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Complementary relationship between familiarity and SNR in word intelligibility test

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1. Introduction

To accurately evaluate personal hearing ability, nonsense monosyllable tests have been widely used in Japan. However, scores obtained by nonsense monosyllable tests do not always reflect personal hearing ability. This must be mainly because we rarely use isolated monosyllables in daily conversation. Therefore, the importance of word intelligibility tests and sentence intelligibility tests has been recognized in Japan and new lists for these tests have been proposed [1]. In intelligibility tests, control of the difficulty of the words used is crucial. Unfortunately, however, the proposed lists do not employ a proper index for such control. We have focused on the word intelligibility test and proposed word-lists using word familiarity as the index of word difficulty [2]. Word familiarity indicates how subjectively familiar a specific word is and is known to be a better index of subjective difficulty than word frequency [3]. However, intelligibility scores obtained by different lists are not exactly equal, although we equalize the average of the word familiarities in each list. This variance might be attributable to the variety of the distribution of word familiarities in each list.

In this study, we performed word intelligibility tests with the proposed word lists in various SNR conditions and examined the complementary relationship between word familiarity and SNR.

2. Outline of the word lists [2]

In the word lists, word familiarity based on a word familiarity database developed by Amano and Kondo [4] was used. In this database, word familiarity is valued from 1 (low familiarity) to 7 (high familiarity) for all 80,000 entry words and subtitles in the Shinmeikai Japanese Dictionary (Fourth Ed.). First, LHHH-accent-type words (Types 0 & 4) consisting of four moras were selected from this database. These types were selected because they are the most common ones in Japanese. Next, the population of words was divided into 4 groups according to word familiarity: 7.0 to 5.5 (high familiarity words), 5.5 to 4.0 (middle high familiarity words), 4.0 to 2.5 (middle low familiarity words), and 2.5 to 1.0 (low familiarity words). For each group, 1,000 words were selected to compose 20 word lists of 50 words each by maximizing the phoneme entropies to achieve optimum phonetic balance. Table 1 shows the average familiarity score of the 20 lists in each familiarity group.

3. Experimental procedure

Word intelligibility tests were performed in a soundproof room of the Research Institute of Electrical Communication, Tohoku University. Seven young male and three young female adult students with normal hearing acuity participated in the experiment. Their ages ranged from 19 to 24. Five lists from each familiarity group were selected and presented with noise to the listeners. The source of speech signal was uttered by a trained female speaker [4]. The noise signal was filtered random noise with the spectrum simulating long-term average of speech. These speech and noise signals were generated by TDT System III. These signals were mixed electrically and monaurally presented via a headphone (Sennheiser HDA-200) to a listener's left ear. The speech signal was presented at 60 dBA and SNR was set to -3, -6, -9 and -12 dB. Listeners were asked to write the moras they heard even if the word heard could not be regarded as a sensible Japanese word.

4. Results and discussion

The intelligibility score of each word was first calculated for further investigation. To do this, for each word, the number of listeners who correctly wrote the word was counted. Then if there were plural words with the same familiarity value, the intelligibility scores of these words were averaged. This averaged score was used to represent the intelligibility for a specific familiarity value. Figure 1 shows the relationship between word familiarity and intelligibility score. The size of the circles is proportional to the number of words with the same familiarity. In this figure, the floor effect was observed at low familiarity for SNR of -9 and -12 dB, while the ceiling effect was slightly observed at high familiarity for SNR -3 dB.

A regression plane was calculated to examine the complementary relationship between familiarity and SNR. A logistic regression model was fitted to the data. As a result, word intelligibility was given by the following equation:

$$Intelligibility(F, SNR) = \frac{100}{1 + \exp(0.91 - 0.53F - 0.25SNR)}, \tag{1}$$

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where F and SNR are word familiarity and SNR, respectively. Coefficient of Determination was 0.66. Figure 2 shows the word intelligibility estimated by Eq. (1) as a function of word familiarity and SNR. Equation (1) and Fig. 2 indicate that a difference of 1.0 in the familiarity value is almost equivalent to a 2 dB difference of SNR. These results suggest a possible compensation of the effect of the difference of word familiarity by controlling SNR. Such a compensation can possibly be realized, for example, by decreasing SNR if word familiarity is above average, while increasing it if word familiarity is below average.

Figure 1 shows there are several circles plotted remarkably apart from the regression plane. This may result from phonetic similarity between target words and other words. If there are many phonetically similar words for a target word, listeners may be apt to mistake the target word for these phonetically similar words, while listeners may easily answer the target word if there are few phonetically similar words. We plan to analyzed the distribution of phonetically similar words for all target words.

Table 1 Average familiarity score of 20 lists in each familiarity group.

familiarity group	average (S.D.)
7.0–5.5	5.81 (0.039)
5.5–4.0	4.84 (0.053)
4.0–2.5	3.15 (0.066)
2.5–1.0	2.16 (0.024)

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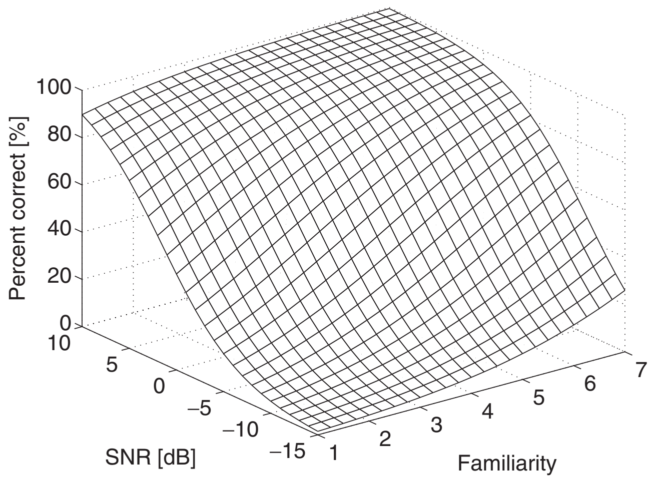

Fig. 2 Relationship among word familiarity, SNR, and word intelligibility given by Eq. (1).

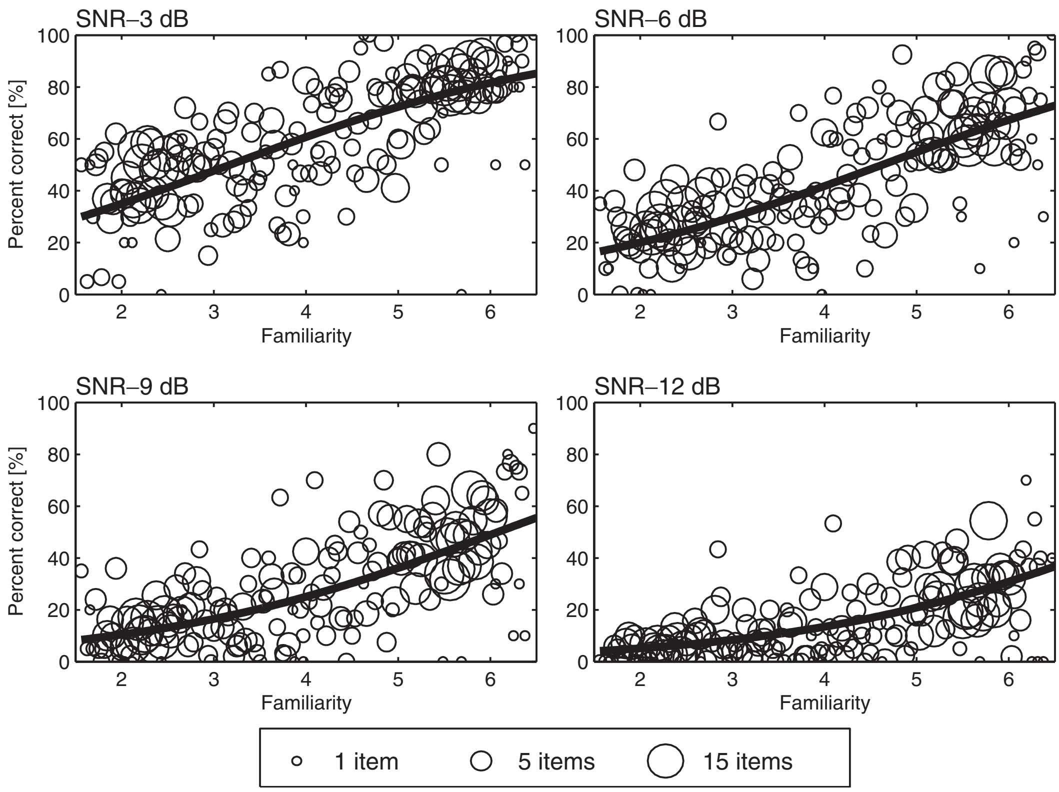

Fig. 1 Distribution of word intelligibility as a function of word familiarity. The solid line is the logistic regression curve given by Eq. (1).

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