kly]**= clearly defined (clearly)

Additions

Illicit onsets, appendix + onset

49 ... get the Ferrari down a /**[flju]** xxx few ^floors? (few)

1278 I don't like the ^/**vriral** ^marketing. (viral)

5599 ... talking a ^dream, what that ^dream /**[mr]**eans ... (means)

Illicit codas/rimes

1526 The ^person /**[keɪmp]** ^up to the desk.

(SFUSED record ID # on left)

Results: illustrations, cont'd

Deletions

3954 ... Lisa, /**S**reech and Lisa. (Screech)

8943 ... I think you're a /**h**u[**ŋ**ə]= hunk-a-rama.

Exchanges

4581 ... the children in the trailer for /**M**oon[ra**ŋ**] /**K**eez= Moonrise Kingdom.

Sequential Blends

4453 ... A diary is a /**[sb]**ook xxx a very special book.

5278 ... you can't quite /**[pjɪrt]** xxx put your finger on.

7211 ... because we /**[spɪlkf]** xxx we, we speak film

Word Blends

870 /**[sastæ]** makes me frisky. (pasta, sauce)

7120 Top ten /**th**ways to make me cry (things, ways)

7270 ... /so[**m-bw**ʌn-di] xxx uh in the ... (someone, somebody)

Results by error type

Observations: % of phonotactic violation differs by type, but overall % of irregularity much higher than 1% found in Stemberger's corpus.

Error type	Example	<i>N</i>	Violations	% of <i>N</i>
Substitutions	pleep for <i>sleep</i>	1,376	44	3.20
Additions	bluy for <i>buy</i>	358	33	9.22
Deletions	pay for <i>play</i>	169	3	1.78
Exchanges	heft lemisphere for <i>left hemisphere</i>	37	2	5.41
Shifts	<i>splare backforests</i> for <i>spare blackforests</i>	7	0	0.0
Sequential Blends	Tennedy for <i>Ted Kennedy</i>	57	4	7.02
Word Blends	tab for <i>taxi/cab</i>	72	4	5.56
<i>Totals</i>		2,076	90	4.34

Perceptual bias: missed phonotactic violations

Conjecture: Cutler 1982, Shattuck Hufnagel 1983 point out that there is probably a perceptual bias against phonotactic violations. Listeners may regularize them or simply fail to hear them.

Probe: Alderete and Davis 2018 used balanced sample of online vs. offline errors and found a significant association between methodology and regularity ($\chi(1)^2=7.902$, $P=0.0049$).

	Offline	Online
Phonotactic Violations	17 (3.19%)	8 (0.95%)
No Violations	516 (96.81%)	831 (99.05%)

Perceptual bias: all sound errors

Conjecture: Cutler 1982, Shattuck Hufnagel 1983 point out that there is probably a perceptual bias against phonotactic violations. Listeners may regularize them or simply fail to hear them.

Probe: counting all sound errors and blends, % of phonotactic violations higher ($X^2 = 16.9618$, $p < .05$); note effect does not depend on what counts as a violation.

		Offline	Online
Phonotactic Violations	Phonotactic Violations	76 (5.5%)	11 (1.6%)
No Violations	No Violations	1,326 (94.5%)	660 (98.4%)

Overwhelmingly regular, but above chance?

Question: the lower standard of phonological regularity raises the question of whether it is significantly above chance levels; intended words are regular, so perhaps just commitment to speech plan is enough.

Permutation test (see Dell & Reich 1981)

1. Randomly permute segments from a list of intruder segments (given from error corpus), holding constant the phonological context (i.e., segments selected independent of context)
2. Use multiple trails to obtain a distribution of the percentage of regular errors under the independence assumption.
3. Test to see if there is sufficient evidence to reject independence hypothesis.

Example: C1 slot in substitutions

1. Take all intruders in C1 slot of C1C2 complex onsets in the error data, randomly permute them in the same slots they occur in errors.
2. Permute segments of C1 randomly many times, get an average rate of phonologically regular words
3. Compare with actual errors in C1 of C1C2 errors to see if deviate significantly.

Results: some, not all, above chance

Finding: in both substitution and addition errors, significantly above chance in non-initial positions (C2 of cluster), but not above chance initially (C1 of cluster)

Type	Context	Example	<i>N</i>	Actual	Random	Significant?
Substitutions	<u>_</u> C of <u>CC</u> _{Onset}	<i>blue</i> → <i>plue</i>	37	81%	78%	No (p=0.38)
	C_ <u>_</u> of <u>CC</u> _{Onset}	<i>dream</i> → <i>dweam</i>	36	100%	83%	Yes (p=1e-6)
Additions	<u>_</u> C into <u>CC</u> _{Onset}	<i>last</i> → <i>flast</i>	29	62%	64%	No (p=0.77)
	C_ <u>_</u> into <u>CC</u> _{Onset}	<i>bad</i> → <i>brad</i>	75	87%	79%	Yes (p=0.005)

Interpretation:

- Non-initial contexts require analysis; ‘structural matrix’ of some kind to predict above chance level.
- C1 errors are dominated by errors that occur word-initially, so could be an effect of the word-onset bias (Wilshire 1999)

Discussion: comparison with SRN

New standard: 93-95% phonologically regular, cf. 99% of Stemberger 1983, (94.5% regularity reported in offline data still probably affected by perceptual bias)

Goodness of fit: Dell et al. 1993 simple recurrent network tested a variety of parameters that compare well with these findings.

- Models trained on frequent vocabulary and with both internal and external representations: **96.3% regularity**
- Range for other assumptions about input: **89-95% regularity**
- Many of the errors with phonotactic violations resemble the phonotactically illicit errors we have found, with illegal clusters and initials.
- Model also predicts more errors word-initially, so accounts for contextual differences in permutation test
- SRN also predicts more errors word-initially, because no prior probability to predict future sounds

Limitations

- Model trained only on three segment words, so no polysyllabic words
- Didn't really allow for additions, which account for a lot irregularity (perhaps 1/3)
- Phonotactics slightly different than one used here (likely less stringent).
- Didn't account for prosody (stress in errors) and other structures.

Take home: with the new standard, tactic frames (cf. syllable templates) are not obviously necessary to the analysis of phonotactic regularity in speech errors.

Take homes

New standard for regularity: errors of phonological encoding are phonotactically regular about 94-95% of the time (cf. prior standard of 99%).

Methodology: this new standard is documented using methods less prone to bias; so lower standard is likely the result of perceptual bias.

Grammar in phonological regularity? Syllable structure templates do not seem to be necessary to overall phonological regularity. Models of phonological encoding without them seem consistent with the fact.

Implications for speech production models

Ingredients of a sufficient model

- Output bias for frequent sounds (consonant substitutions)
- Output bias for frequent sequences (general phonotactics)

Models that meet these criteria

- SRN of Dell et al. 1993
- Original Dell-net of Dell 1986 (with some overkill)
- Harmonic Grammar with weights for important constraints (Goldrick and Daland 2009, also Smolensky et al. 2014)
- Two step interactive model (Dell et al. 1997)

Explanation of frequency effects

- Stems from interactivity in lexical network: type frequency effects a direct result from links to actual words.
- Frequency from learning: repeated exposure to words re-enforces associations between plan and sequence.

Implications: but we still do need syllables ...

Missing: explicit syllabification algorithm for organizing segments in a frame.

Roles for syllables in phonological encoding:

Syllable position constraint (Boomer and Laver 1968, Fromkin 1971)

Onsets slip with onsets, codas with codas, etc.

Syllable errors in languages like Mandarin (Chen 2000)

Whole syllables slip at rates greater than expected by chance (probably only in languages with very small syllabaries)

Masked Priming (Ferrand, Segui and Grainger 1996, cf. Schiller 1998)

Shorted masked syllables speed up picture naming if exact syllable in test word.

Implicit priming (Chen, Chen, Dell 2002, cf. Meyer 1991)

Syllables implied in production planning because facilitate picture named in cued recall experiments (may be a language particular effect).

Syllables are stored

Common assumption: Syllables can be stored in the mental lexicon without being actively generated in tactic frames. Assumed in most models built off the Dell (1986) spreading-activation model, and some have argued that languages like Mandarin actually represent and select syllables in phonological encoding — see O’Seaghdha et al. 2010 on the proximate unit hypothesis.

Syllable position constraint: filler-role bindings from Legendre and Smolensky 2006, syllable position a kind of similarity effect.

Syllable errors and implicit priming in Mandarin: syllables are stored and selected in phonological encoding (see ‘proximate unit’ hypothesis of O’Seaghdha et al. 2010)

Masked priming: if syllables are stored, then should prime later words that have identical syllables.

Conclusion: while a syllable template does not appear to be intrinsic to phonological encoding, syllables seem to be necessary representations in the mental lexical and production planning.

Part 2 tomorrow: Université Paris Diderot

Markedness

- Markedness is “the stuff” of most grammars in contemporary phonology. If we could find a role for markedness, this would be a clear role.
- Focus is on cross-linguistic markedness, not language particular markedness relations, because latter is hard to separate from frequency.

Segmental markedness

- Aphasics: Blumenstein 1973: single feature consonant substitutions favour marked → unmarked mappings
- Experimentally induced speech errors have been argued to have a role for markedness (Kupin 1982, Goldrick 2002)
- Against segmental markedness: some collections of naturally occurring speech errors argued not to be shaped by markedness.

Syllable structure markedness

- Frequent observation in aphasic speech that errors resolve clusters (Blumstein 1973, Romani and Calabrese 1999)
- Onsets vs. codas: Goldrick and Rapp 2007: brain-damaged subject with deficit in post-lexical phonological processes found to be more accurate with onsets (96%) than codas (91%)
- Sonority dispersion: Romani and Calabrese 1999, Romani et al. 2002: syllable structure in aphasic speech reduces syllable complexity, including increasing the sonority dispersion from onset to peak (e.g., ka > la)

Contributors to SFUSED



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Why are we still collecting speech errors?

Problem: speech errors 'in the wild' are very time-consuming, prone to mistakes in observation and interpretation; often can't get enough data from a particular pattern to test specific hypothesis.

Stemberger 1992: there is considerable overlap in the patterns of errors collected in naturalistic and experimental settings. So speech errors 'in the wild' present valid data patterns worthy of analysis.

Some patterns not suitable for experimental study: % of exchanges, lexical bias, non-native segments, phoneme frequency effects, etc.

This research shows that a new approach to data collection (offline, many listeners), has potential for new observations, e.g., phonological regularity

Large databases can be re-purposed and extended, not really true of experiments.

Offline methodology is actually very efficient (see Alderete & Davies 2018 for research costs estimates); can produce a database of 3,000 errors in about the same amount of time it takes to run two experiments.

Idiolectal features are very important in understanding errors (habitual, so not an error), but can only really analyze them after a few hours of listening to a single talker.

Estimating error frequency

*Alderete & Davies 2018,
Language and Speech*

Prior assumption: speech errors are rare in general (**error every 5-6 minutes**), motivates focus on normal language production

Problem: prior estimates of error frequency based on online collection, and many failed to address the fact of missed errors (though all studies concede they miss them).

Capture-recapture: common tool in ecology for estimating a population when exhaustive is impossible or impractical

Take home: speech errors occur much more commonly than enumerated in prior research, at least as often as **48.5 seconds** (upper bound because of non-homogeneity)

Second	A	B	C	AB	AC	BC	ABC	n	\tilde{m}	\tilde{v}	SPE
2,100	2	18	3	2	0	3	5	33	16.3	49.3	42.60
1,690	6	5	4	5	0	2	9	31	13.48	44.48	38.00
1,993	2	9	5	1	0	1	5	23	20.08	43.08	46.26
2,385	6	6	5	8	2	1	5	33	11.7	44.70	53.36
4,143	24	9	1	5	1	1	3	44	21.84	65.84	62.93
3,000	9	2	7	3	5	1	2	29	10.63	39.63	75.70
1,800	9	9	3	2	0	1	1	25	29.87	54.87	32.81
2,377	15	2	4	3	2	1	3	30	13.39	43.39	54.78
2,400	18	4	6	1	2	0	7	38	41.93	79.93	30.03