Feature Distance Effects in a Word Reconstruction Task

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ABSTRACT

Some models of spoken word recognition assume that the phonetic segments of a word are composed of distinctive features. A match between a feature detector and feature information in the acoustic signal increases the chance of identifying the phonetic segment. If only some of the detectors for a segment match, the chances of identifying the segment drop. Pairs of segments differ in the number of features they share, e.g., /f/ and /v/ differ by just one feature whereas /f/ and /g/ differ by six. Correctly identifying /f/ should occur more often if it were replaced by /v/ than if it were replaced by /g/. The present experiment tested the hypothesis that the greater the feature distance between a target segment and a replacing segment, the poorer the chance of correctly identifying the target segment. The hypothesis was tested for two feature systems and with two matching strategies. This experiment offers some support for the hypothesis.

1. BACKGROUND

Do distinctive features influence the ease with which we retrieve words from our mental lexicons?

Stevens [8] assumes the phonemes of a word are represented by bundles of distinctive features. Word identification involves a match between the features in the acoustic signal and the bundles of distinctive features in the mental representation. The TRACE model [4] begins word recognition by identifying features in the acoustic signal. These combine to identify phonemes.

Connine et al. [3] found effects for feature distances of 1 and 2, but no higher. Bölte [1] used the same task that we used and found effects for feature distance (1) vs (2 or 3), but only when the segment to be changed was final in a nonword. Moates, Bond, Stockmal and Lee [5] found differences across three levels of feature difference in a word reconstruction task. Can we find broader evidence for the effects of feature distance?

1.1. Feature Distance.

Phonemes can be ordered in similarity by their degree of feature overlap. Two segments that are + on all the same features except one are highly similar and are said to have a feature distance of one. Two segments that differ in value on several features have lower similarity as shown in Fig. 1.

Figure 1. /d/ and /t/ show a feature distance of 1, while /d/ and /k/ show a distance of 3.

	/d/	/t/	/d/	/k/
Consonantal	+	+	+	+
Coronal+	+	+	-	
Anterior	+	+	+	-
Voice	+	-	+	-

Recognizing a phoneme involves detecting the features of that phoneme. If a phoneme is replaced by another phoneme, recognition should be best when the replacing phoneme has a small feature distance from the target phoneme and should be poorest when the replacing phoneme has a large feature distance.

1.2. Hypothesis.

The smaller the feature distance between two phonemes, the greater the likelihood that the first phoneme will be recovered if replaced by the second phoneme.

This hypothesis was tested in a word reconstruction task. Participants heard a nonword that could be changed into a real word by changing the first consonant.

2. METHOD

2.1. Materials

We created 75 nonwords from pairs of real words that differed in only one consonant and one vowel. e. g.,

docket and *racket* => the nonword *dacket.*

sunny and *zany* => the nonword *sany*,

dunking and *winking* => the nonword *wunking*

All words were two-syllable with stress on the first syllable. The consonant to be changed occurred in the onset of the stressed syllable. The defining features for phonemes were taken from O'Grady, Dobrovolsky and Aronoff [6, 7].

2.2. Matching strategies.

How does one measure feature distance, e.g., for the nonword/target word pair *dacket-racket?*

(A-B). This strategy sums the + features of the initial consonant in the nonword and subtracts those features in the initial consonant in the target word that are also +. For example, *dacket* has four + features for the /d/. The /r/ in the target word is + for all four of the same features, so 4-4=0, which is the feature distance between /d/ and /r/ by this strategy. Using this strategy yielded seven levels of feature distance for the 75 nonwords and their target words, with varying number of items at the seven levels.

(A or B). The strategy sums the number of + features in the consonant in the nonword or the consonant in the target word but not both. For the /d/ in *dacket* there are 0 features that are + for /d/ but not for /r/. For the /r/ in *racket* there are 2 + features that are not + in /d/. 0+2=2, which is the feature distance by the (A or B) strategy. This strategy also yielded seven levels of feature distance with varying numbers of items at the seven levels.

2.3. Participants

Fifty-five native speakers of English enrolled in a General Psychology course participated in the experiment.

2.4.Procedure

The participants were asked to listen to each nonword (spoken twice for clarity), then to change the segment that follows, e.g., *dacket dacket d* (target word is *racket*). They were asked to write down the target word if they could think of it.

3. RESULTS

Responses were scored for errors, which were any response other than the target word. Mean error rates were computed for each target word. Target words were controlled for word frequency, word length, number of neighbors, and uniqueness point. All controls showed low and nonsignificant correlations with mean error rates for the target words.

ANOVAs on mean error rates for the two feature systems and the two matching stragegies all showed highly significant effects, $p<.001$. See Figs. 2-5.

A feature distance of 0 occurs in the 2005 analyses when two segments differ only on place of articulation, which is not cross classified in this feature system.

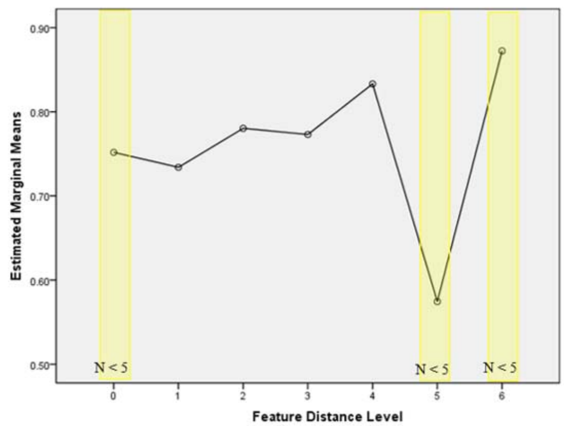

Fig. 2. Mean error rate across seven levels of feature distance for the 1997 feature set, (A-B) scoring. Levels 1-4, 1-5, 1-6, 2-5, 3-4, 3-5, 4-5, and 4-6 are significantly different, though levels 0, 5, and 6 have fewer than 5 items. Levels having fewer than 5 items are not included in comparisons that support the hypothesis.

The hypothesis predicted that the smaller the feature distance, the lower would be the mean error rate. The hypothesis is confirmed for the comparisons of 1 - 4 and 3 - 4 but not others.

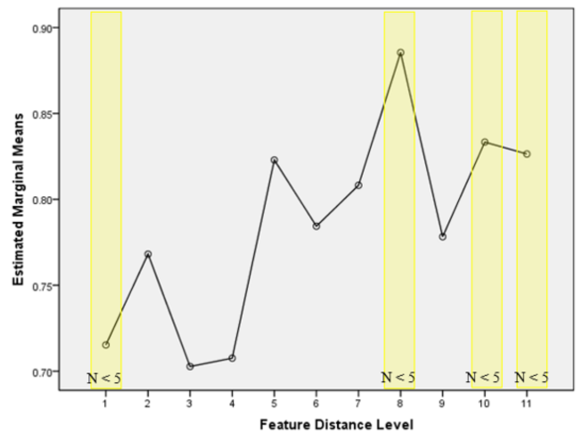

Fig. 3. Mean error rates across eleven levels of feature distance for the 1997 feature set, (A or B) scoring. Levels 3 - 7, 3 - 8, 4 - 7, and 4 -.8 are significantly different. Comparisons 3 - 7 and 4 - 7 support the hypothesis.

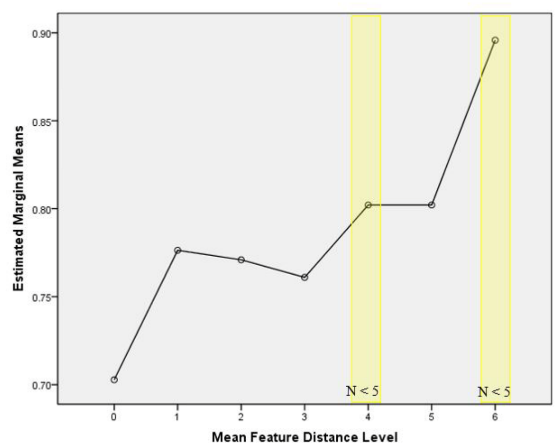

Fig. 4. Mean error rates across seven levels of feature distance for 2005 feature set, (A-B) scoring. Levels 0 - 4, 0 - 5, and 0 - 6 are significantly different though 4 and 6 have fewer than 5 items. Comparison 0 - 5 supports the hypothesis.

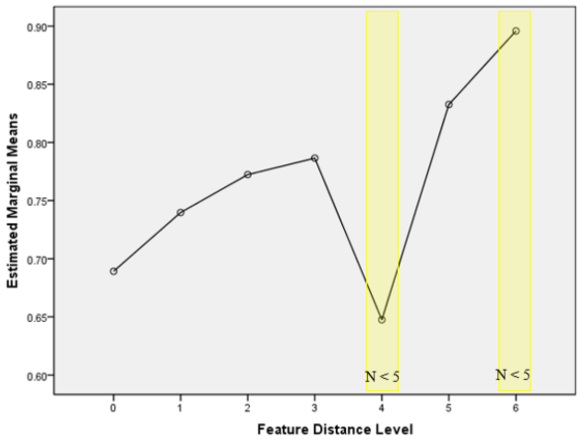

Fig. 5. Mean error rates across seven levels of feature distance for 2005 feature set, (A or B) scoring. Levels 0 – 3, 0 – 5, 0 – 6, 1 – 5, 1 – 6, 3 – 4, 4 – 5, and 4 – 6 are significantly different. Comparisons 0 – 3, 0 – 5, and 1 - 5 support the hypothesis for 2005 (A or B).

4. DISCUSSION

Connine et al. [2] and Bölte [1] found effects for feature distances of 1 and 2, but no higher. Our materials permitted testing feature distances of up to seven in three analyses and eleven in a fourth. Feature distance effects varied across (A-B**)** and (A or B) matching strategies as well as 1997 and 2005 feature analyses. The strongest effect showed rising error rates across the levels of feature distance using the (A or B) strategy and the 2005 feature analysis. Slightly smaller effects appeared for the 1997 feature system for both the (A-B) and (A or B) strategies. A still smaller effect appears in the (A-B) strategy for the 2005 feature system. These outcomes expand the range of feature distance effects seen in the Connine et al. [2] and Bölte [1] studies and parallel those shown by Moates, et al. [5]. The (A or B) scoring scheme seems to be a bit more revealing of feature distance effects than does the (A-B) strategy. The (A or B) strategy is not directional; it merely scores features that are + on either of the segments being compared.

The 2005 feature analysis differs from the 1997 feature analysis largely in that manner features are not included for segments to which they do not apply.

The results in this study are hampered by the unequal samples in the levels of feature distance. A design that controls sample size could show effects even more clearly. Furthermore, feature distance effects do not appear to be simply additive.

The variance accounted for in the ANOVAs (partial eta squared) varies somewhat.

2005 (A-B) 12%, (A or B) 17%

1997 (A-B) 27%, (A or B) 8%

Cohen [2], who developed the partial eta squared measure, suggested minimum values of .0099 for small effects, .0588 for medium effects, and .1379 for large effects. Two of the values observed in the present study are large even by the large effect standard, suggesting that the methodology used for testing this hypothesis is promising.

5. CONCLUSION

The feature distance effect shows encouraging results in the word reconstruction task, suggesting that the effect may represent aspects of lexical access. The large values for partial eta squared suggest an effect that may be more prominent in a different experimental design.

6. REFERENCES

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7. ACKNOWLEDGEMENTS

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