

Does order matter?

Numquam ponenda est pluralitas sine necessitate

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Acknowledgment



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Why am I speaking about phone order in honoring Didier?



Didier has always looked closely at the phonetics of speech, often applying the phonetician's equivalents of a microscope in his investigations. Today, I will talk about how essential is phonetic detail in parsing the stream of speech, because the abstract constraints on phone order represented by one language's phonotactics fail to capture the observed limits on phone order in its lexicon. Far fewer words differ in the order of their phones than are permitted by the phonotactics, and lexical access is not constrained by phone order. Order is instead recoverable from the acoustic consequences of articulatory coordination and coarticulation, i.e., from the phonetic detail that Didier's investigations have emphasized.

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Phones assimilate perceptually to following phones, contrast with preceding phones.¹

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¹Rysling, Jesse, and Kingston 2019.



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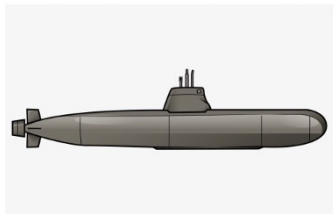
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When order does not matter: Eye tracking²

When hearing [b2s] *bus*, listeners look at a picture of its anadrome [s2b] *sub*



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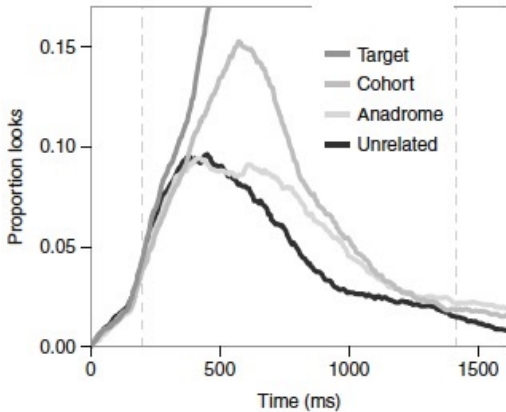
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²Toscano, Anderson, and McMurray 2013.



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When order does not matter: Eye tracking²



*why don't listeners confuse words with their anadromes?
... fine-grained phonetic detail could serve as a proxy for
temporal order. The acoustic forms of consonants vary with
syllable positions ... a fine-grained description of sub will
di er from that of bus, even if phoneme order is ignored. p.
986*

²Toscano, Anderson, and McMurray 2013. A set of small navigation icons including arrows, a square, and a magnifying glass.

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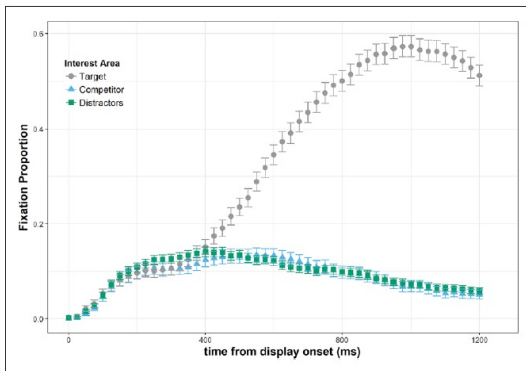
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Organization of phones into syllables is respected³



Listeners don't look at [lif] *leaf* when hearing [fli] *flea*



³Gregg, Inho, and Connine 2019.

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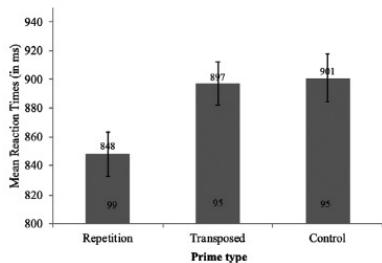
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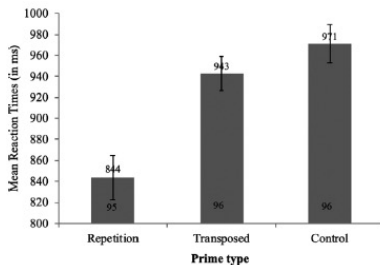
When order does not matter: Primed lexical decision⁴

Prime [byt] *butte* does not facilitate lexical decision for target anadrome [tyb] *tube* when prime and target are in successive blocks (Exp. 1), but does do so when the target occurs 20 ms after the prime (Exp. 2)

Experiment 1



Experiment 2



⁴Dufour and Grainger 2019.

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- 1 Eye tracking and immediate priming show consonants do not remain strictly ordered relative to vowels in CVC strings in pre-lexical representations,
- 2 Is there any grammar here? To what extent is phone order predictable from the phonotactics?
- 3 Recall that hearing *flea* doesn't produce looks to *leaf*.

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How typical are *cat*, *tack*, and *act* or *leaf*, *feel*, and *flea*?



- 1 How often does transposing consonants produce another word, e.g., *bus* *sub*?
- 2 How often do words differ in the order of their phonemes alone?
- 3 How much does phonotactics limit the possible orders of phonemes?
- 4 How many phoneme orders are actually words within the orders permitted by the phonotactics?

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First step

- 1 Extracted the 8429 one-syllable words from IPhOD2,⁵
- 2 7101 after collapsing homophones; discarded:
 - a 12: just 1 phoneme,
 - b 251: more than 5,
 - c Maximum: 8;
- 3 # phonemes – # words – # permutations (= $n!$):
 - a 2 – 293 – 2,
 - b 3 – 2108 – 6,
 - c 4 – 2978 – 24,
 - d 5 – 1459 – 120;
- 4 Possible words = all phonotactically permitted⁶ permutations of phonemes,
- 5 For each word, how many possible words derived by permuting its phonemes are actual words?

⁵Vaden, Halpin, and Hickok 2009.

⁶Hammond 1999.

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Possible-Actual-Difference

For each phoneme string that is a word

- 1 Possible: Number of phoneme permutations that are permitted by the phonotactics,
- 2 Actual: Number of permissible permutations that are words,
- 3 Difference: Possible - actual = shortfall.



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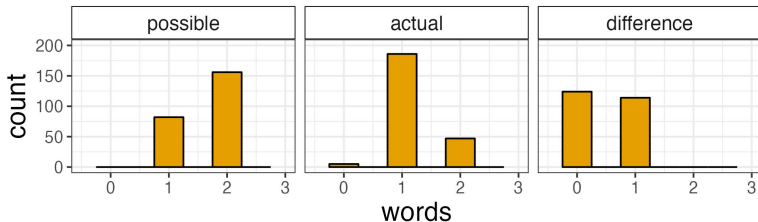
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2 (2 permutations)



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The lexicon falls short

For any given word/number of phonemes

- 1 The number of permutations of its phonemes that make **possible** words is reliably more than one,
- 2 The number of possible words that are **actual** words is most often just one, i.e., the original word itself,
- 3 The difference between the number of actual and possible words is most often one or two,
- 4 cat, tack, and act = all **possible** permutations of /k/, /æ/, and /t/ = **actual** words, are very rare, not typical.

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- 1 Lexicon: Irregular properties of words (morphemes),
Lexicon 1 - out-of-time, underlying representations,
Lexicon 2 - real-time, word-recognition or word-production,
ne-grained, phonetic detail;
- 2 Phonotactics (grammar): Regular properties,
Phonotactics 1 - out-of-time, abstract mental grammar,
Phonotactics 2 - real-time parsing grammar, which governs
the performance of a speaker or listener;
- 3 Strict division of labor (strongest hypothesis) Phonemes can
be unordered in many lexical (2) entries, because phonotactics
(2) partially regulates their order, c̄.

⁷Cairns 1988; Golston 1996.

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- 1 Yet lexicon (2) **underuses** the orders permitted by the phonotactics (2),
- 2 Only some densely used phonemes *e/ɪæt/, /ækt/, /tæk/* require storage of order information,
- 3 Less completely used phoneme combinations don't require storage of order information, because not all alternative orders are used,
- 4 Phonotactics (2) is learned as words are learned, but acquires independence⁸.

⁸McQueen 1998.

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- 1 English phonotactics (1) is permissive relative to many (most?) other languages: Is its permissiveness responsible for the inefficiency of its lexicon (2)?
 - 1 So many phonotactically licit orders not used,
 - 2 But using all of them would require listeners to attend to order information earlier in processing;
- 2 Perhaps, listeners only need to attend on-line to order information in densely used phonemic groups, /lkeət/, /ækt/, /tæk/ ,
- 3 Less densely used phonemic groups, - e/loes/, */æsb/, */sæb/ - can find their order from the parsing grammar, i.e., phonotactics (2).

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Why might the lexicon underuse phone order?

- 1 Acoustic information regarding articulatory coordination and coarticulation might be all that conveys phone order,
- 2 That information might be ephemeral, i.e., soon unavailable,
- 3 Context does not rule out lexical competitors, nor reliably facilitate the contextually appropriate choice.⁹

⁹Marslen-Wilson 1987.

References I

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Does order matter?

Kingston

When order does matter

When order does not matter

Lexicon

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References

Appendix:
Probabilistic phonotactics

Probabilistic phonotactics¹⁰

Frequency-weighted mean phoneme probability

Does order matter?

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When order does matter

When order does not matter

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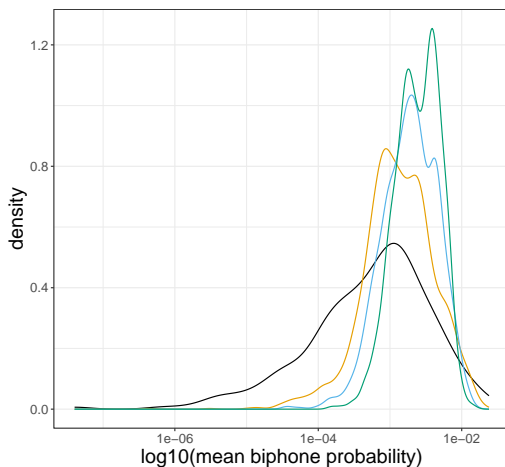
References

Appendix:
Probabilistic phonotactics

¹⁰Vitevitch and Luce 1998; Vitevitch and Luce 1999.

Probabilistic phonotactics

Frequency-weighted mean biphone probability



Number of phones 2 3 4 5

Does order matter?

Kingston

When order does matter

When order does not matter

Lexicon

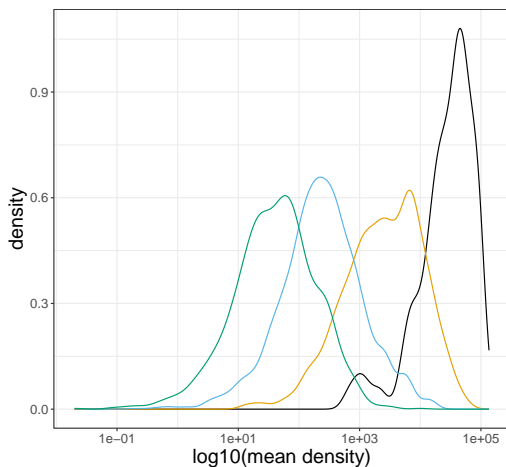
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Appendix: Probabilistic phonotactics

Probabilistic phonotactics

Frequency-weighted neighborhood density



Does order matter?

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When order does matter

When order does not matter

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Appendix: Probabilistic phonotactics