The Role of Global Processes in the Perceptual Cohesion of Harmonic Complex Tones

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Abstract: In Experiment 1, 2-4 consecutive components were removed from a 14-harmonic complex and replaced with a "probe" component, located at one of a set of regularly spaced positions spanning the spectral gap ("probe window") created in the complex. In Experiment 2, the components on either side of the probe window were harmonics of different fundamental frequencies. On any trial, subjects heard the complex, followed by an adjustable pure tone played in a continuous loop. In both experiments, subjects were well able to match the pitch of the pure tone to that of the probe, unless the probe coincided with an "in tune" harmonic position. Profiles of hit rates across the probe window imply that the pitches of in-tune partials are actively suppressed. Suppression at non-consecutive harmonic positions is consistent with predictions based on template models.

BACKGROUND

Spectral models suggest that the pitch of a complex tone corresponds to the fundamental frequency of a "template" or "sieve" that best matches the distribution of its components (1). Partials are rejected if they lie outside narrow regions around harmonic values defined by this fundamental frequency. It has been suggested that "in tune" partials are difficult to hear out from a periodic complex because their pitches are actively inhibited by the auditory system (2). By this account, a template is used to estimate the low pitch of a complex, and the auditory system then inhibits the independent pitches of partials that fall near integer multiples of its fundamental frequency. A pitch-matching procedure previously used to investigate the segregation of mistuned harmonics (3) was adapted and used here to test this proposal.

EXPERIMENT 1

Within each trial, subjects listened to a repeating cycle consisting of: a complex "test" tone (420 ms) → silence (200 ms) → an adjustable pure tone (310 ms) → silence (500 ms). The test tones used in conditions 1-3, respectively, were created by removing either 2, 3, or 4 consecutive harmonics (6 and above) from complex tones comprising harmonics 1-14. A "probe" was inserted at one of 17, 25, or 33 (for conditions 1-3, respectively) equally spaced positions in a "probe window" that spanned the gap in the spectrum. Subjects were instructed to adjust the pitch of the matching tone to that of a pure tone-like sound embedded in the test tone. Accurate matches were taken as evidence of segregation. The fundamental frequency of the test tones was roved around 200 Hz in the range +/- 20%. All stimuli were presented binaurally. The partials were in sine phase and set to 60 dB SPL. The probe and adjustable tone were set to 54 dB SPL. Six subjects provided 12 matches to all probes in each condition. Subjects were given feedback on their performance at the end of each trial. Figure 1 shows the mean inter-subject hit rates and standard errors for all probe positions in each condition. Hit rates were high except when the probe coincided with an in-tune position (see dotted vertical lines).

FIGURE 1. Proportion of correct matches to the frequency of the probe.
EXPERIMENT 2

Each complex comprised harmonics 1-4 of a 100-Hz nominal fundamental, and harmonics 7-10 of a 110-Hz nominal fundamental. Both fundamentals were roved using the same multiplier, in the range 1.0 to 2.0. Probes were inserted at one of 27 positions in the gap between the lower and higher sets of partials. The lowest and highest probe positions corresponded to the 4th harmonic of the higher nominal fundamental and the 7th harmonic of the lower nominal fundamental, respectively. Hit rates were lower at the in-tune positions in the spectral gap, as defined by the lower and the upper sets of harmonics. These positions are marked as dashed and dotted lines, respectively, in Figure 2.

![Figure 2](image)

**FIGURE 2.** Proportion of correct matches to the frequency of the probe.

GENERAL DISCUSSION

Probe tones corresponding to harmonic frequencies were less successfully matched than those at other positions. This implies that the pitches of in-tune probes were actively suppressed. In Experiment 1, suppression was found at both consecutive and non-consecutive in-tune positions. Non-consecutive suppression was not dependent upon equidistance between neighboring components (condition 3). Experiment 2 showed that this suppression can extend both upwards and downwards in frequency from a set of consecutive partials. In both experiments, troughs in the hit-rate profiles were shallower at non-consecutive probe positions. These findings are best reconciled with a model of a template that induces a suppression at harmonic values that attenuates away from regions of consecutively spaced components.

Matches to a mistuned partial are typically somewhat displaced from its true frequency in the same direction as the mistuning (3). Comparable pitch shifts have been reported even when neighboring harmonics are removed (4). This provides complementary evidence in favor of template models. Other recent findings have shown that similar pitch shifts can be found when a partial in a frequency-shifted complex is mistuned (5). The location of slot centers in the template was inferred by estimating the point at which pitch shifts changed direction. This approach was based on the proposal that pitch shifts are directly related to the frequency displacement between a partial and the center of a slot in the template (6). The method introduced here provides a more accurate profile of the perceptual suppression of partial pitches. In future, it may be used to explore the pattern of suppression induced by regular inharmonic complexes.

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REFERENCES