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THE EFFECT OF VOWEL QUALITY ON PITCH

1. Introduction

A number of studies (House & Fairbanks, 1953; Lehiste & Peterson, 1961; Peterson & Barney, 1952) have shown that vowels have an intrinsic fundamental frequency related to their height: high vowels (low F1) have a higher fundamental frequency than low vowels (high F1). Very little research has been done on the perception of these F0 differences intrinsically linked to vowel quality (Beeckmans et al., 1974; Slawson, 1968). In this paper I will investigate to what extent these F0 differences are influenced by vowel quality.

2. Experimental paradigm

Ten subjects (5 Females and 5 Males), all native speakers of American English, participated in this experiment. They were asked to compare the pitch of two synthesized vowels of different quality. Only those who were able to achieve a score of 95% or better in a control experiment involving the comparison of the pitch of two pure tones were selected as subjects. The formant values of the three vowels used in this experiment are given in table 1.

Table 1. Formant values of synthesized vowels i,a,u.

	i	a	u
F1 (in Hz)	270	730	300
F2	2600	1090	870
F3	2800	2440	2240

Three fundamental frequencies: 115,120 and 125 Hz were superimposed on each of these three vowels which had a duration of 250 ms (with a rise and decay time of 20 ms). The interval separating the first (V1) and the second vowel (V2) was 500 ms. The fundamental frequency of the second vowel was either 5 Hz below, equal to, or 5 Hz above the F0 of the first vowel (in other words, the fundamental frequency range of V2 was from 110 Hz to 130 Hz). V1 and V2 always differed in quality (i.e. there were no i-i, a-a or u-u sequences). Six repetitions of all possible V1-V2 comparisons were presented making a total of 324 judgements (3V1 qualities x 3V1 F0 x 2V2 qualities x 3V2 F0 x 6 repetitions).

Overall amplitude levels were equalized for the three vowels. Subjects were asked to judge whether the first or the second vowel was higher in pitch (i.e. two-way forced choice). They were instructed to mark the corresponding vowel on their answer sheet. They had three seconds in which to make a response. The experiment was divided into two parts preceded by a short training session in which six pairs were presented. The same stimulus presentation format was adopted in the control experiment in which synthesized vowels were replaced by pure tones. The role of this control experiment was twofold; it was used to determine the accuracy of the subjects' pitch perception and also to investigate the effect of stimulus ordering on the perception of pitch, especially when the two tones had the same frequency.

3. Results and discussion

Since the criterion used to select subjects was quite strict (minimum of 95% correct in the control experiment), they made very few mistakes when the vowels were 5 Hz apart (90% correct or better). As a result, in the following analysis, I will only consider the pairs which had identical F0 on both vowels. The subjects' responses for these pairs are presented in table 2.

Table 2. Number of times each vowel Was judged to be the higher in pitch when comparing the pitch of vowels of different quality but equal fundamental frequency (10 Subjects).

i/a comparison (i-a and a-i pairs)	u/a comparison (u-a and a-u pairs)	u/i comparison (u-i and i-u pairs)
a = 257	a = 261	i = 185
i = 103	u = 99	u = 175

From this table it is clear that the low vowel [a] has a tendency to be judged higher in pitch than the high vowels [i] or [u] (although their fundamental frequencies were in fact equal). These data were sujected to a three-way analysis of variance. The hypothesis being tested was found to be statistically significant ($P < 0.0005$). The ordering effect was found to be non-significant. Since the low vowel [a] has a tendency to be perceived higher in pitch than high vowels of identical F0, this implies that vowel quality affects pitch perception of vowels and more precisely that the pitch difference between high and low vowels is smaller than their intrinsic fundamental frequency differences. This is important for explaining why intrinsic fundamental frequency differences caused by vowel height did not give rise to tonal development as frequently as we would have expected considering the magnitude of these intrinsic differences (Hombert, 1975).

References

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