Pitch mechanisms for unresolved harmonics I: Duration effects

Louise J. White and Christopher J. Plack

Laboratory of Experimental Psychology, University of Sussex, Brighton, BN1 9QG England

Abstract: The effects of duration, fundamental frequency (F0), spectral region, and relative phase of harmonics on F0 discrimination were measured for complex tones consisting of unresolved harmonics. The complex tones had F0's of 62.5 and 125 Hz. They were bandpass filtered between 2750 and 3750 Hz or between 5500 and 7500 Hz. For the 62.5 Hz complex, all the harmonics were either in sine phase (SINE) or alternately in sine and cosine phase (ALT). For the 125 Hz complex all the harmonics were in sine phase. The pitch of an unresolved ALT complex is one octave higher than that of an unresolved SINE complex with the same F0 (1). Overall the results suggest that pitch, rather than F0 or spectral region, is the main determinate of the duration effect and also possibly of the integration time of the pitch mechanism.

INTRODUCTION AND RATIONALE

Previous work has shown a large increase in F0 discrimination performance for unresolved harmonic complexes with increasing tone duration for durations up to approximately 100 ms (2). The size of this effect appears to be dependent upon the F0 of the complex (2). This has led to the hypothesis that the pitch mechanism for unresolved harmonics uses a long integration window (2).

It has also been demonstrated (1) that, for unresolved harmonic complexes only, when consecutive harmonics alternated between sine and cosine phase the pitch of the complex was one octave higher than the F0. For these stimuli, the envelope of the waveform is repeating at 2F0 and it has been shown that auditory nerve fibres phase lock to the envelope of an unresolved complex (3). This suggests that the pitch mechanism is using timing information present in the auditory nerve to determine pitch.

Therefore, using this method of phase shifts on alternating harmonics it should possible to discriminate between the effects of F0 and the effects of pitch. The purpose of the experiment is to determine whether it is the F0, the pitch or the spectral region of the complex which determines the size of the duration effect.

STIMULI AND PROCEDURE

The stimuli consisted of the harmonics of 62.5 Hz and 125 Hz F0's bandpass filtered between 2750 and 3750 Hz or between 5500 Hz and 7500 Hz. They were gated on and off with 10-ms cosine ramps with total durations of 20, 40, 80 and 160 ms. For the 62.5-Hz F0 either all the harmonics were in sine phase (SINE) or harmonics alternated between sine and cosine phase (ALT), for the 125 Hz complex all the harmonics were in sine phase (SINE).

A two-interval 2AFC paradigm was used with feedback provided after every trial. A two-down one-up adaptive procedure was used to track the 71% correct point on the psychometric function (4). At the beginning of each adaptive track the F0 of the stimulus in the 'comparison' interval was 20% higher in frequency than the F0 of the stimulus in the 'standard' interval. During the tracking the F0 in the comparison interval was increased and decreased by a factor of 1.41. Sixteen turnpoints were measured and the threshold estimate was taken as the geometric mean of the last 12. Ten thresholds estimates were taken for each condition and the final estimate was the geometric mean of these 10. Mean results are the geometric means of the final thresholds across listeners.

Five listeners took part. One was author LW and the others were paid an hourly wage. They all had hearing levels within normal clinical limits and were all experienced in psychoacoustical tasks. Stimuli were presented to the right ear via Sennheiser HD414 headphones.

RESULTS AND DISCUSSION

The mean F0 discrimination thresholds are shown Fig. 1. For all conditions thresholds decrease with increasing tone duration. This is in agreement with previous findings. An analysis of variance showed a highly significant interaction between spectral region and tone duration [F(3,12)=106.39, p< 0.01]. However, the differences in thresholds between spectral region were due to the 20-ms condition thresholds only.

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Across spectral region, the two 62.5 Hz conditions show highly significantly different thresholds \[ F(2,8) = 68.45, \ p < 0.01 \]. There is a greater reduction in threshold with duration for the 62.5 Hz SINE condition than the 62.5 Hz ALT condition for both spectral regions \[ F(96,24) = 45.90, \ p < 0.01 \]. The 62.5 Hz ALT condition and the 125 Hz SINE condition show very similar performance and there is no significant difference between them \[ F(2,8) = 0.138, \ p > 0.05 \]. According to previous pitch matching data (1), the 62.5 Hz ALT and the 125 Hz SINE conditions have the same perceived pitch.

![Graph showing mean F0 discrimination thresholds](image)

**FIGURE 1.** The mean F0 discrimination thresholds obtained using the procedure described in the text. Error bars show standard errors between listeners.

These data support the hypothesis that the pitch mechanism for unresolved harmonics uses a long-duration integrator which extracts information about the F0 using timing information in the auditory nerve, so that when the timing information is manipulated, as it is here, then F0 discrimination performance is affected. The data also suggest that it is predominantly pitch, not F0 or spectral region, that determines the size of the duration effect and therefore the duration of the integration window.

**ACKNOWLEDGMENTS**

The first author is supported by the Medical Research Council (UK), and the second author by a Royal Society University Research Fellowship.

**REFERENCES**