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Phonological similarity relations and the emergence of sublexical units

Network organization of the lexicon and phonology

Encuentro Internacionál de Lingüística en el Noroeste 8
November 2004

Questions&Answers

- 1) What words are stored close to each other in phonological space, i.e. are strongly associated based on phonological similarity?
- Words that share many and differ by few
  - segments
  - syllables
  - syllabic constituents
  - stretches of speech?

- 2) Do hearers pay more attention to units in some positions inside the word than to those in other positions?
  - Word-final >> word-initial >> medial close to word beginning >> medial close to word end

- 3) Is the perceptual salience of some units affected by position inside the word differently than the perceptual salience of their parts?
  - Segmental, constituent-level, and subsegmental emergent units

I

What words are stored close to each other in phonological space?

What are the units of similarity?

Length of matched and mismatched stretches of speech

- Vitz and Winkler (1973), Derwing and Nearey (1986), Bendrien (1992): words that differ by two segments are perceived to sound less similar than words that differ in one segment even when words that differ in one segment differ by more features, e.g. se**f**-se**n** place+manner+voice+nasal vs. **sef-tep** place+manner
- The SSJ (Sound Similarity Judgment) task (Greenberg and Jenkins 1964): subjects are presented with a pair of words and asked to rate them on how similar they sound to each other
- Problems: sek-sen sen-tef
  - all studies used naturalistic monosyllabic CVC stimuli

  → words that differ by two segments also
    - Differ by two syllabic constituents
    - Have a discontinuous mismatched stretch of speech
    - Contain mismatches at two word boundaries
    - Differ by longer stretches of speech in terms of temporal duration

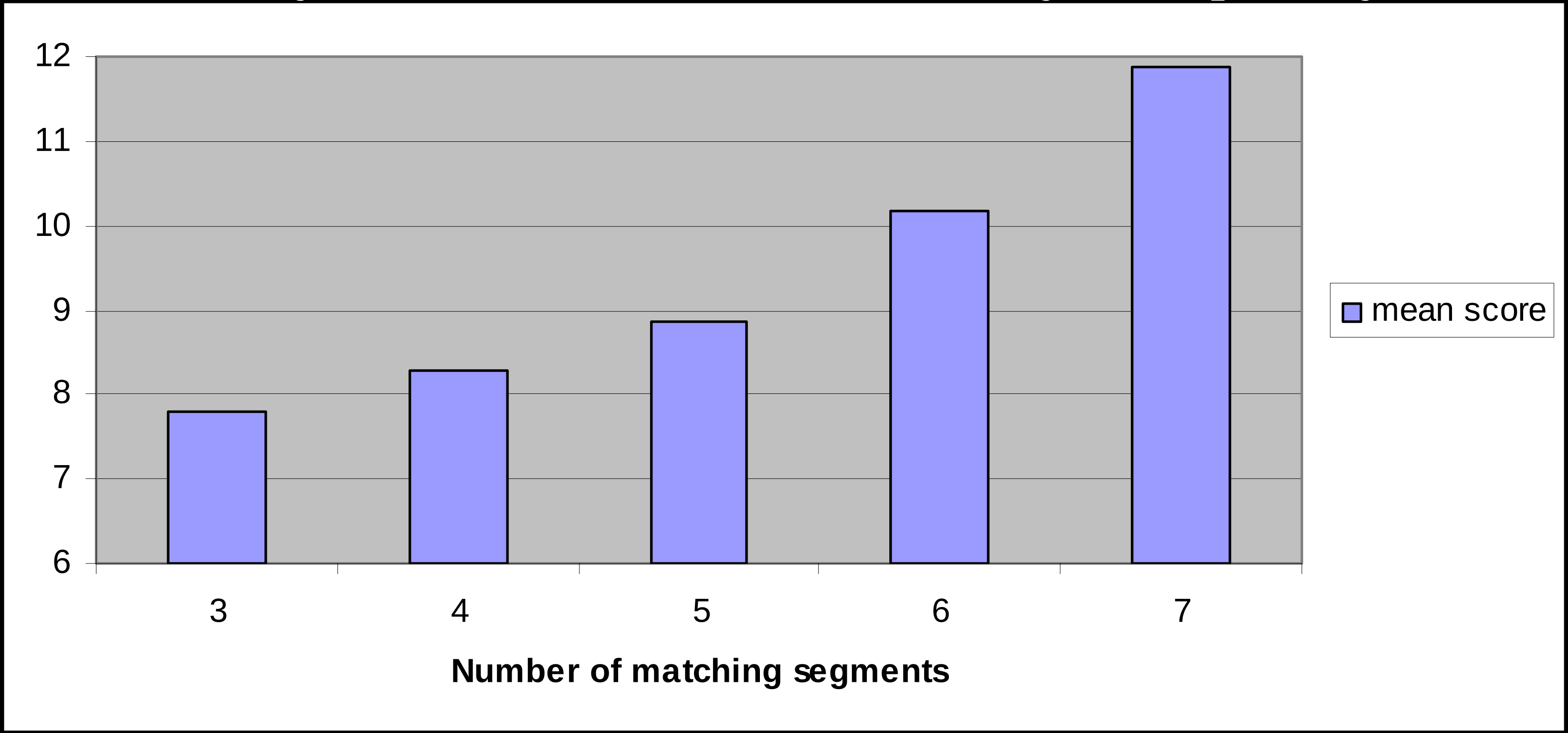
Thus the findings do not necessarily offer support for the segment as a unit of similarity.

Length of matched

- Sound similarity judgments
- 36 native English speakers
- 164 pairs of nonsense, phonotactically legal bisyllabic words that differed from each other by two segments
- All consonant clusters by which words in a pair differed had high type frequency in all positions in bisyllabic words in the Switchboard Corpus (Godfrey et al 1992)
- An ANOVA where length of matched competed against participant identity and a variable comprising the influence of position of mismatch relative to word boundaries, number of mismatched syllabic constituents, number of mismatched syllables, mismatch onset, number of mismatched consonants that belonged to consonant clusters, and continuity of the mismatched stretches of speech

Length of matched: results

Larger score = greater perceived similarity
21 = the same, identical;
1 = don't share any sounds at all, as dissimilar as they could possibly be



P=0.000, F=7.896

Thus two words are more similar if they contain longer matched stretches of speech and shorter mismatched stretches of speech

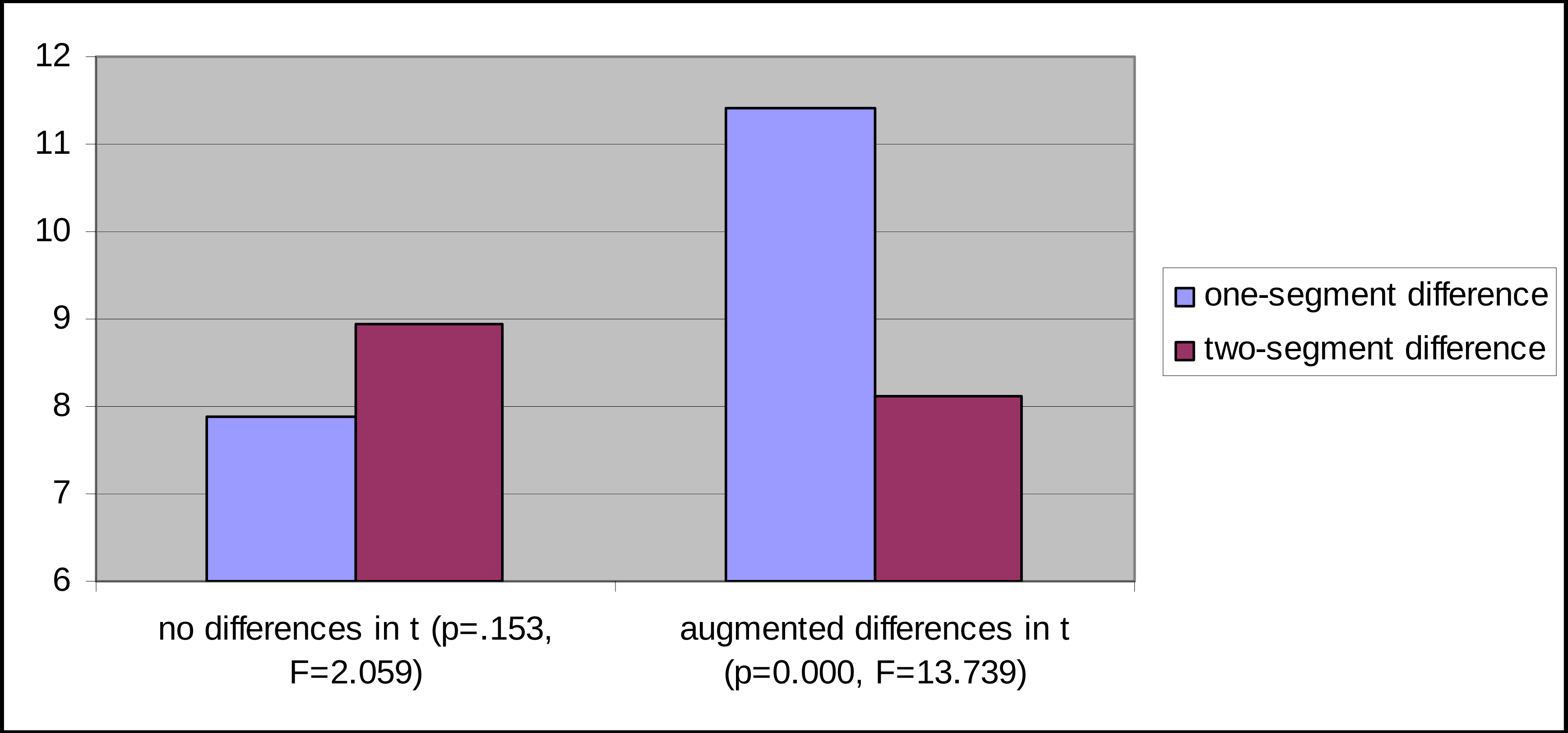
Number of segments or temporal duration? Methods

- Sound Similarity Judgments
- 68 native English speakers
- Stimuli
  - → differ by two contiguous segments
  - → differ by one segment
- For 37 subjects, the temporal duration of the mismatched stretches of speech was altered so that mismatched stretches of speech were always the same length (15ms) regardless of how many segments they contained. All stimuli were altered, regardless of how many segments they differed by.
- For 31 subjects, the temporal duration of mismatched stretches of speech that contained two segments was increased to 40ms while that of stretches of speech that contained one segment was decreased to 7ms

Number of segments or temporal duration? Methods

- Same stimuli were used in both conditions
- In each group of subjects, 7 subjects were asked to write down the stimuli
- Only stimuli whose written versions corresponded unambiguously to the same pronunciation for all 14 control subjects in both conditions were used for further analysis (N=8) thus the results are not due to misperceiving the mismatched segments
- All of the stimuli were matched in length and temporal duration of matched stretches of speech
- Stimuli in each pair differed from each other in nasality, voice, place, and manner

Number of segments or temporal duration? Results



Temporal duration of mismatched stretches of speech, not number of mismatched segments determines degree of perceptual similarity between two words. Note also that words that differ by one segment are perceived to be more similar if the segment is acoustically shorter but phonologically identical (p=.000, F=24.022).

Implications

- Phonetic detail is stored with words for several seconds at least and is used to compare a word to other words situating it in the mental lexicon
- This finding supports exemplar models of categorization (e.g. Pierrehumbert 2002) where details about a word's pronunciation in a particular context are stored in the lexicon and a word type is represented by a whole set of phonetically specific exemplars

II

Do hearers pay more attention to units in some positions inside the word than to those in other positions?

Bathtub effects

- Aitchison (1987): beginnings and ends of words are recalled easier than their middles
- Brown and McNeill (1966): read definitions of uncommon words, ask for the word, in a TOT state, subjects named similar words that shared beginnings and ends but not those that shared middles (replicated by Koriat and Lieblich 1974, Rubin 1975, Browman 1978)

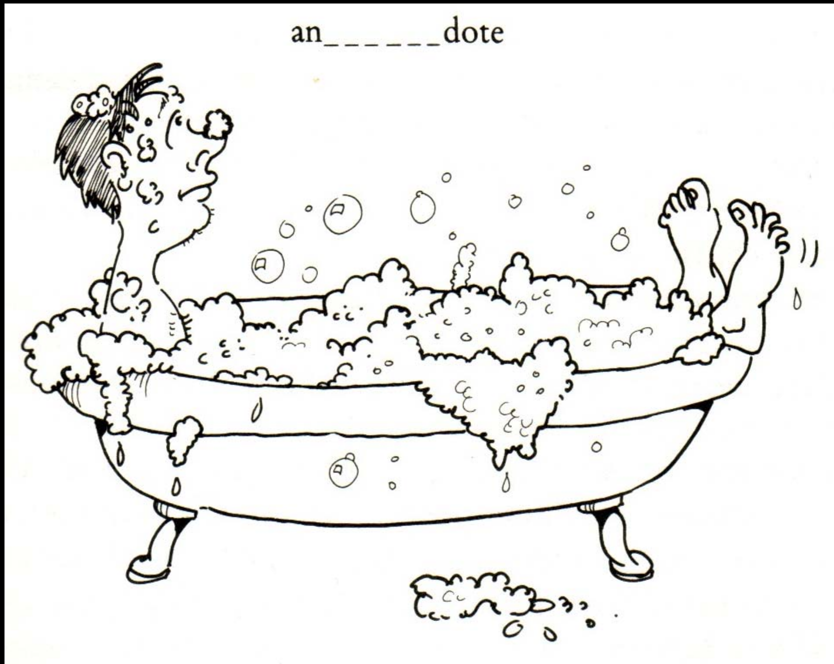


Figure 11.1 The bathtub effect

•Tweney et al (1975), Fay and Cutler (1977), Hurford (1981), Aitchison and Straf (1981): in malapropisms, confused words typically share beginnings and endings

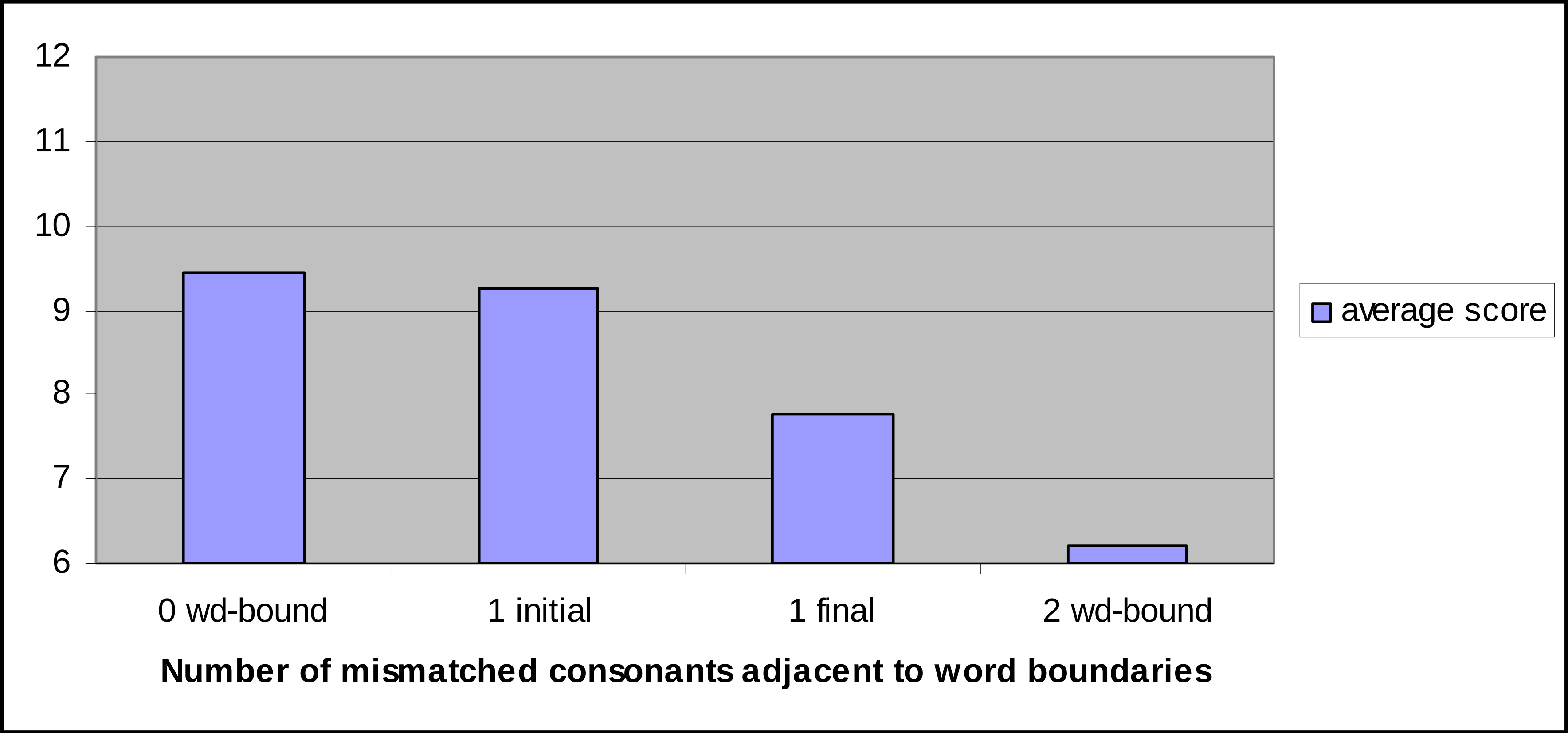
•Question: Is this effect due to how prominent word edges are in perception? Do listeners pay more attention to word-boundary-adjacent sounds?

Methods

- 36 native English speakers
- SSJ
- Length of matched entered as an independent factor into ANOVA
- Bisyllabic stimuli differing in 2 segments
- Mismatches in
  - 1) word-medial C and a word-final C
  - 2) word-medial C and a word-initial C
  - 3) word-initial C and a word-final C
  - 4) two word-medial C's
- Control: number of mismatched segments, number of matched segments, number of segments in consonant clusters, number of syllabic constituents, number of syllables, type of mismatch

Figure 11.1 The bathtub effect

Bathtub results



The difference between pairs with no mismatched consonants adjacent to word boundaries and pairs with a mismatched word-initial C was not significant. All other differences are significant at the 0.0005 level.

Perceptual prominence/attention allocation:

Word-final > Word-initial > Word-medial

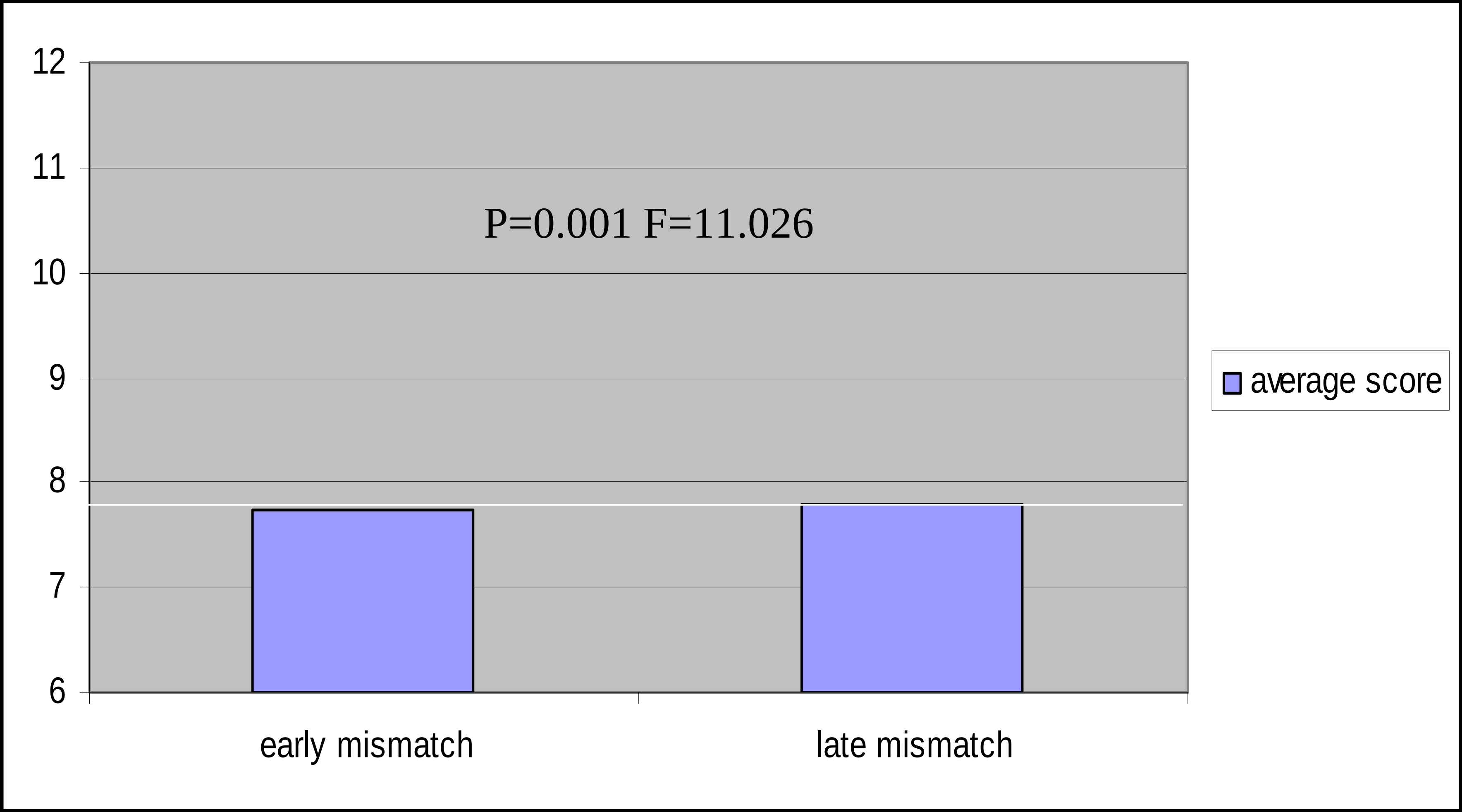
What comes in and out of the bathtub: Interactions with morphology

- Albright and Hayes (2003) have shown that a model that is equally sensitive to differences between words in all positions inside the word cannot fully acquire the distribution of competing English past tense patterns
- Slobin (1973): synonymous suffixes and sentence-final particles are learned before prepositions and preposed articles with the same meaning;
- Perceptual sensitivity to word-final C reflected in the bathtub effect would allow children to zero in on phonemes that are most informative for acquisition of suffixing morphology (Slobin's Operating Principle A).
- On the other hand, sensitivity to word-final C may be a consequence of the greater productivity of suffixation in a language in that children learn to attend to what is most informative in the language they are exposed to.

Cohort effect

- Marslen-Wilson (1990/1995): In lexical access, hearers access all words consistent with the input so far (a cohort) and then narrow it down as more input becomes available
- Mismatches beginning early might have a greater effect on phonological relatedness between two words
- Test:
  - Mismatches involving a non-initial consonant that is part of the word-initial cluster and the word-final consonant vs. mismatches involving a consonant that is part of a medial cluster and the word-final consonant
    - E.g. drE**k**souk**s** – drE**p**souk**t**, vs. s**p**Erpaik**s** - s**k**Erpaik**t**

Cohort (mismatch onset) effect



The effect is very small but significant.
Thus we should refine our hierarchy of attention allocation:
Wd-final >> wd-initial >> close to wd beginning > close to wd end

I

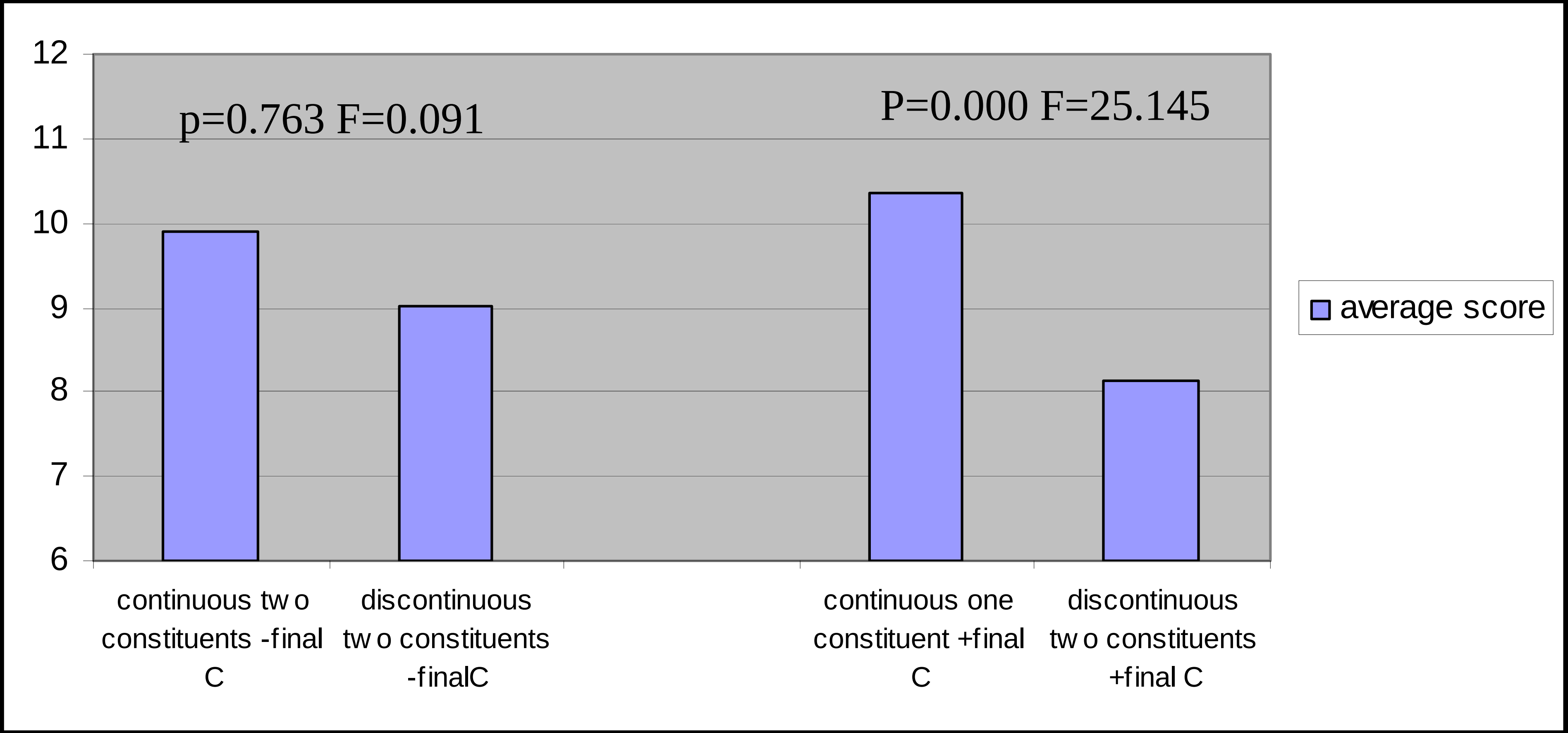
What words are stored close to each other in phonological space?

What are the units of similarity?

Contiguity of segments or number of syllabic constituents?

- Mismatch in two contiguous segments within a single syllabic constituent vs. mismatch in two contguous segments in two syllabic constituents (N=40)
  - E.g. eklipt-ekliks vs. eksern-eptern
  - Problem: counteracting salience of final C
- Mismatch in two contiguous segments within a single syllabic constituent vs. mismatch in two non-contiguous segments in two syllabic constituents (N=40) with final C containment controlled
  - E.g. eklipt-ekliks vs. eskent – espens
- Mismatch in two contiguous segments in two syllabic constituents vs. mismatch in two non-contiguous segments in two syllabic constituents (N=40) with final C containment controlled
  - E.g. meksern-meptern vs. peksern-tektern

Contiguity vs. number of constituents

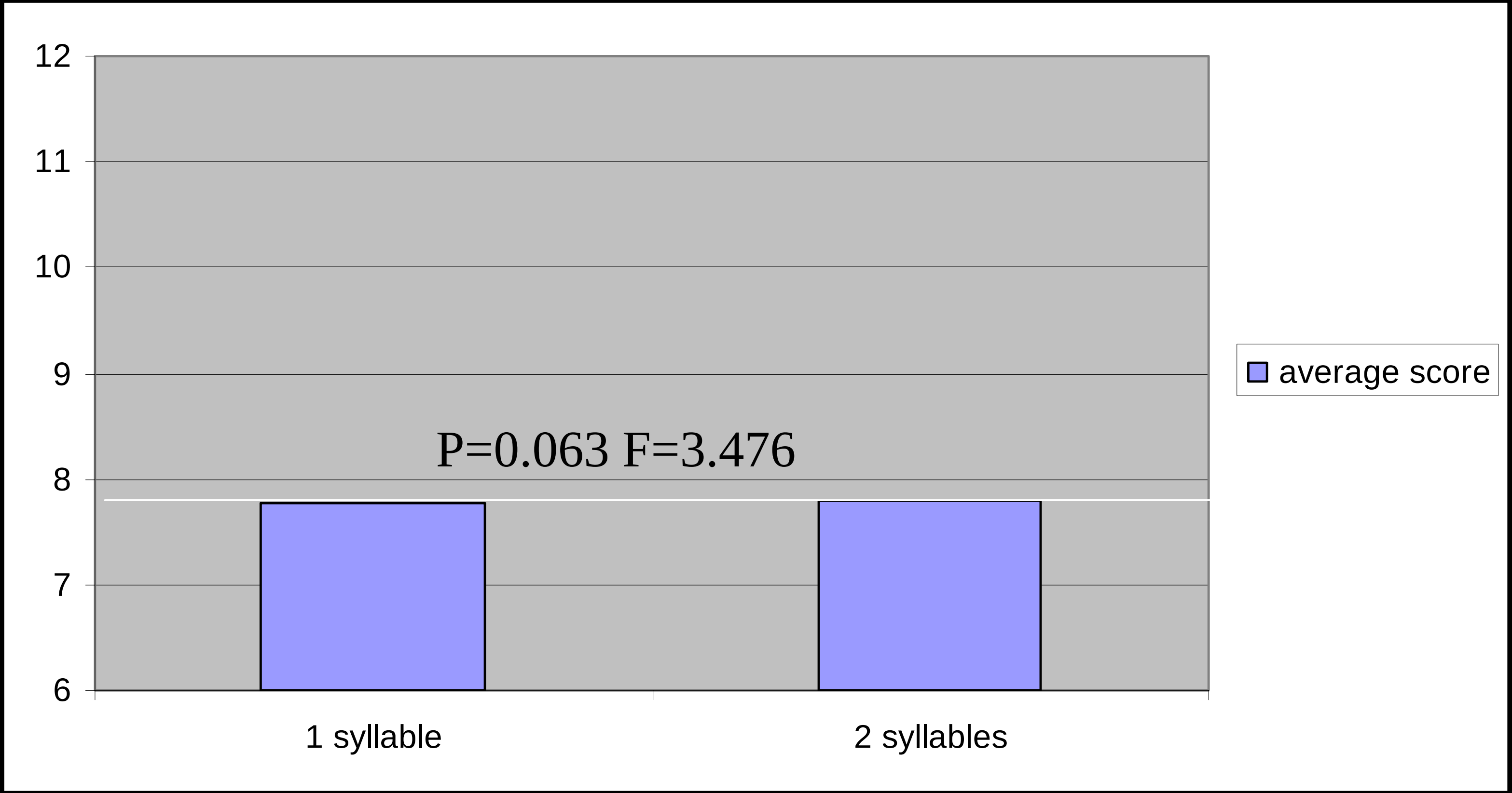


Thus number of mismatched syllabic constituents does have an effect on perceived phonological similarity while contiguity of mismatched Segments appears to have no effect. However, we still don’t know whether number of syllabic constituents or number of syllables is responsible.

Syllabic constituents or syllables?

One syllable vs. two syllables with two non-contiguous mismatched segments in two syllabic constituents, neither of which contains the word-final consonant.

Effect of number of mismatched syllables



The results are not significant and not in the direction predicted by the hypothesis that the greater the number of mismatched syllables, the lower the perceived similarity.

Thus the differences between groups of stimuli in perceived similarity must be due to the number of mismatched syllabic constituents (cf. Bailey and Hahn 2001).

Implications

- Sublexical units differ in their importance to the hearer: on the vertical, hierarchical dimension, hearers pay much attention to syllabic constituents, less to segments and syllables
- On the horizontal, sequential dimension, hearers pay much attention to word-final consonants, less to word-initial ones, still less to word-internal consonants close to the beginning of the word and even less to word-internal consonants close to the word's end
- Differences in prominence may be related to how important the various units are for acquisition and execution of various cognitive tasks, such as lexical access, segmentation, and the acquisition of morphology

III
Is the perceptual salience of some units affected by position inside the word differently than the perceptual salience of their parts?

Emergence of sub-segmental units and a model of similarity judgment

- Hypothesis:
  - features are nodes in a localist associative network
  - connected by links strengthened based on co-occurrence
  - allowing more activation to flow between them
  - and for subsegmental, as well as segmental units to emerge
  - SSJ's are based on how many of the sublexical units of any size associated with the compared words are and are not shared and how prominent the shared and non-shared units are

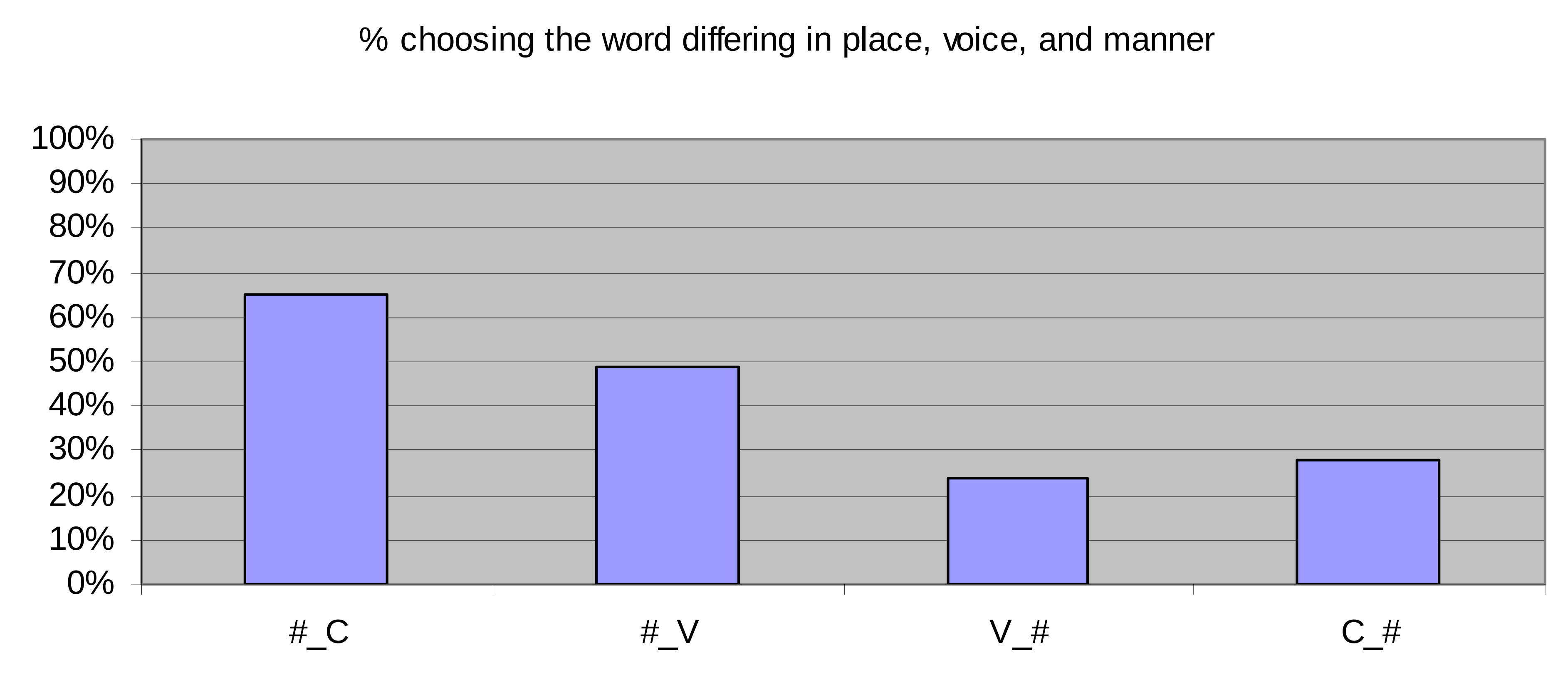
The AXB/XAB task

- shraup – braup – trauf place+voice+manner
- 34 native English speakers were presented with 450 nonsense phonotactically legal monosyllabic spoken words three at a time
- 16 subjects were asked to decide whether the second word sounded more like the first or the last word (the AXB setup)
- 18 subjects were asked to decide whether the first word sounded more like the second or the third word (the XAB setup)
- 25 subjects heard the stimuli in noise, 9 heard them without noise

Emergence of sub-segmental units

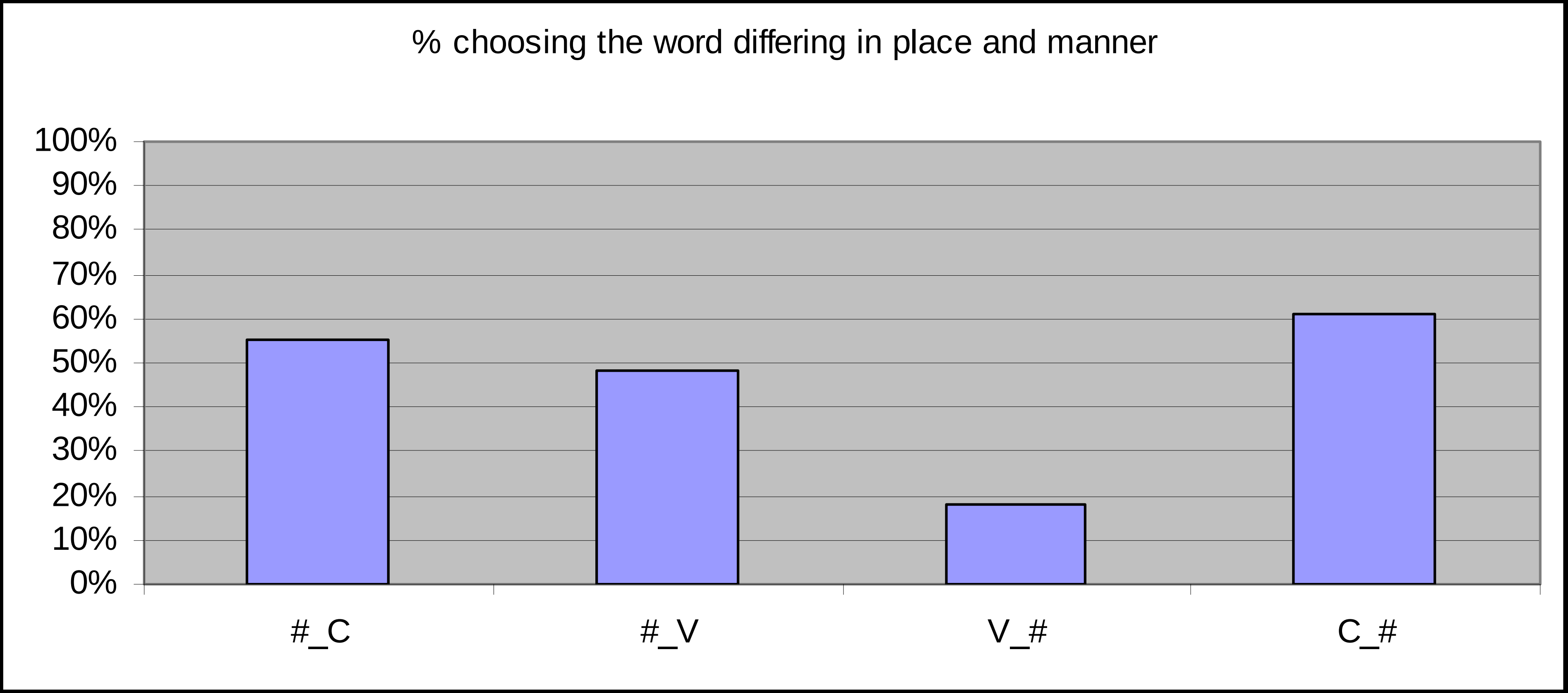
- Position within the word had significant effects for all groups of subjects for only two types of mismatches, both of which involve multiple features

Place+Voice+Manner



Changes in place, voice, and manner are particularly perceptually salient in the word-final position.

Place+Manner



Place+manner differences are extremely salient in word-final position only when they involve an entire syllabic constituent.
Thus feature clusters may have emergent properties that are not inherited from their component features.

Conclusion

- Lexical representations contain exemplar-specific information about their temporal duration
- The emergent segmental, constituent-level, and subsegmental units whose tokens the lexical representations contain may have properties not shared with their parts.
- Different positions within the word also receive different amounts of attention, perhaps, depending on the usefulness of units they usually contain for different cognitive tasks.

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Implications for the rules vs. analogy debate

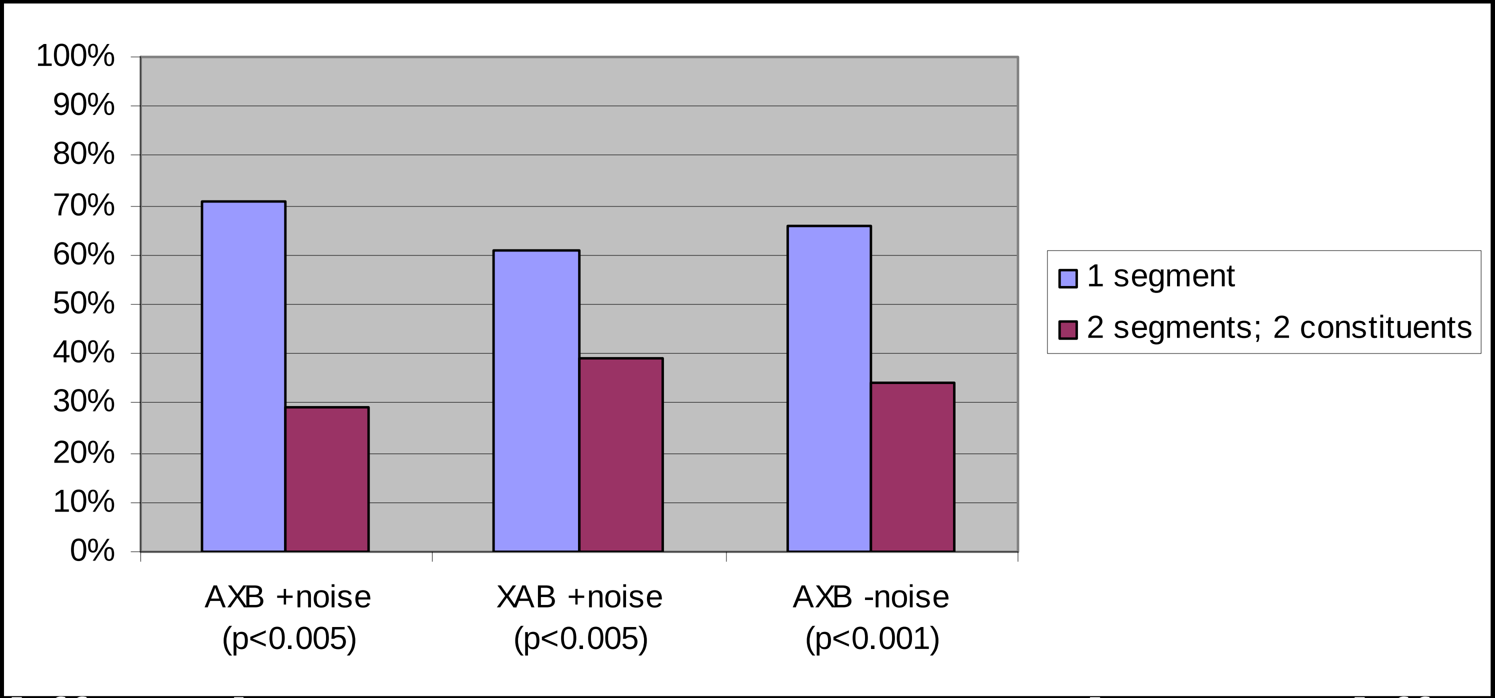
- We need to know the proximity of existing words to a nonce stimulus to determine how likely they are to become analogical models for the stimulus in a wug test → to test susceptibility of a morphological pattern to similarity effects

- For instance, Albright and Hayes (2003) compare a model that weighs features in all positions inside the word equally to determine which words a nonce stimulus is similar to and a model that gave greater weights to features located close to the end of the word as predictors of English past tense pattern assignment. The model that weighed features in different positions differently was able to come up with stimuli that allowed Albright and Hayes to find similarity effects even for the regular –ed suffix.

Comparison

- Words differing in one segment vs. 2 non-contiguous segments were matched in the features they differed in
- shraup – braup – trauf place+voice+manner

Results



Words differing by more segments were perceived as more different showing that the effect holds across tasks.

Questions still remain:

-Is the length of the mismatched stretches of speech, matched stretches of speech or both important?

-Is the effect due to number of mismatched segments, their temporal duration, contiguity, or number of syllabic constituents?

A possible objection: Non-words are not stored in the lexicon but in STM

- In repetition priming, high frequency target words are primed more than low frequency words Scarborough et al (1977), Jacoby and Dallas (1981), Jacoby (1983), Forster and Davis (1984), Norris (1984), Jacoby and Hayman (1987), Stark (1997), Nevers and Versace (1998), Versace (1998), Perea and Rosa (2000), Stark and McClelland (2000), Versace and Nevers (2003)
- Stark (1997), Stark and McClelland (2000): pronounceable nonwords, like the ones used in this study, are primed at long lags and are primed even more than low frequency words while non-pronounceable non-words are primed very little and the priming effect observed with them decays quickly like a sublexical priming effect
- cf. Versace and Nevers (2003) who show that with very short prime presentations which do not allow the lexical entry for the prime to be activated repetition priming is small in magnitude and short-lived, like sublexical priming
- Thus, pronounceable nonwords behave like extremely low frequency words and must have stored lexical entries

Emergence of cross-segmental units

- Our hypothesis would receive even stronger support if connections between co-occurring features from adjacent segments could strengthen due to co-occurrence causing adjacent co-occurring features to prime each other

Russian Stem Extensions

- Nominal root + stem extension + t’ = infinitive
- Forms: -a-; -i-; -e-; -nu-; -{o;e}va-
- -i- and -a- have similar and high type frequency:
  - -i- accounts for 34% of types in Sheveleva et al (1974) while -a- accounts for 32%

- E.g. svet + i + t’ – ‘to light’
  (‘a light’)
  mot + a + t’ – ‘to waste’
  (‘a spendthrift’)

Defining the Neighborhood to Find Nonce Roots Similar to no Existing Roots: The Fixed Radius Method

- Invent a nonce syllable
- Choose a unit of similarity, e.g. a feature
- Choose a neighborhood radius, e.g. 4 features
- Ensure that there are no verbs whose roots differ from the stimulus by the radius or less

[place]-dependent productivity

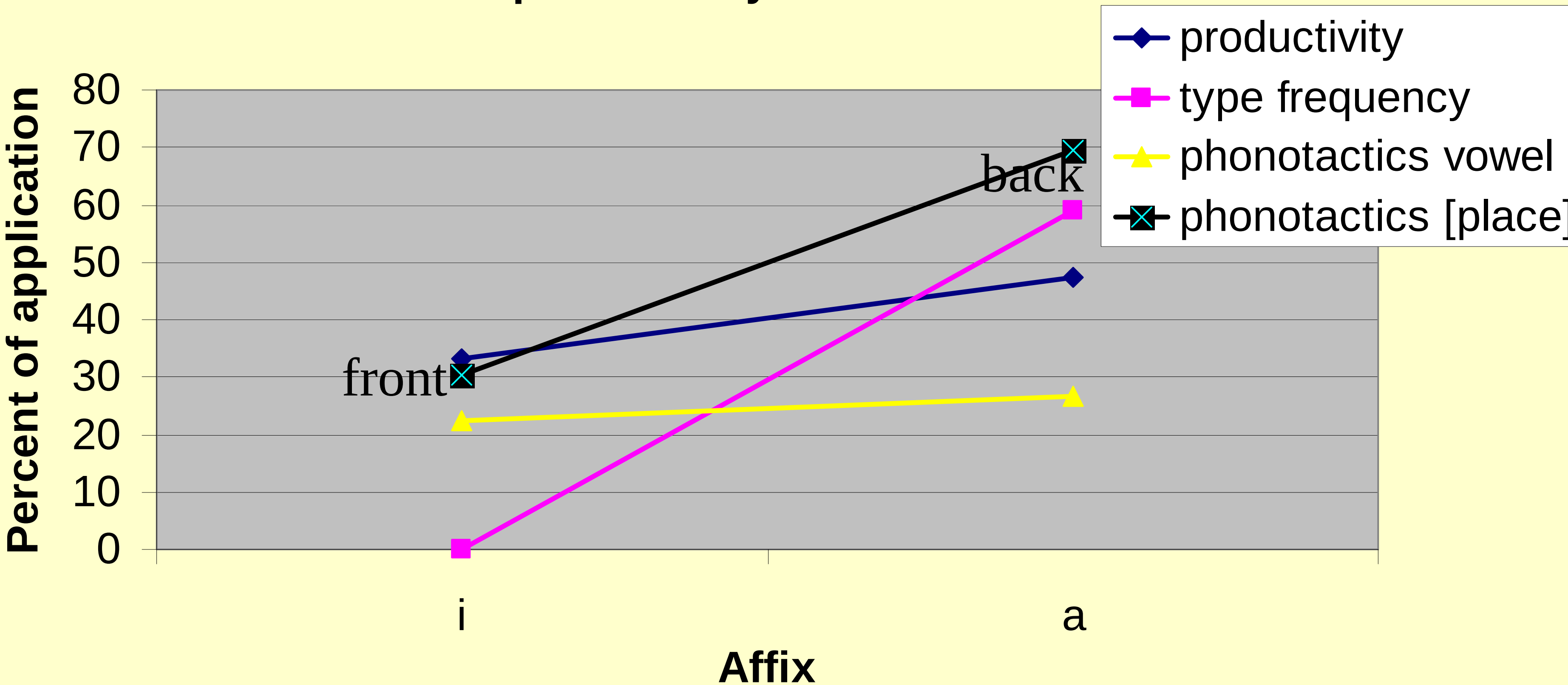
- While -i- is the most productive suffix for coronal- and palatal-final roots, -a- is the most productive suffix for labial-final and velar-final roots?

- Bybee (1995): the higher the type frequency of a pattern, the higher its productivity
- Bybee (1995): the higher the average token frequency of forms derived with a pattern, the lower its productivity
- Hay (2003): the lower the average frequency of the derived relative to the frequency of the base for a pattern, the higher its productivity

- Probability of the V beginning the suffix given the root-final C's [place] (regardless of where in the word the combination occurs)
- Probability of the suffix-initial V's [place] given the root-final C's [place]

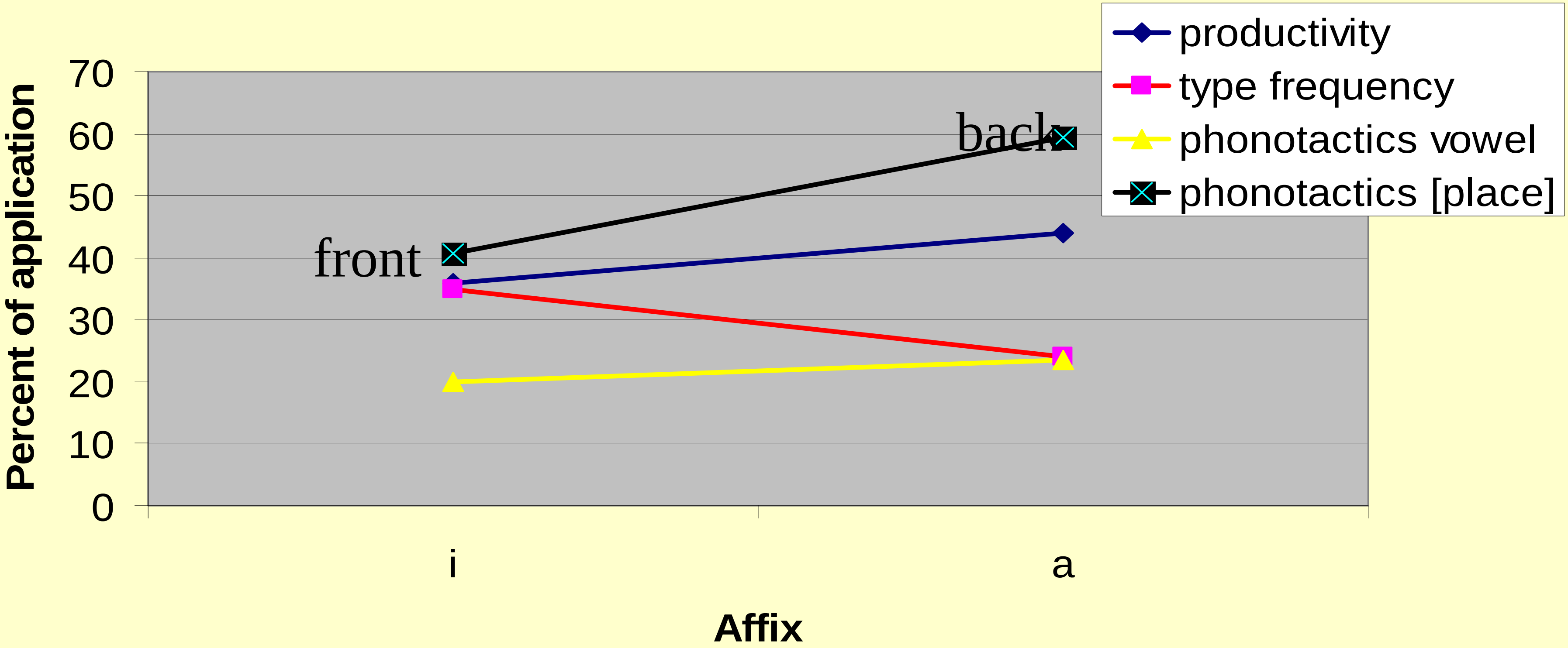
- Frequency and phonotactic probability calculations are based on the Ogonek Corpus: written, 1996-2002, 7,000,000 words total (SFB-441, 2002)

Type frequency and phonotactic probability as predictors of affix productivity for velar-final roots



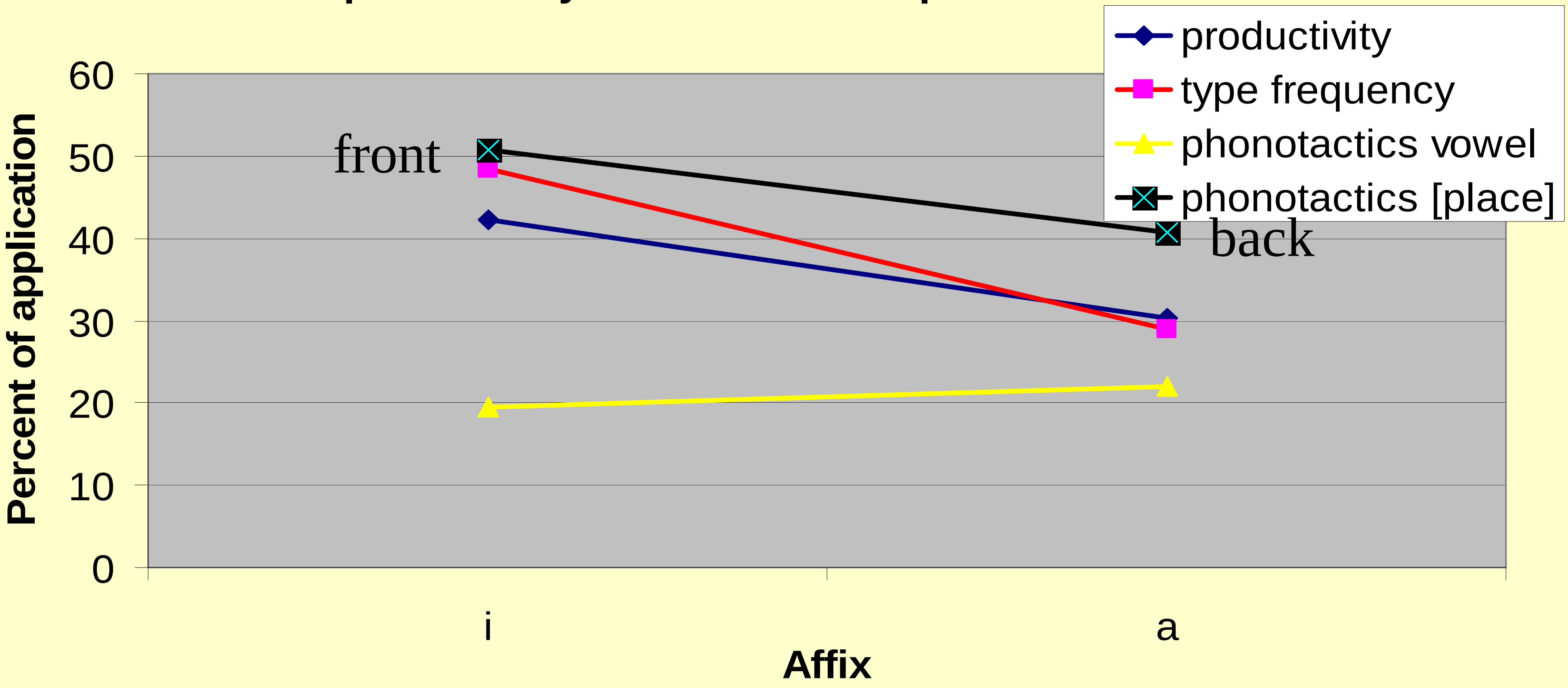
Probability of [-back] vs. [+back] after [Velar]	+
Probability of [i] vs. [a] after [Velar]	+
Type frequency of –i- vs. –a- after [velar]	+
Token frequency	N/A
Relative frequency	N/A

Type frequency and phonotactics as predictors of affix productivity for labial-final roots



Probability of [-back] vs. [+back] after [Labial]	+
Probability of [i] vs. [a] after [Labial]	+
Type frequency of –i- vs. –a- after [Labial]	-
Token frequency	-
Relative frequency	-

Type frequency and phonotactic probability as predictors of affix productivity for coronal- and palatal-final roots



Probability of [-back] vs. [+back] after [Coronal] or [Palatal]	+
Probability of [i] vs. [a] after [Coronal] or [Palatal]	-
Type frequency of –i- vs. –a- after [Coronal] or [Palatal]	+
Token frequency	+
Relative frequency	-

Implications for Phonology

- Phonotactic probability of a vowel with a certain [place] after a consonant with a certain [place] is an excellent predictor of morphological productivity
- Co-occurring features from adjacent segments appear to prime each other thereby priming the morphemes that contain them
- This is expected if features are nodes in a localist associative network in which co-activation strengthens connections between nodes allowing more activation to spread between them (e.g. Bybee 2001).