Effects of Vowel Prototypicality and Extremity on Discrimination Sensitivity

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Abstract: This paper examines the relationships between vowel prototypicality and extremity, and their effects on listeners’ ability to discriminate between members of a single vowel category. Based on her 1991 study, Kuhl (1993) hypothesises that vowel prototypes assimilate other category members, causing discrimination sensitivity to be poor around these prototypes. However, from studies on vowel prototypes to date it is not clear what constitutes vowel prototypicality, or whether it is vowel prototypicality or extremity that correlates with poor discrimination sensitivity. In an attempt to answer these questions, experiments were conducted using Japanese and Greek subjects whose high, back vowels differ in their extremity.

THEORETICAL BACKGROUND

This paper is concerned with the relationships between vowel prototypicality and extremity, and the effects they have on listeners’ ability to discriminate between members of a single vowel category. Kuhl (1993) (1) proposes a native language magnet (NLM) theory, which holds that vowel prototypes assimilate other category members, causing discrimination sensitivity to be poor around these prototypes. NLM is originally based on Kuhl’s 1991 study (2), where she found that listeners had more difficulty distinguishing other variants of /i/ from a prototypical /ii/ stimulus, i.e., a stimulus that received the highest-goodness rating [hereafter called Kuhl’s (1991) P], than a non-prototypical /i/ stimulus (a stimulus that received a low goodness rating), although the psychoacoustic distance between the stimuli was kept constant. Kuhl (1991) was replicated by a number of researchers, based on which I would like to bring forward two questions: (a) What constitutes vowel prototypicality?; and (b) Is it vowel prototypicality or extremity that correlates with poor discrimination sensitivity?

Question (a) derives from discrepancy between the results of Kuhl’s (1991) goodness-rating task and its replications. The formant-frequency values of Kuhl’s (1991) P, which was given the highest goodness rating by American listeners, coincide with the average production values obtained from male speakers of American English by Peterson and Barney (1952) (3). However, Lively (1993) (4) reports that in his replication of Kuhl (1991) listeners gave higher ratings to more extreme /i/, and that the results were more variable. Later replications also report that listeners preferred more extreme stimuli than Kuhl’s (1991) P [e.g., Iverson and Kuhl (1995) (5)]. The discrepancy between the locations of the best exemplar of a vowel category and the production average observed in later studies brings up a question of what constitutes vowel prototypicality. Following the prototype theory in the visual domain [e.g., Mervis and Rosch 1981 (6)], the assumptions that prototypes are those category members that are perceived as ‘best’ and that they are situated at the centre of the category in the geometrically represented stimulus space seem to be both undertaken in the field of speech perception. Thus, production average and goodness-rating tasks have been alternatively used in determining the locations of phonetic prototypes [e.g., Repp and Crowder 1990 (7), Samuel 1982 (8)]. However, the replications of Kuhl (1991) suggest that the best exemplar of a vowel category (hereafter-called category ideal) may not necessarily match the production average.

Question (b) derives from the results of discrimination tests in Iverson and Kuhl (1995) that the perceptual distance between Kuhl’s (1991) P and more extreme /i/ stimuli is shorter than that between Kuhl’s (1991) P and less extreme /i/ stimuli. Considering evidence suggesting that discrimination sensitivity may decline towards the periphery of the vowel space [e.g., Schouten and van IJessen 1992 (9)], it is not clear whether the poor discrimination sensitivity observed around Kuhl’s (1991) P in comparison to a less extreme stimulus is due to prototypicality or extremity of Kuhl’s (1991) P.
EXPERIMENTAL DESIGN

Two sets of experiments were designed with the purpose of answering the above two questions. In Experiment 1, F1 and F2 of category ideals and production of three Japanese and Greek vowels /al, /u/ and /u/ were obtained in order to examine whether category ideals were more extreme than the production average as observed in studies on English /i/. Japanese and Greek vowels were studied for comparison, for the two languages have phonologically equivalent sets of vowels. Johnson et al.’s (1993) (10) MOA (method of adjustment) technique was used in order to obtain category ideals from male subjects of the two language groups, from whom production data were also obtained. In Experiment 2, the same subjects were given a same-different task using a /u/ stimulus continuum whose F2 varied in equal mel steps, in order to investigate whether discrimination sensitivity decreased towards the production average, category ideals, or the periphery of the vowel space. As the Japanese high back vowel [u] is not cardinal, it was possible to create a stimulus set whose F2 stretches towards the extremity beyond both the Japanese subjects’ category ideals and production values. Thus, it was expected that the effects of extremity and prototypicality would be distinguished on Japanese subjects’ discrimination sensitivity.

PRELIMINARY RESULTS

The results of Experiment 1 suggest that there is considerable variability in the locations of category ideals even within the same language population as shown in Lively (1993). On the whole, category ideals appear to be more extreme than the production average in F2 for the Japanese and Greek /u/, and the Japanese /u/, but not for other cases (i.e., in neither F1 nor F2 of Greek /u/). The change in discrimination sensitivity obtained in Experiment 2 was plotted for each subject using d’ (bias-free measure). Some, but not all, discrimination sensitivity curves have dips where each subject’s category ideal and production value lie and also at an extreme location, suggesting that both vowel prototypicality and extremity may play a role in lowering discrimination sensitivity. An examination of each subject’s false alarm and hit rates suggests that across the two populations individuals may have used different strategies in coping with the task. Methodological questions on vowel discrimination tasks will be discussed.

REFERENCES