Spectral Weights for Pitch Judgment

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Abstract: Spectral weighting functions are measured to assess how listeners use spectral information in judging the pitch of harmonic complex tones. Random, independent perturbations are added to the frequencies of the spectral components and are correlated with listeners' responses. The correlation coefficient (or weight) associated with each component measures the importance of that component in the listeners' pitch judgments. The obtained weighting functions show a dominant influence from low-ranked partials. When these dominant partials are removed, partials closest to the dominance region become the most influential.

INTRODUCTION

The purpose of this study is to gain insight into the way listeners extract the pitch from harmonic complex tones. In a previous paper[1] that measured listeners' spectral weighting functions for pitch judgments, we found that partials of relatively low harmonic rank, particularly those around 600 Hz, tend to have the strongest influence on listeners' responses. These results generally conform to the idea of a low-frequency dominance region put forth by previous investigators (see Ref. [1] for additional references). In the present study we focus on the auditory organization for pitch perception[2] when partials in the dominance region are absent. Specifically, we measured listeners' spectral weighting functions in a pitch discrimination task using harmonic complex tones whose lower partials are systematically removed.

METHODS

The method is similar to that described in the earlier paper[1] with the following exceptions: 1) Here each two-interval trial begins with a standard harmonic complex tone, and 2) the second stimulus is identical to the standard except that the frequencies of individual components are randomly perturbed. The perturbation is drawn from a Gaussian distribution with zero mean and a sigma that is 2% of each nominal frequency. The listener indicates which interval has the higher pitch. The stimuli are harmonic complex tones with a fundamental frequency of 200 Hz. The highest partial is fixed at the twelfth. The lowest partial is the independent variable; it is the fundamental (f1 = 200 Hz) in Cond. A, the third (f1 = 600 Hz) in Cond. B, the fifth (f1 = 1000 Hz) in Cond. C, and the seventh (f1 = 1400 Hz) in Cond. D. Two musicians participated in this experiment. After at least N=2000 trials for each condition with each listener, the responses, which consist of 1s and 2s, are correlated with the perturbations given to each component, and the correlation coefficients provide an estimate of the decision weights associated with individual components.[3]

RESULTS AND DISCUSSION

FIGURE 1. Weights (correlation coefficients) as a function of harmonic number obtained from two subjects in four conditions (A, B, C, and D) with different starting harmonics. The fundamental frequency is 200 Hz. The shaded area in each panel is bounded by plus and minus two standard errors around the zero-correlation line; weights that fall inside these areas are deemed not to differ significantly from zero.
Figure 1 presents the estimated spectral weighting functions for the four conditions. When all 12 partials are present (circles), the first three dominated listeners' pitch judgments. The third partial at 600 Hz tends to be most influential, which is consistent with the previous report. As the lowest partials are excluded from the complex tone, the weights redistributed, with the dominant weights moving to the lowest partials available in the stimuli. The only exception is for S2 who show maximum weight at the highest partial for Cond. D (diamonds, right panel). We have no good explanation for this behavior.

The negative weights for S1 in Conds. C and D are intriguing. On the surface, a negative correlation simply implies that an upward frequency shift of that component would cause a downward shift of pitch. Such an effect, however, has not been observed in the past. One interpretation relates the negative weights to the possible role of the nonlinear cubic distortion tones generated by the two lowest partials at \( f_1 \) and \( f_2 \). If the cubic tone has a strong influence on listeners' responses, this will be reflected in the weights associated with the two primary partials. Specifically, because the frequency of the cubic distortion tone equals \( 2f_1-f_2 \), the estimated weight for \( f_2 \) would be expected to be half the magnitude of the weight for \( f_1 \), but of opposite sign. This is roughly the case for both weighting functions (in Conds. C and D) showing negative weights.

If the above hypothesis is correct, then one could expect the negative weight at \( f_2 \) to disappear when the cubic distortion tone is masked. We tested this by repeating Cond. C with S1, adding a lowpass continuous masking noise \( (f \leq 800 \text{ Hz}, N_0 = 25 \text{ dB SPL}) \) to make the possible cubic distortion tone at \( 2f_1-f_2 \) (800 Hz) ineffective. Figure 2 presents the obtained weighting function (filled triangles), along with the function from the left panel of Fig. 1 (unfilled triangles) for comparison. The negative weight at \( f_2 \) (or the 6th harmonic) is eliminated by the lowpass masking noise. This suggests that, when the lowest harmonic available in the complex is outside the dominance region, some listeners may fall back on the cubic distortion tone to extract pitch, perhaps because the cubic tone is closer to the dominance region than any component present in the stimuli, albeit much less audible.

FIGURE 2. Weighting functions as for Fig. 1, but only for Cond. C. The function represented by filled triangles is obtained in the presence of a lowpass masking noise. The function with unfilled triangles is taken from Fig. 1 for comparison.

To summarize, partials within a dominance region around 600 Hz appear to have the strongest influence on the listeners' pitch judgments, as reflected in the magnitude of the measured spectral weighting functions. When these low-ranked dominant partials are absent, the listeners will likely turn to the new lowest components available. Because it is closest to the dominance region, even a much weaker nonlinear cubic distortion tone can become the most influential.

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REFERENCES

