Context Effects in recognition of German disyllabic words and nonwords by native and non-native listeners

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Research Goals

- Test the prediction made by combinatorial models of Lexical Access (e.g. Clahsen et al. 2001; Taft & Forster 1975; Taft 1988) that morphological complexity can affect language comprehension
- Compare effects of lexical status, lexical frequency, and neighborhood density to previous results from speech-in-noise tasks
- Determine how differences in the lexicon between native and non-native listeners affects spoken word recognition

Method

Materials

- 150 nonwords and 150 German words (half monomorphemic and half bimorphemic).
- All stimuli were of the form CVCCVC (where V includes short and long vowels as well as diphthongs), with stress on the first syllable.
- Word stimuli were selected from the CELEX (Baayen and Rijn 1993) database.
- Nonword stimuli were based upon the word stimuli such that the two sets were fairly phonemically balanced.

Lexicostatistical measures

- **Lexical frequency** was computed following the method of Newman et al. (1997, p. 875, footnote 1). Both wordform and lemma-based measures were computed.
- **Neighborhood density** was calculated in two different ways — a phonological one, in which all words with an edit distance of 1 are treated as neighbors, e.g. *pat* has neighbors *pet* and *rat*, and a phonetic measure was also calculated, based on the confusion matrices from the nonword data. The phonetic measure treats *pet* as a closer neighbor to *pat* than *rat*, given that /æ/ and /ɛ/ are more highly confusable than /ɹ/ and /p/.

Participants

- 30 native speakers of American English were recruited from the University of Michigan for Experiment One.
- 32 non-native speakers of English (L1=German) were recruited from the University of Konstanz, Germany, for Experiment Two.
- All subjects reported no known hearing deficiencies.

Task — Speech-in-noise

- Participants listened to the recorded materials over headphones and typed in what they heard using standard orthography.
- Signal dependent noise was added to the stimuli according to the method described by Schroeder (1968).

Analysis

- The data was analyzed using the j-factor model of Boothroyd & Nittrouer (1988).
- The j-factor model provides a measure of the number of independent units in a stimulus.
- A result of $j = n$ for **nonwords** (where n is the number of phonemes in the stimulus) can be interpreted as evidence that phonemes are perceived **independently** of each other.
- A result of $j < n$ for **words** is interpreted as evidence that context effects provide a bias towards words.
- j is derived from the following equations
  The probability of correctly identifying a given word (or nonword) can be calculated as the product of the probabilities of its constituent phonemes.

$$p_w = p_{C1} p_{V1} p_{C2} p_{C3} p_{V2} p_{C4} \tag{1}$$

where p_w is the probability of correctly identifying a word (or nonword). Assuming that phonemes are perceived independently, (1) can be rewritten as:

$$p_w = p_p^j \tag{2}$$

where j is the number of phonemes, and p_p is the geometric mean of the probabilities of each constituent phoneme. Rewriting (2), the quantity j can be empirically determined from confusion matrices by:

$$j = \frac{log(p_w)}{log(p_p)} \tag{3}$$

Predictions

$$j_{nonword} \approx 6$$
$$j_{nonword} > j_{word}$$
$$j_{word} \propto \frac{1}{\text{frequency}}$$
$$j_{word} \propto \text{density}$$

These predictions based on Benkí (2003) and Boothroyd & Nittrouer (1988). Since j can be thought of as the number of independent units in a word, the facilitatory effect of higher lexical frequency should result in a lower j, while the competitive effect of a dense neighborhood should resulted in a higher j.

$$j_{bi} > j_{mono}$$

This predicts that additional morphemes will add to the overall number of independent units of the word.

Effects of neighborhood density are predicted to be smaller for non-native listeners than for native listeners due to the reduced size of the non-native listeners' lexicons.

J-Factor Analysis Results

Results

- As predicted, words had significantly lower j-scores than nonwords for both native and non-native listeners, indicating a facilitatory effect of lexical status.
- As predicted, bimorphemic words had significantly higher j-scores than monomorphemic words, indicating that bimorphemic words are composed of more independent units than monomorphemic words.
- **Opposite of predictions**, high-frequency words had significantly higher j-scores than low-frequency words.
- As predicted, word in dense neighborhoods had significantly higher j-scores than words in sparse neighborhoods, indicating an inhibitory effect of neighborhood density.

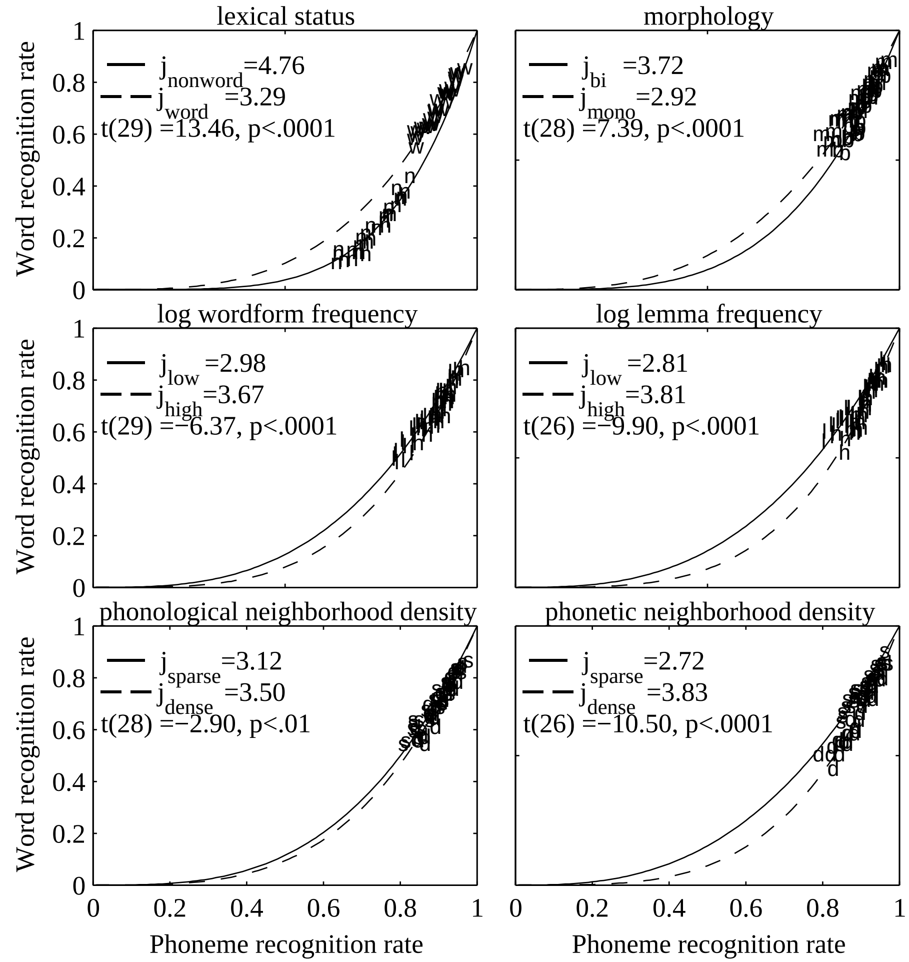

Figure 1: Native listener j-factor results — Each plot compares two subsets of results from the subject analysis. Curves represent $p_w = p_p^j$. Statistics given are from paired t-tests; before computing the statistics, all points lying in the floor or ceiling ranges ($>$ .95 or $<$ .05) were removed, but are still shown on the plot.

Discussion

Word Length and Perceptual Independence

- Lower than predicted j-scores of nonwords were partially explained by excluding post-vocalic /ʀ/, which is often phonetically realized as an off-glide of the preceding vowel in German.
- $j_{word} \approx 3.5$ suggests that listeners may be perceiving units larger than phonemes, perhaps syllables.

Morphology and Response Bias

- Of the inflectional endings in German, -*m* and -*n* are highly confusable, yet the -*n* ending occurs much more frequently.
- In order to investigate a possible interaction between morphology and response bias, a Signal Detection Theory (SDT) analysis was carried out.
- To carry out the SDT analysis, the original confusion matrices for each S/N were transformed into 2x2 submatrices. An SDT analysis was then applied to each submatrix.
- In the absence of lexical context effects (nonword condition), /m/ and /n/ are highly confusable, with a small bias towards /n/
- /m/ and /n/ are perceived as most distinct in the monomorphemic condition,

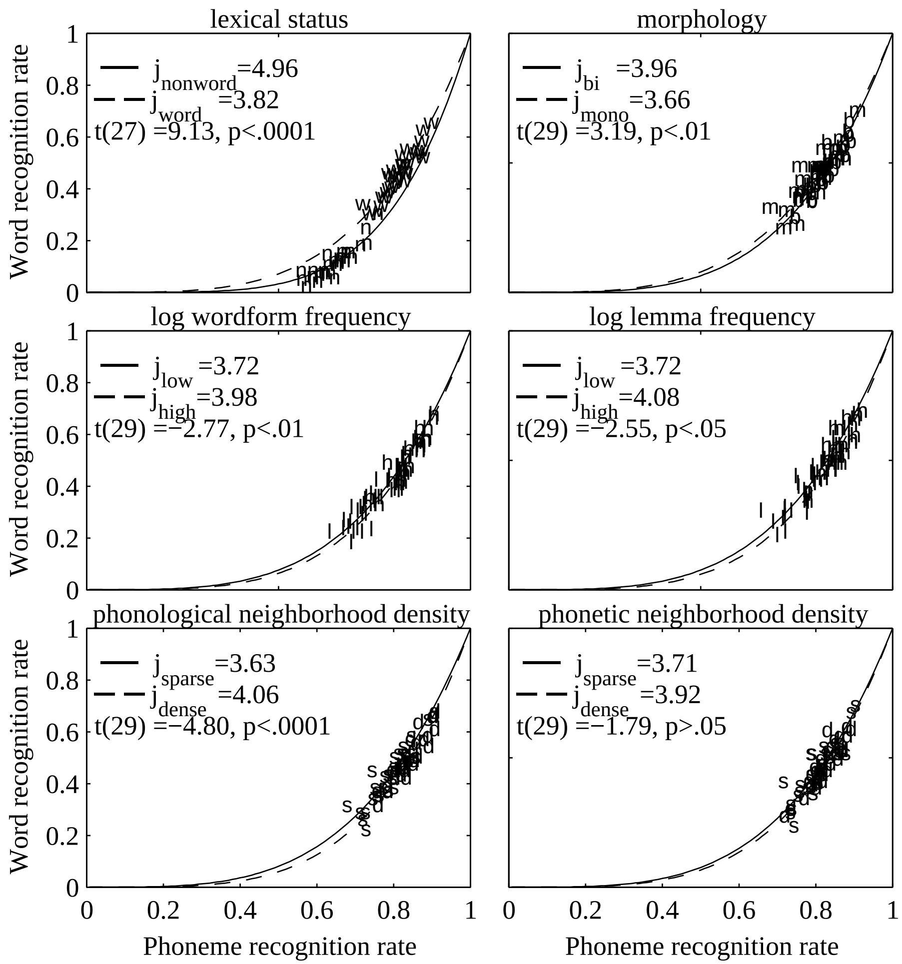

Figure 2: Non-native listener *j*-factor results — Each plot compares two subsets of results from the subject analysis. Curves represent $p_w = p_p^j$. Statistics given are from paired t-tests; before computing the statistics, all points lying in the floor or ceiling ranges ($> .95$ or $< .05$) were removed, but are still shown on the plot.

- Bias towards /n/ is greatest in the bimorphemic case.
- The SDT analysis lends greater support to the notion that morphology is encoded in the mental lexicon.

Native vs. Non-native listeners

- Frequency effects in non-native speakers are very similar to native speakers, suggesting that frequency is encoded early on in L2 acquisition
- It is possible that the smaller lexicon of non-native listeners could reduce the inhibitory effect of neighborhood density.
- However, results show that words in sparse neighborhoods were processed more similarly to words in dense neighborhoods by non-native listeners.
- In addition, non-native listeners incorrect responses included fewer neighbors than did native listeners incorrect responses. (German native = 12.3%, German non-native $= 8.2\%, t(298) = 1.81, p < .05$);
- This suggests that non-native listeners have additional sources of competition in the lexicon, consistent with the findings of Weber & Cutler (2004).

Table 1: Signal Detection Theory analysis of /m/ and /n/ submatrix in final position comparing native and non-native listeners — (a) repeats the results from Experiment Two for native listeners; (b) shows results for non-native listeners. For this analysis /m/ is considered to be the target stimulus. Positive values of *c* indicate a bias towards /n/. The final two columns list the total number of presentations of /m/ and /n/ which were used to compute the SDT analysis

	(a) Native listeners				(b) Non-native listeners			
	d'	c	/m/	/n/	d'	c	/m/	/n/
Nonwords								
lower S/N (2 dB)	-0.182	0.555	240	240	-0.201	0.851	225	225
higher S/N (7 dB)	0.664	0.743	240	240	0.116	1.026	225	225
Bimorphemes								
lower S/N (2 dB)	1.616	0.984	128	352	0.964	1.510	120	330
higher S/N (7 dB)	1.913	0.556	128	352	1.128	1.436	120	330
Monomorphemes								
lower S/N (2 dB)	3.514	0.239	48	192	2.386	0.641	45	180
higher S/N (7 dB)	4.733	-0.060	48	192	3.301	0.636	45	180

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