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 /s/ 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.

\[
P_w = p_{C1}p_{V1}p_{C2}p_{C3}p_{V2}p_{C4}
\]

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

\[
P_w = p_j^j
\]

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

\[
j = \frac{\log(p_w)}{\log(p_j)}
\]
Predictions

These predictions based on Benkő (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 $j$.

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.

Discussion

Word Length and Perceptual Independence

- Lower than predicted $j$-scores of nonwords were partially explained by excluding post-vocalic /n/, 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 $p_u = p_j$. 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 bimorphic 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).

References


the Acoustical Society of America, 44, 1735–1736.

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