NEIGHBORHOOD AND COHORT IN LEXICAL PROCESSING OF JAPANESE SPOKEN WORDS

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ABSTRACT
Statistical and correlational analyses were conducted on a neighborhood and cohort to examine their validity in the lexical processing of Japanese spoken words. The statistical analysis revealed that the characteristics of the neighborhood and cohort depend on the number of words that was used to obtain the neighborhood and cohort. This suggests that the number of words corresponding to the size of a mental lexicon should be used for analyzing the neighborhood and cohort. Partial correlation analysis between the subjects’ performance and descriptive variables of the neighborhood and cohort showed that the neighborhood affects recognition scores but the cohort affects very little. While, neither one seemed to affect the lexical decision time. The results suggest that the neighborhood is more plausible than the cohort as a lexical competitor set, and that some amount of time is necessary for the neighborhood to be activated in the lexical processing of spoken word recognition.

1. INTRODUCTION
Research on spoken word recognition suggests that multiple word candidates are activated during the recognition process (e.g., [1], [2], [3]), and that these candidates compete with each other (e.g., [4], [5], [6], [7]). However, there has been no general agreement on the set of the word candidates. Previous studies suggested several different sets of word candidates for spoken word recognition. Neighborhood ([8]) and cohort ([9]) are the most well-known sets. The neighborhood is defined as a collection of words in which only one segment differs from a particular target word. The cohort is a set of words sharing the initial segment.

Amano & Kondo [10] have shown that the neighborhood affects the spoken word recognition in Japanese. However, there were some problems with this study. First, it was not investigated whether cohort affects spoken word recognition. Second, the entire words in the word familiarity database ([11]) were used to obtain the neighborhood assuming that the database corresponds to a mental lexicon. However, this assumption might be wrong, because Amano & Kondo [12] estimated a smaller number of words for a mental lexicon than the total number of words in the database.

If the characteristics of neighborhood and cohort are uniform for any number of words in the database, the assumption might not cause a problem. However, the characteristics of neighborhood and cohort most likely differ according to the number of words in the database. This study will investigate this difference by conducting statistical analysis on the neighborhood and cohort as a function of the number of words in the database.

This study will also investigate how the neighborhood and cohort affect spoken word recognition by conducting partial correlation analyses between the subjects’ performance (lexical decision time and recognition score) and the descriptive variables of the neighborhood and cohort in the limited number of words in the database, which corresponds to the estimated size of a mental lexicon.

2. DEFINITION OF NEIGHBORHOOD AND COHORT
The neighborhood and cohort of a Japanese spoken word were defined with the following conditions in this study.

1. A neighborhood is a set of words with a single mora substitution, addition, or deletion with a target word.
2. A cohort is a set of words sharing the initial mora with a target words.
3. Words with the same mora sequence but with a different pitch accent were regarded as different words.
4. Homophones are regarded as different words.

The neighborhood and cohort were defined using a mora as a segment, because the mora is said to be a segmentation unit of speech perception for Japanese natives ([13], [14]) and therefore, it is most likely used in the lexical processing of Japanese spoken words.

3. STATISTICAL ANALYSIS
3.1. Variables of Neighborhood and Cohort
Neighborhood and cohort were described with the following variables.

1. Density.
2. Mean familiarity.
4. Sum of familiarity.

The ‘density’ is the number of words in a neighborhood or cohort. The ‘mean familiarity’ is the averaged auditory word familiarity of all the words in a neighborhood or cohort. The ‘maximum familiarity’ is the highest auditory word familiarity of a word in a neighborhood or cohort. The ‘sum of familiarity’ is the total amount of auditory word familiarity of words in a
neighborhood or cohort. The auditory word familiarity, which ranged from 1 (unfamiliar) to 7 (familiar), was obtained from a Japanese word familiarity database ([11]).

In this study, auditory word familiarity was used instead of word frequency which has been frequently used in other studies (e.g., [8]). This is because the auditory word familiarity greatly affects spoken word recognition in Japanese ([11], [15], [16]), but word frequency does not ([16]). Therefore, auditory word familiarity is better than word frequency for describing the neighborhood and cohort of Japanese spoken words.

The cohort size decreases with time in spoken word processing ([9]). It is possible to analyze the cohort at each mora position. However, for simplification, only the cohort at the initial mora position (i.e., initial cohort) was analyzed in this study. In addition to the four descriptive variables, the uniqueness point ([9]), at which all other words are excluded from the cohort, was used as a descriptive variable of the cohort. The number of words having the uniqueness point was also used as a descriptive variable of the cohort.

### 3.2. Results and Discussion

Statistical values were obtained for the variables of the neighborhood and cohort as a function of the number of words selected from the familiarity database. The number of words were controlled by the lower limit of auditory word familiarity with which words were selected from the word familiarity database. Table 1 shows the values for the neighborhood and Table 2 shows the values for the cohort.

In the case of the neighborhood, the density and the sum of familiarity tend to be small when the number of words decreases. While, the mean and maximum familiarity is high at the mid range of the lower limit of auditory word familiarity. In the case of the cohort, the density, the sum of familiarity, the uniqueness point (U.P.), and the number of words having U.P. tend to be small when the number of words decreases, but the mean familiarity tends to be larger. On the other hand, the maximum familiarity remains at almost the same value.

These results show that the neighborhood and cohort have different characteristics according to the number of words which are used to obtain them. This indicates that appropriate number of words, which corresponds to mental lexicon size, should be used to obtain the neighborhood and cohort.

#### Table 1. Neighborhood values as a function of the number of words in word familiarity database

<table>
<thead>
<tr>
<th>Auditory Word Familiarity</th>
<th>Number of Words in Familiarity Database</th>
<th>Density</th>
<th>Mean Familiarity</th>
<th>Maximum Familiarity</th>
<th>Sum of Familiarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 - 7.0</td>
<td>75794</td>
<td>38.6(63.8)</td>
<td>3.52(1.86)</td>
<td>4.55(2.40)</td>
<td>172.4(294.1)</td>
</tr>
<tr>
<td>2.0 - 7.0</td>
<td>73028</td>
<td>38.5(63.7)</td>
<td>3.59(1.86)</td>
<td>4.59(2.38)</td>
<td>174.3(296.3)</td>
</tr>
<tr>
<td>3.0 - 7.0</td>
<td>59101</td>
<td>36.2(62.9)</td>
<td>3.87(2.00)</td>
<td>4.61(2.40)</td>
<td>175.6(304.8)</td>
</tr>
<tr>
<td>4.0 - 7.0</td>
<td>46613</td>
<td>31.8(55.4)</td>
<td>4.07(2.15)</td>
<td>4.62(2.46)</td>
<td>163.3(282.4)</td>
</tr>
<tr>
<td>5.0 - 7.0</td>
<td>29510</td>
<td>19.3(32.6)</td>
<td>4.17(2.41)</td>
<td>4.49(2.60)</td>
<td>106.6(178.8)</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>3851</td>
<td>4.8(7.9)</td>
<td>3.68(3.03)</td>
<td>3.73(3.07)</td>
<td>29.8(48.8)</td>
</tr>
</tbody>
</table>

Note: Standard deviation in parentheses.

#### Table 2. Cohort values as a function of the number of words in word familiarity database

<table>
<thead>
<tr>
<th>Auditory Word Familiarity</th>
<th>Number of Words in Familiarity Database</th>
<th>Density</th>
<th>Mean Familiarity</th>
<th>Maximum Familiarity</th>
<th>Sum of Familiarity</th>
<th>U.P.</th>
<th>Number of Words Having U.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 - 7.0</td>
<td>75794</td>
<td>1113.1(866.4)</td>
<td>4.28(0.19)</td>
<td>6.46(0.17)</td>
<td>4809.6(3799.6)</td>
<td>3.7(0.9)</td>
<td>49834(65.7)</td>
</tr>
<tr>
<td>2.0 - 7.0</td>
<td>73028</td>
<td>1081.6(843.1)</td>
<td>4.37(0.18)</td>
<td>6.46(0.17)</td>
<td>4765.1(3760.4)</td>
<td>3.7(0.9)</td>
<td>47486(65.0)</td>
</tr>
<tr>
<td>3.0 - 7.0</td>
<td>59101</td>
<td>896.8(704.7)</td>
<td>4.82(0.13)</td>
<td>6.46(0.16)</td>
<td>4331.8(3423.0)</td>
<td>3.7(0.9)</td>
<td>37046(62.7)</td>
</tr>
<tr>
<td>4.0 - 7.0</td>
<td>46613</td>
<td>721.5(573.9)</td>
<td>5.17(0.11)</td>
<td>6.47(0.16)</td>
<td>3732.6(2973.3)</td>
<td>3.6(0.9)</td>
<td>28666(61.5)</td>
</tr>
<tr>
<td>5.0 - 7.0</td>
<td>29510</td>
<td>467.9(379.9)</td>
<td>5.54(0.12)</td>
<td>6.47(0.17)</td>
<td>2589.6(2098.8)</td>
<td>3.5(0.9)</td>
<td>18579(63.0)</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>3851</td>
<td>55.4(50.0)</td>
<td>6.13(0.42)</td>
<td>6.45(0.46)</td>
<td>341.5 (307.8)</td>
<td>2.8(0.7)</td>
<td>2618(68.0)</td>
</tr>
</tbody>
</table>

Note: Standard deviation is in parentheses. Percentage is in brackets.
4. PARTIAL CORRELATION ANALYSIS WITH EXPERIMENTAL DATA

4.1. Experimental Data

Amano & Kondo [10] measured the lexical decision time and recognition score for 200 Japanese spoken words that had between 4.0 and 7.0 of auditory word familiarity. The lexical decision time was obtained for the words without noise, while the recognition score was obtained for the words with noise in five signal-to-noise ratios (-5.0, -2.5, 0.0, and 2.5 dB, or no noise which is hereafter called 'org'). These data were used for the following partial correlation analysis.

4.2. Neighborhood and Cohort for Experimental Data

The results of statistical analysis in the previous section showed that the neighborhood and cohort have different characteristics according to the number of words which are used to obtain them. Therefore, to obtain the neighborhood and cohort for the 200 spoken words in the experimental data ([10]), the number of words corresponding to a mental lexicon size should be used.

The mental lexicon size was estimated to be about 68,000 for Japanese (Amano & Kondo [12]). However, this size cannot be directly adapted to this study, because the estimation was based on the beta version of the word familiarity database ([12]) which contains different number of words from the current version ([11]). Instead of using the size itself, the word familiarity of 3.0, which corresponds to the 50% point of know-response to stimulus words in Amano & Kondo’s study ([12]), was used for estimating the mental lexicon size. This familiarity value was assumed as the lower limit for words in the mental lexicon. That is, the mental lexicon size was estimated by counting the words having the auditory word familiarity between 3.0 and 7.0 in the current word familiarity database. The estimated size was about 59,000. This number of words was used to obtain the neighborhood and cohort for the 200 spoken words.

4.3. Partial Correlation Analysis

Since auditory word familiarity so strongly affects spoken word recognition ([11], [15], [16]), the neighborhood and cohort effects may be difficult to detect. Therefore, partial correlation coefficients were calculated between the experimental data (lexical decision time and word recognition score) and descriptive variables (density, mean familiarity,
maximum familiarity, sum of familiarity, and uniqueness point) of neighborhood and cohort by excluding the auditory word familiarity of the 200 spoken words.

4.4. Results and Discussion

Almost all of the partial correlation coefficients between the word recognition score and descriptive variables of the neighborhood were negative and significant, as shown in Figure 1. They clearly show the inhibitory effects of neighborhood on spoken word recognition. The coefficients for the density and the sum of familiarity were larger than those for the mean and maximum familiarity in almost all signal-to-noise ratios. This suggests that the density and sum of familiarity would be better descriptors of neighborhood than the other two variables.

Partial correlation coefficients between word recognition score and descriptive variables of the cohort were plotted in Figure 2. Almost all coefficients were insignificant, except for two coefficients in the ‘org’ condition. This suggests that the cohort has very little effect on spoken word recognition.

However, this small effect can be explained by the fact that the cohort does not assume direct competition among words which might be reflected in the density and other variables described above. The cohort effects might be observed if it is analyzed in terms of the uniqueness point, because this point is the most important characteristics of the cohort. However, partial correlation coefficients between the word recognition score and the uniqueness point in the cohort were insignificant in all signal-to-noise ratios. Therefore, the cohort has little or no effect on spoken word recognition, and it is less plausible than the neighborhood as a lexical competitor set.

None of partial correlation coefficients between lexical decision time and descriptive variables of the neighborhood and cohort were significant. Since subjects must respond in a shorter time in a lexical decision task than in a word recognition task, it is suggested that the neighborhood (and perhaps the cohort) requires some amount of time to be activated to compete with a target word.

5. CONCLUSION

The present study investigated how the neighborhood and cohort affect spoken word recognition in Japanese. The statistical analysis showed the importance of using a number of words that corresponds to the size of the mental lexicon when the neighborhood and cohort are examined. Partial correlation analysis showed the inhibitory neighborhood effects on recognition, but the very small cohort effects. Neither effects were observed on lexical decision. It is suggested that the neighborhood is more plausible than the cohort as a lexical competitor set, and that the neighborhood requires some time to be activated for lexical competition with a target word.

6. REFERENCES