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# The effect of phase in the perception of octave height P38

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## Abstract

Attenuation of the odd harmonics of a complex harmonic tone eventually leads to a shift of one complete octave in the perception. In a 2AFC experiment, we assessed how much the odd harmonics had to be attenuated to make a sound indistinguishable from its octave. Thresholds were measured for four fundamental frequencies [31, 63, 125, 250 Hz]. The phase of the odd harmonics was shifted by 0, 1/3 π or 1/2 π and the lowest harmonic was number 2, 4, 8 or 16. The design was complete and orthogonal. The stimulus conditions included complex tones containing (a) only resolved harmonics, (b) only unresolved harmonics, or (c) both resolved and unresolved harmonics. A model based on the spectral and temporal profiles of the auditory image (Patterson et al, 1995) was used to predict the data.

## Pitch Helix

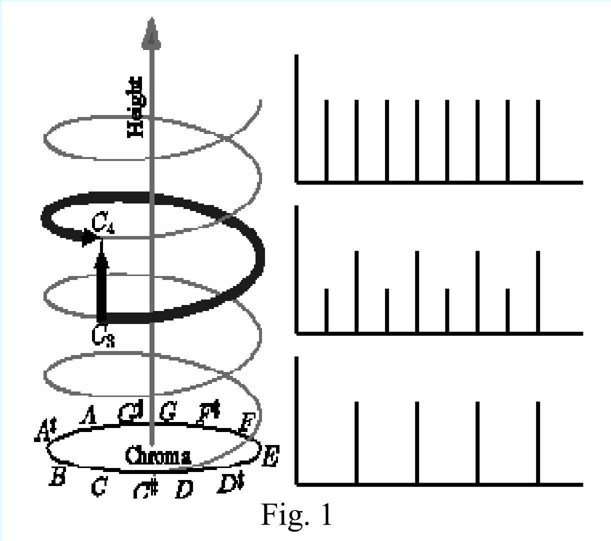


Fig. 1

For musicians, pitch has two dimensions in the sense that a note has an octave (C1, C2,…) and a position on the cycle of notes within the octave (C,D,..). In auditory perception, these dimensions are referred to as octave height and pitch chroma. Computers enable us to change the octave of a note without going through the cycle of notes within the octave:

- Attenuation of the odd harmonics of a complex harmonic tone eventually leads to a shift of one complete octave in the perception (Fig. 1 on the right)
- Alternating phase can lead to a near octave shift

The perception of octave height has been investigated in a number of studies (e.g. Patterson, 1990; Patterson et al. 1993; Carlyon and Shackleton, 1994; Shackleton and Carlyon, 1994; Warren et al, 2003). The experiment in this study is designed to increase the sensitivity of the perceptual judgements to the effect of phase on octave perception.

## Experiment

- How much do we have to attenuate the odd harmonics to reach an octave shift?
- Does F0, phase shifts of odd harmonics and/or frequency region affect the amount of attenuation?

### Stimuli

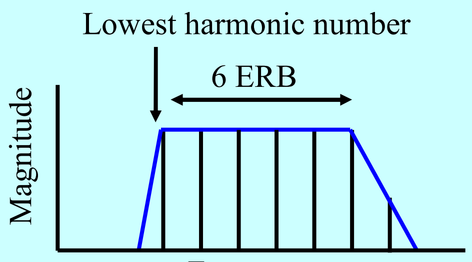


Fig. 2

- F0: 31.25, 62.5, 125 or 250 Hz
- Lowest harmonic number: 2, 4, 8 or 16
- Phase shift of odd harmonics: 0, 1/3 π or 1/2 π
- To mask distortion products, white noise was added to the stimuli

### Procedure

Thresholds were measured using a two-alternative forced-choice adaptive procedure. On each trial two complex tones were presented. For the standard stimulus, the odd harmonics were attenuated by 60 dB, and thus this stimulus had essentially a fundamental twice the number as the test stimulus. The first tone was either the test or the standard stimulus. The listener had to indicate which of the stimuli had the higher pitch by pressing one of two buttons on a response box. After a correct response the odd harmonics of the test stimulus were attenuated. Six listeners participated in the experiment.

### Results

Measured thresholds averaged across listeners are shown in Fig. 3. The panels show the results for the lowest harmonic numbers 2, 4, 8 and 16. In each panel the thresholds (ordinate) are plotted as function of F0 (abscissa). The blue, green and red lines correspond to the phase shifts 0, 1/3 π and 1/2 π, respectively.

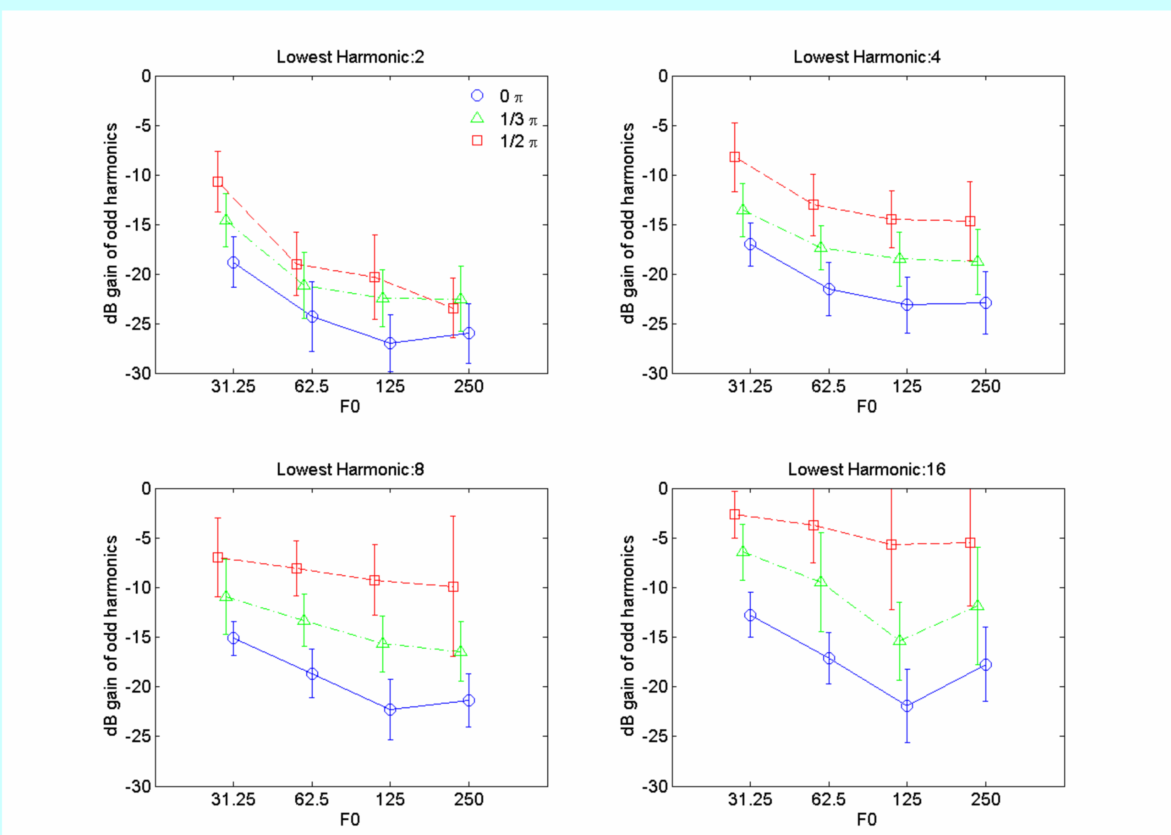


Fig. 3

## Conclusions

The results show that all three manipulations (phase shift, F0 and lowest harmonic number) affect the amount of attenuation required to eliminate discrimination with the octave, and the effect can differ by up to 20 dB in different conditions. It is shown that the temporal profile, which preserves a summary of the temporal fine structure, is a good candidate for predicting the data; 95 % of the predicted thresholds fall within one standard deviation of the empirical data. The spectral profile did not have sufficient resolution to predict the data and it could not explain the effect of the phase manipulation.

## Dual profile

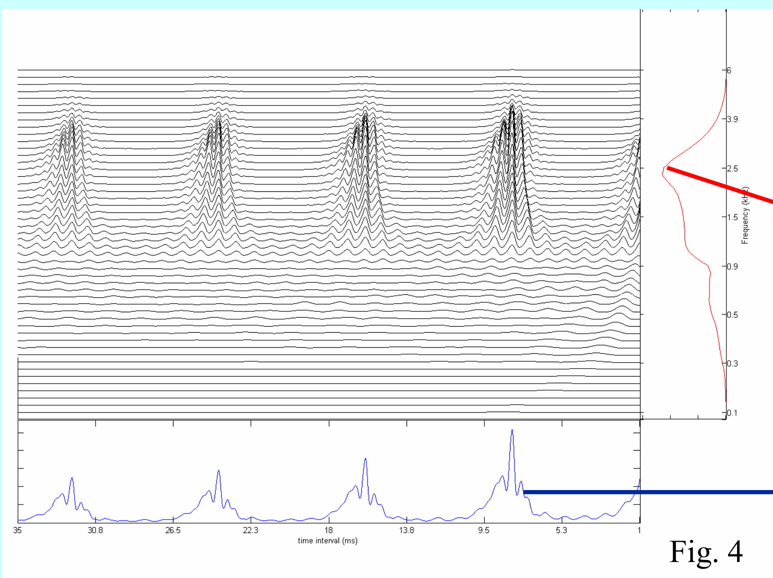

Fig. 4

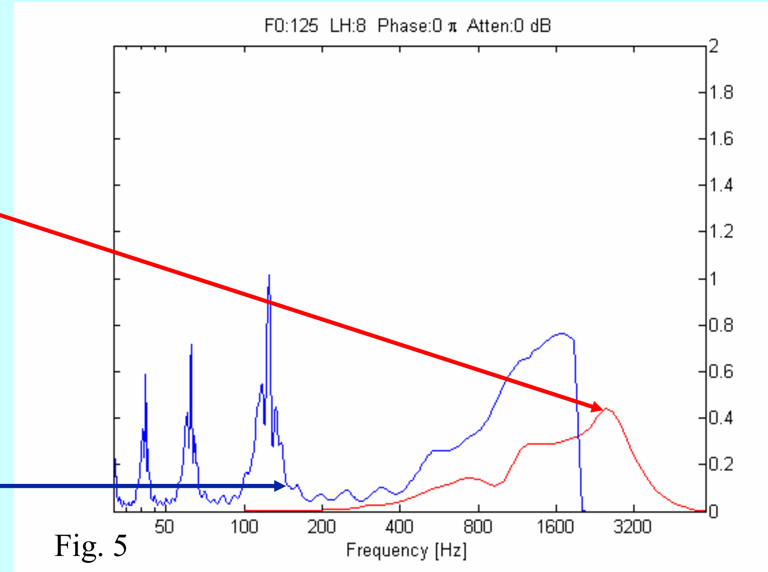


Fig. 5

Fig.4: Auditory image of a harmonic complex sound. The profile to the right of the auditory image is the average activity across time interval (spectral profile). The profile below the image shows the activity averaged across channel (temporal profile). Fig. 5: The spectral profile (red line) and temporal profile (blue line) in one figure (Dual profile).

## Phase shift

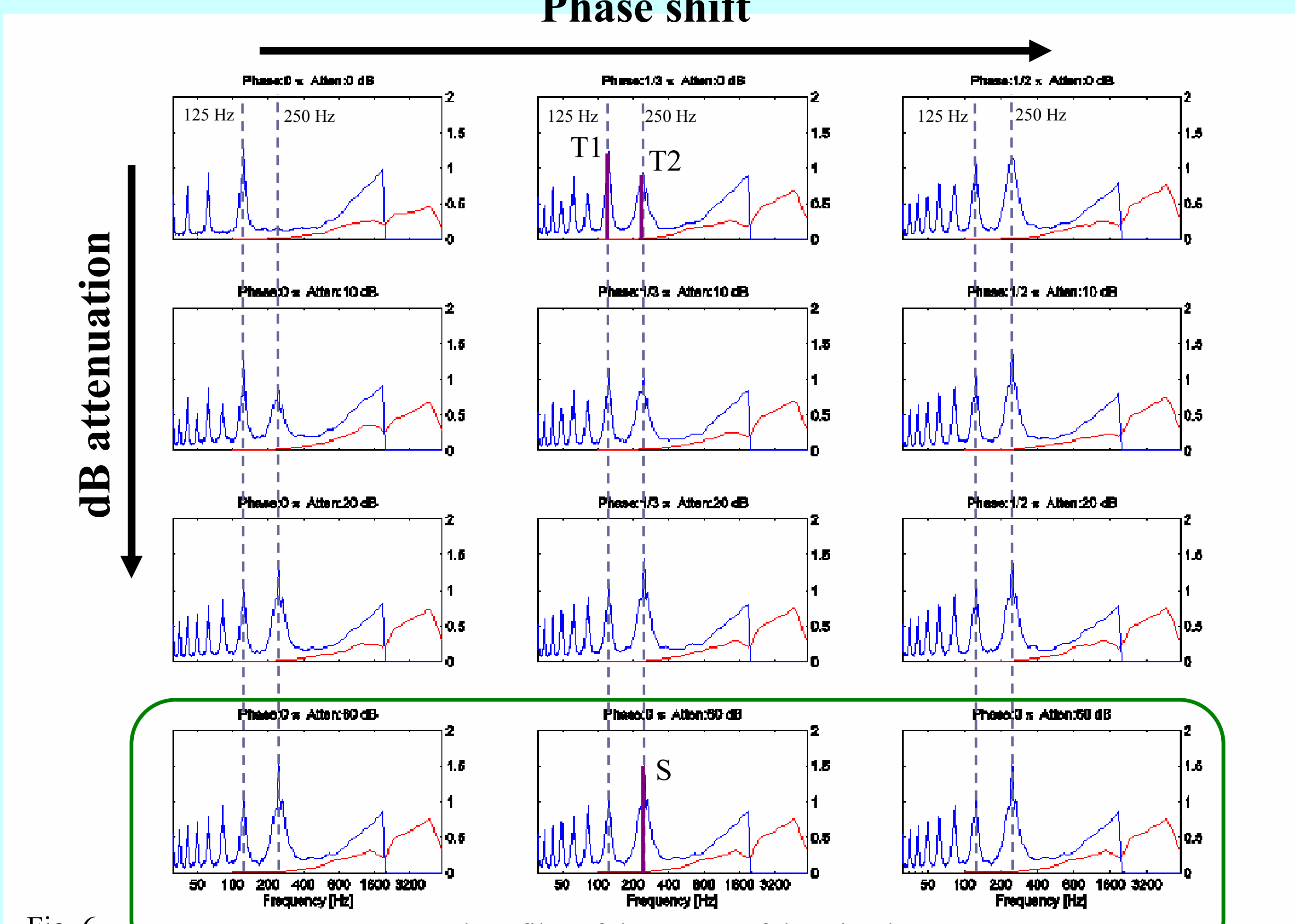


Fig. 6 Dual profiles of the octave of the stimulus

Dual profiles for complex tones with F0=125 Hz and lowest component n=16. Attenuating odd harmonics or shifting phase leads to a peak at 250 Hz in the temporal profile (blue line). The spectral profiles (red lines) show nearly no effect for these manipulations.

A model was used to predict the data, based on the temporal profiles of the stimulus and its octave. The prediction is determined as follows: (2T2-T1)/S,
where T1, T2 and S are small areas under the temporal profiles (magenta), as indicated in the figure.

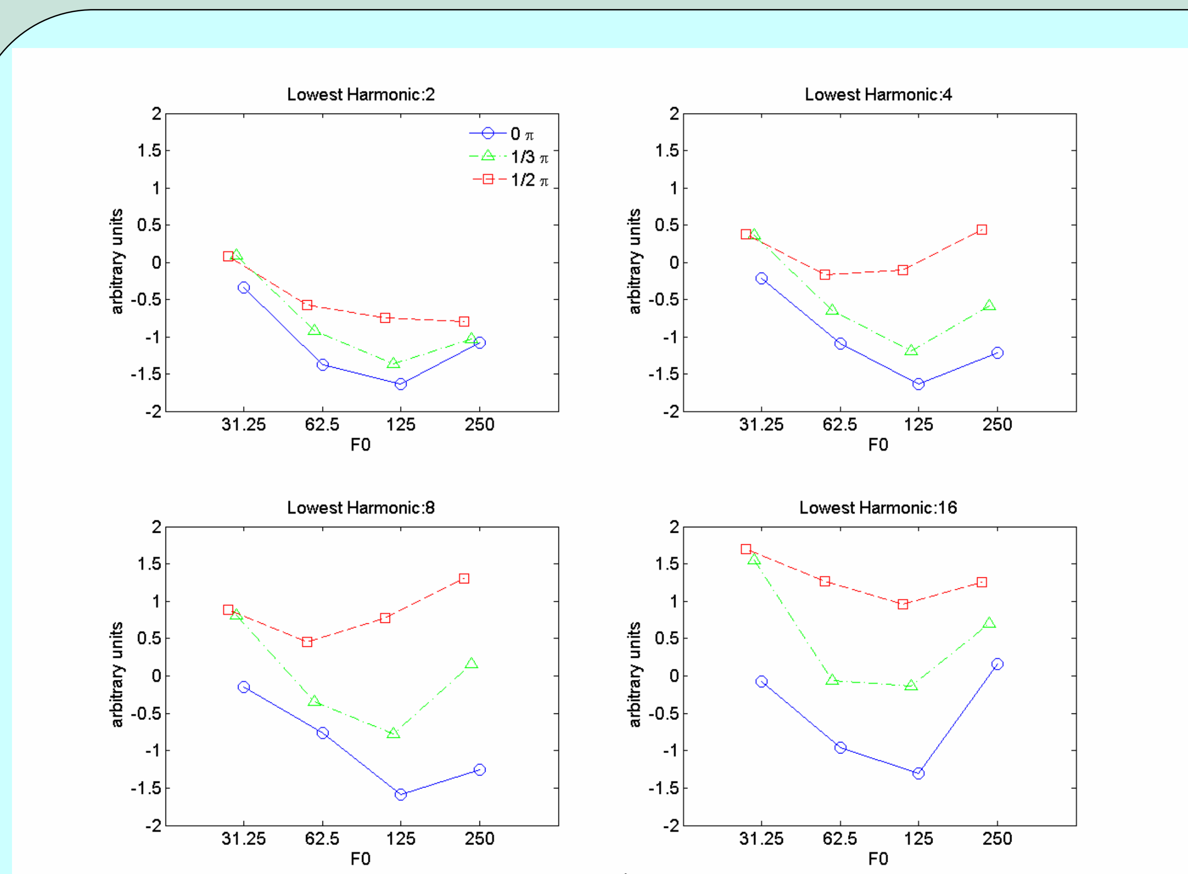


Fig 7.

Predictions of the data in Fig. 3.

The predicted thresholds follow the trends of the data in Fig. 3 reasonably well. 95 % of the predicted thresholds fall within one standard deviation of the empirical data.

### Acknowledgements

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