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PERCEPTUAL CUES TO THE END OF ASPIRATION

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INTRODUCTION AND SUMMARY

Fischer-Jørgensen and Hutters (1981) have drawn attention to the phonetic problem of delimiting the end of aspiration in aspirated stops. Particularly before low vowels, periodic excitation may be present at the fundamental (F0) or in low harmonics (around F1) some centi-seconds before it appears at higher frequencies. Fischer-Jørgensen and Hutters present evidence that durational measurements are more regular if aspiration is considered to have ended when buzz excitation has spread at least beyond the fundamental and probably to the second and third formant region (when presumably the vocal folds close completely during the glottal cycle). The perceptual significance of such incomplete buzz excitation has not been investigated systematically. What effect does buzz excitation confined to the first formant have on a /b/-/p/ boundary; will it be treated as the end of aspiration or the start of voicing?

We have investigated the position of the phoneme boundary between aspirated [p^ha] and unaspirated [ba] stops for English speakers, when the first 30ms of buzz excitation (at various levels) is restricted to the first formant (F1-only conditions) compared with control conditions in which buzz excitation is present in all three formants (F123 conditions). We find that buzz in the F1 region is perceptually similar (as far as aspiration is concerned) to buzz of the same peak intensity in all three formants, and is thus not perceived as being part of the aspiration.

We have also looked at how the /b/-/p/ boundary is influenced by the intensity of buzz onset (relative to the vowel) and the intensity of aspiration. For all buzz onset intensities we find that, when aspiration intensity is increased, the VOT boundary shifts by about the 0.43ms/dB found by Repp (1979). When buzz onset intensity is attenuated (during the first 30 ms of voicing), the boundary shift follows Repp's ratio provided the attenuation is less than 15dB; at greater attenuations the stops sound more aspirated than predicted. This departure from Repp's ratio perhaps reflects the criterion used to determine when buzz excitation has started.

EXPERIMENT 1

All stimuli were 300ms long, with 3-formants (digital parallel synthesis; F0=100Hz) following a natural [p^h] burst.
The 9 different, 10-member, [ba] - [p^ha] continua were:
Abrupt: conventional abrupt onset of buzz in all 3 formants;

F123: 4 continua with reduced intensity during first 30 ms of buzz (present in all 3 formants). The first glottal pulse was either 10,15,20 or 25dB down from the steady vowel level, and the second and third 5dB higher than the first;

F1-only: 4 continua with reduced intensity during the first 30ms of buzz, but with buzz confined to F1. The level of buzz in F1 was either 5,10,15 or 20dB down from its steady-state for the first glottal pulse, again rising by 5dB for the second and third.

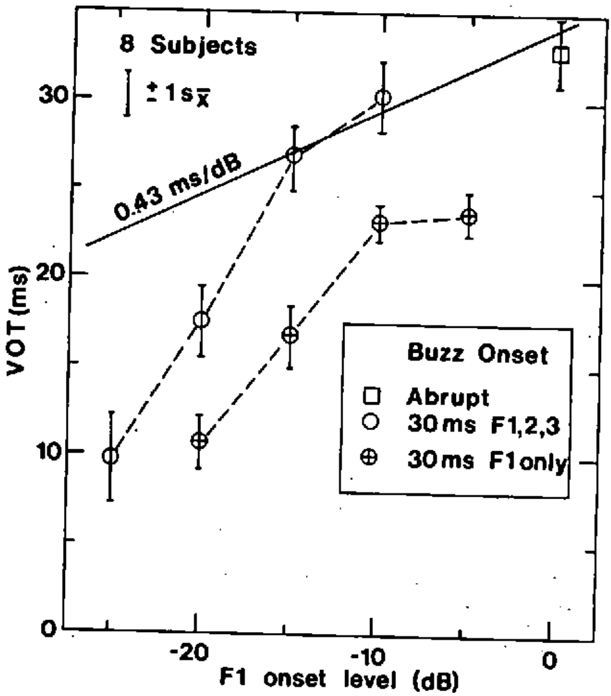

Figure 1. /b/-/p/ boundaries from Experiment 1 for sounds differing in intensity and spectrum of buzz excitation during first 30ms of voicing.

Results

Phoneme boundaries (8 subjects; 10 replications) are plotted in Figure 1 as the time from burst onset to the onset of any buzz excitation. If buzz confined to F1 were treated perceptually as part of the aspiration, the F1-only boundaries should be at a VOT 30ms less than the Abrupt condition's boundary. They are not. Aspiration is not delimited perceptually as the time at which buzz spreads to the higher formants. Nor is it delimited by the onset of low-frequency buzz. If it were, we would expect sounds with the same F1 buzz energy to have the same boundaries. They do not. Additional buzz in F2 and F3 makes the sounds more voiced. It is more nearly the case that peak buzz intensity (irrespective of frequency) determines the boundary. If the two curves are plotted as a function of peak intensity (shifting the F1-only curve to the left by about 5dB in Figure 1) then they overlap at the three lowest onset intensities.

Both the F1 only and F123 conditions show a slope of around 1.5ms/dB across the three lowest intensity values, while the higher intensity points lie quite well on a line with a slope of 0.43 ms/dB. This value was found by Repp (1979) when he varied the intensity of aspiration relative to voicing. The steeper slope is sufficiently different from Repp's value that it is unlikely to be due to a trading-relation between aspiration and buzz intensity. Instead it may reflect the criterion used to determine when buzz excitation has started (see Darwin and Pearson, 1982). The next experiment looks at this possibility.

EXPERIMENT 2

By varying the level of aspiration directly, we can manipulate the aspiration/buzz onset ratio independently of the actual buzz onset level. Manipulations involving aspiration intensity should follow Repp's ration, and manipulation of buzz onset level at higher onset levels should also follow this ratio, but at lower levels should follow the steeper slope found in Experiment 1. The Abrupt and F123 conditions from the first experiment were repeated here together with the same sounds but with the burst and aspiration boosted by 10dB.

The boundary values for 9 subjects are plotted as a function of the ratio of the level at onset of buzz (L_V) to the aspiration level (L_A). The value of this ratio for the Abrupt condition is taken as 0dB. As in the first experiment, the conditions with high onset levels follow approximately Repp's relation (indicating the importance of aspiration level relative to buzz onset level) as both buzz onset level and aspiration level change. Even at low intensities of buzz onset, the effect of boosting the aspiration by 10dB still follows Repp's ratio. But as the level of buzz onset is lowered to less than 15dB down from the steady-state, the stops become aspirated too quickly for Repp's ratio (replicating Experiment 1). In other words, the differences between corresponding points on the quiet and the +10dB curves in Figure 2 follows Repp's ratio, but the slopes of the individual curves at low buzz onset levels do not. The latter slope more likely reflects a decision criterion about buzz onset.

REFERENCES

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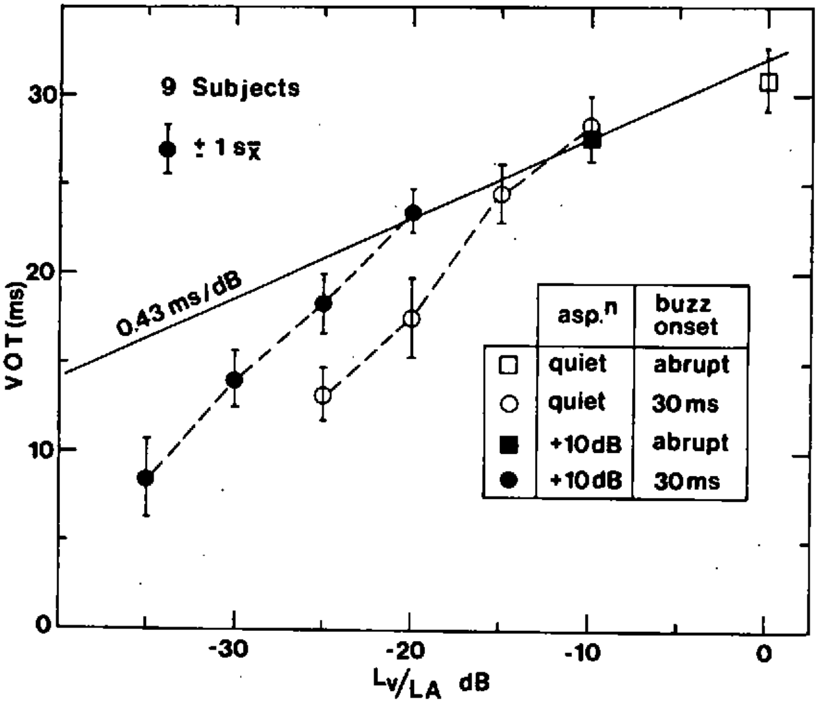

Figure 2. /b/-/p/ phoneme boundaries from Experiment 2 for sounds differing in intensity of buzz excitation during first 30ms of voicing and in intensity of aspiration.