Discrimination of Frequency Transitions: or, Can You Distinguish the Different Birds Chirping by the Waterfall?

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Overview

One method which has become increasingly popular to study complex phenomena such as speech perception is the use of non-speech analogs (eg. frequency transitions). In this study, the discrimination of frequency transitions was examined as a function of frequency region, trajectory direction, and presence of background noise.

Methods

Subjects:

Subjects were 5 young adults aged 19-30 years (mean 24 yrs) audiologically screened for normal hearing.

Stimuli:

Eight continua of 17 signals (60 msec in duration including 5 msec rise/fall times) were sampled at 20 kHz, 12 bit resolution, low passed at 5 kHz and output through a Macintosh II computer. Four continua were centered at 1 kHz; four at 3 kHz. At each frequency region, for both upward and downward trajectories, signals converged on a common offset frequency or diverged to varying offset frequencies. Increments were 10 Hz steps at 1 kHz; 30 Hz steps at 3 kHz.

Procedure:

A two-alternative forced-choice paradigm designed to determine the just noticeable differences (jnds) was used. Trials consisted of 2 stimuli with an ISI of 500 ms and the required response was 'same' or 'different'. Stimuli were delivered monaurally via AKG headphones at 65 dB SPL. For converging signals, speech spectrum noise was added and presented at an S/N ratio of +5 dB.

Results and Discussion

Logit transformations were computed on percentage correct scores as a function of frequency separation. Average psychometric functions were calculated with logistic analysis and are shown in Figures 1 and 2.

(NOTE: FOR ALL FIGURES: D = Diverging; C= Converging; DN = Down; N = Noise)

At 1 kHz, the functions for signals with a downward trajectory show a displacement to the right relative to the other series. The reverse pattern is seen for the 3 kHz signals where the signals which sweep downward are shifted to the left of those which have an upward trajectory.

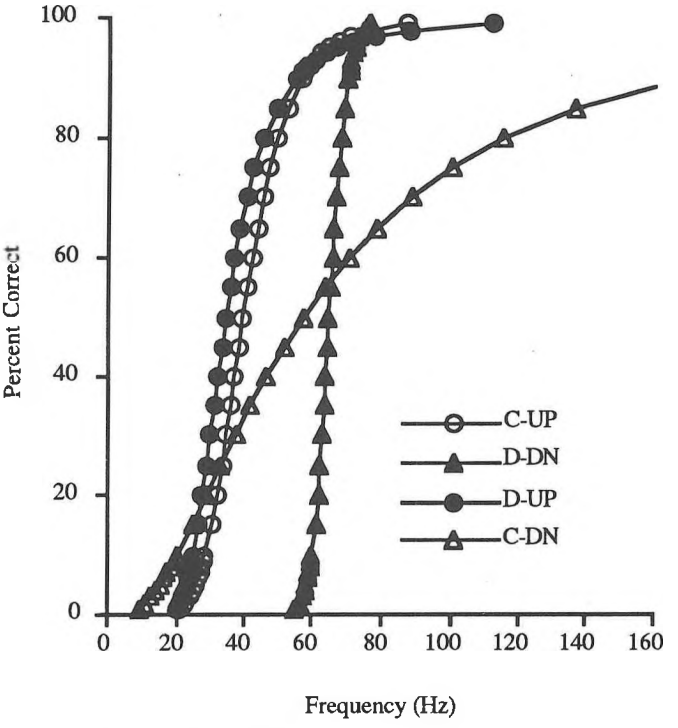

Figure 1. Functions at 1 kHz

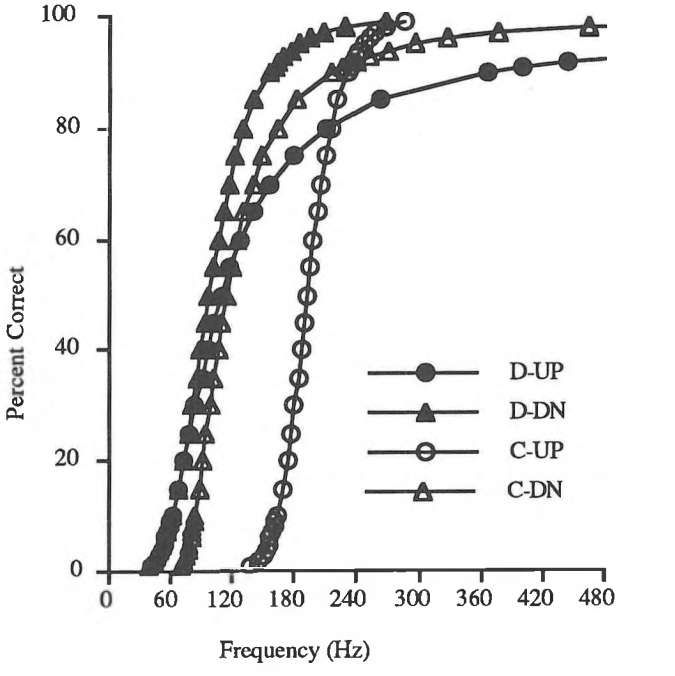

Figure 2. Functions at 3 kHz

Mean jnds (defined as the 70% correct position) across signal type are summarized in Figures 3 and 4.

A 2-factor within-subjects analysis of variance (transition direction: up or down, and end frequency: diverging or converging) was conducted separately for the data at each frequency region. At 1 kHz, there were significant main effects of direction [$F(1,4) = 101.1$, $p < .001$] and end frequency [$F(1,4) = 35.22$, $p < .001$]. At 3 kHz, the effect for direction was significant, [$F(1,4) = 22.15$, $p < .01$; however, neither the effect for end frequency, nor the interaction term were significant. At 1 kHz, diverging offset frequency signals were easier to discriminate than converging signals. Decreases in frequency over time were more difficult than increases in frequency over time. At 3 kHz, signals which decreased in frequency over time, regardless of whether they converged or diverged to differing offset frequencies, were easier to discriminate then signals which swept in an upward trajectory. There was no significant effect for 1 kHz signals embedded in a background of noise. At 3 kHz, only signals which converged upward to a common frequency were adversely affected by noise.

There are two major findings from this study: a minimal effect for noise and frequency dependent directional sensitivity. Directional preference for different frequency regions is consistent with other findings involving both human (Porter et al, 1991) and animal studies (Heil et al; 1992). Asymmetries in tuning curves where above 1 kHz, the high frequency slopes are very steep, might also account for the finding that signals in this region which decrease in frequency over time may provide 'clearer' cues for discrimination.

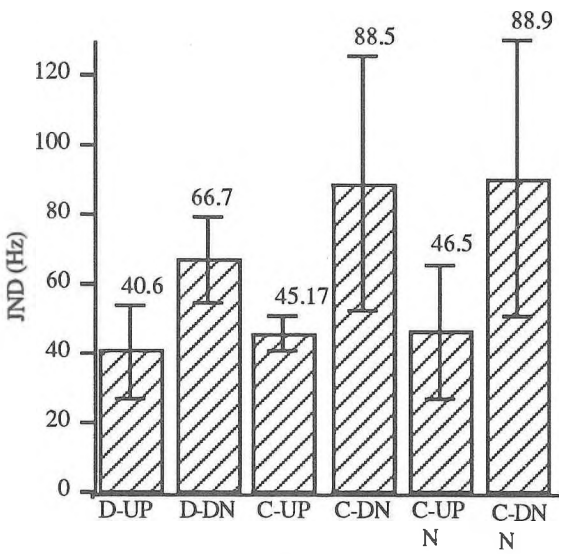

Figure 3. Thresholds at 1 kHz

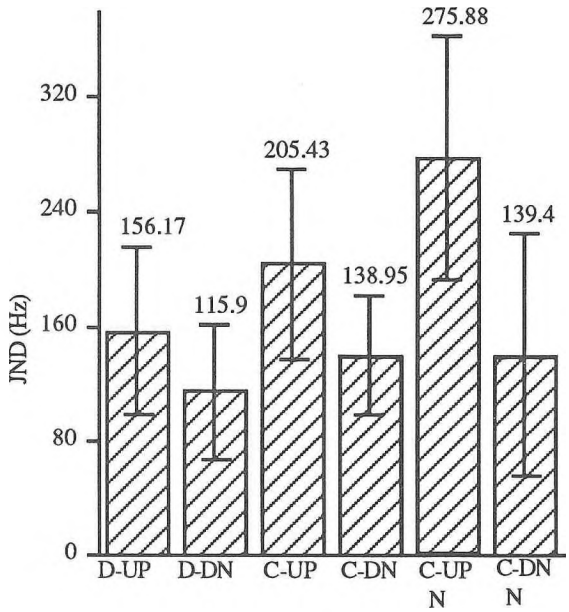

Figure 4. Thresholds at 3 kHz.

References

Heil, P., Langner, G., & Scheich, H. (1992). Processing of frequency modulated stimuli in the chick auditory cortex analogue: evidence for topographic representations and possible mechanisms of rate and directional sensitivity. *J. Comp. Physiology A, 171*, 583-600.

Porter, R.J., Cullen, J.K., Collins, M.J., & Jackson, D. F. (1991). Discrimination of formant transition onset frequency: psychoacoustic cues at short, moderate, and long durations, *J. Acoust. Soc. Am., 90(3)*, 1298-1308.

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