Inhibitory Influences on Asynchrony as a Cue for Auditory Segregation

Auditory grouping involves the formation of auditory objects from the sound mixture reaching the ears. The cues used to integrate or segregate these sounds and so form auditory objects have been defined by several authors (e.g., Bregman, 1990; Darwin, 1997; Darwin & Carlyon, 1995). The key acoustic cues for segregating concurrent acoustic elements are differences in onset time (e.g., Dannenbring & Bregman, 1978; Rasch, 1978) and harmonic relations (e.g., Brunstrom & Roberts, 1998; Moore, Glasberg, & Peters, 1986). In an example of the importance of onset time, Darwin (1984a, 1984b) showed that increasing the level of a harmonic near the first formant (F1) frequency by adding a synchronous pure tone changes the phonetic quality of a vowel. However, when the added tone began a few hundred milliseconds before the vowel, it was essentially removed from the vowel percept.

General Method

Overview

In the experiments reported here, we used a paradigm developed by Darwin to assess the perceptual integration of additional energy in the F1 region of a vowel through its effect on phonetic quality (Darwin, 1984a, 1984b; Darwin & Sutherland, 1984). Amplitude and phase values for the vowel harmonics were obtained from the vocal-tract transfer function using cascaded formant resonators (Klatt, 1980). F1 values varied in 10-Hz steps from 360-550 Hz—except in Experiment 3, which used values from 350-540 Hz—to produce a continuum of 20 tokens.

Listeners

INHIBITORY INFLUENCES ON ASYCHRONY

Listeners were volunteers recruited from the student population of the University of Birmingham and were paid for their participation. All listeners were native speakers of British English who reported normal hearing and had successfully completed a screening procedure (described below). For each experiment, the data for 12 listeners are presented. Procedure

At the start of each session, listeners took part in a warm-up block. Depending on the number of conditions in a particular experiment, the warm-up block consisted of one block of all the experimental stimuli or every second or fourth F1 step in that block. This gave between 85 and 100 randomized trials.

Data Analysis

The data for each listener consisted of the number of /I/ responses out of 10 repetitions for each nominal F1 value in each condition. An estimate of the F1 frequency at the phoneme boundary was obtained by fitting a probit function (Finney, 1971) to a listener’s identification data for each condition. The phoneme boundary was defined as the mean of the probit function (the 50% point).

Experiment 1

There were nine conditions: the three standard ones (vowel alone, incremented fourth, and leading fourth) plus three captor conditions and their controls. A lead time of 240 ms was used for the added 500-Hz tone. Results and Discussion

Figure 4 shows the mean phoneme boundaries for all conditions and the restoration effect for each captor type. The restoration effects are shown above the histogram bars both as a boundary shift in hertz and as a percentage of the difference in boundary position between the incremented-fourth and leading-fourth conditions.

Experiment 2

This experiment considers the case where the added 500-Hz tone begins at the same time as the vowel but continues after the vowel ends.

Method

There were five conditions: two of the standard ones (vowel alone and incremented fourth), a lagging-fourth condition (analogous to the leading-fourth condition used elsewhere), and a captor condition and its control. A lag time of 240 ms was used for the added 500-Hz tone.

Results and Discussion
Method

There were 17 conditions: the three standard ones (vowel alone, incremented fourth, and leading fourth), five captor conditions and their controls, and four additional conditions (described separately below). A lead time of 320 ms was used for the added 500-Hz tone. The captor conditions were created by adding a 1.1-kHz pure-tone captor, of various durations, to each member of the leading-fourth continuum. …[section continues].

Results

Figure 6 shows the mean phoneme boundaries for all conditions. There was a highly significant effect of condition on the phoneme boundary values, $F(16, 176) = 39.10, p < .001$. Incrementing the level of the fourth harmonic lowered the phoneme boundary relative to the vowel-alone condition (by 58 Hz, $p < .001$), which indicates that the extra energy was integrated into the vowel percept. …[section continues].

Discussion

The results of this experiment show that the effect of the captor disappears somewhere between 80 and 160 ms after captor offset. This indicates that the captor effect takes quite a long time to decay away relative to the time constants typically found for cells in the CN using physiological measures (e.g., Needham & Paolini, 2003). …[section continues].

Summary and Concluding Discussion

Darwin and Sutherland (1984) first demonstrated that accompanying the leading portion of additional energy in the F1 region of a vowel with a captor tone partly reversed the effect of the onset asynchrony on perceived vowel quality. This finding was attributed to the formation of a perceptual group between the leading portion and the captor tone, on the basis of their common onset time and harmonic relationship, leaving the remainder of the extra energy to integrate into the vowel percept. …[section continues].

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