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*CNBH, Department of Physiology, Development and Neuroscience, Cambridge University*
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# 2pPP3

# The effect of phase, fundamental and lowest component on the perception of octave height

***Ralph van Dinther and Roy D. Patterson***
***rv230@cam.ac.uk, rdp1@cam.ac.uk***

## Pitch Helix

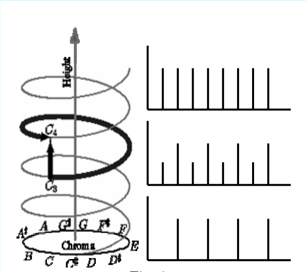

Fig. 1

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,C#,D,..). In auditory perception, these dimensions are referred to as octave height and pitch chroma. Computers enable us to change the octave height of a note gradually 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 shifting on octave perception.

## Experiment

- How much do we have to attenuate the odd harmonics of a harmonic complex to achieve an octave shift in perception?
- How is this cosine attenuation threshold affected by a complimentary phase shift of the odd harmonics, and how is the pattern of results affected by the frequency of the fundamental and/or the frequency region of the energy (i.e., harmonic number)?

### Stimuli

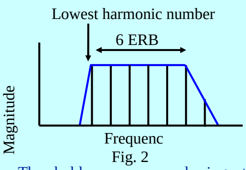

Fig. 2

- 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 that of 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. The two stimuli always had the same chroma, so the judgement was one of octave height in all cases. After a correct response the odd harmonics of the test stimulus were attenuated adaptively to determine threshold. Six listeners participated in the experiment.

### Results

The threshold attenuation values (negative gain), averaged across listeners, are shown in Fig. 3. The four panels show the results for individual lowest harmonic numbers (2, 4, 8 and 16). Within a panel, threshold is plotted as function of F0 (abscissa). The blue, green and red lines correspond to the three phase shifts 0, 1/3 π and 1/2 π radians, respectively.

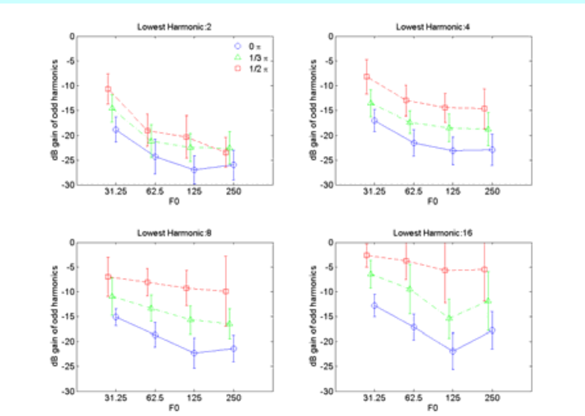

Fig. 3

**Acknowledgements**

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**References**

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## The auditory image

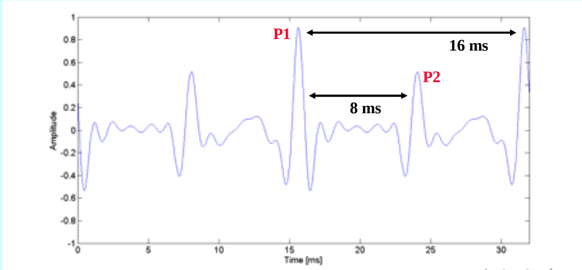

Fig. 4

Fig.4: Time wave of a harmonic complex sound with F0 = 62.5 Hz, lowest harmonic number = 4 and a 1/3 π radians phase shift of the odd harmonics. The phase shift introduces a peak (P2) half way through the period.

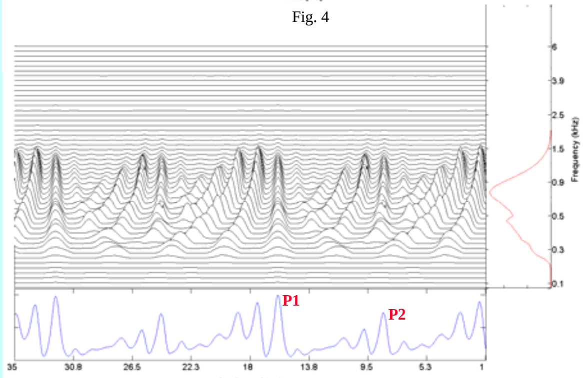

Fig. 5

Fig.5: Auditory image of the harmonic complex sound in Fig. 4. 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 channels (temporal profile). The auditory model shows that many of the characteristics of the time wave are preserved in the auditory image, which might be expected since the auditory image is like an array of time-interval histograms showing the temporal information in the frequency channels formed in the cochlea by the basilar partition. The relative heights of the main and secondary peaks (P1 and P2) in the temporal profile of the auditory image are used to model tone height perception.

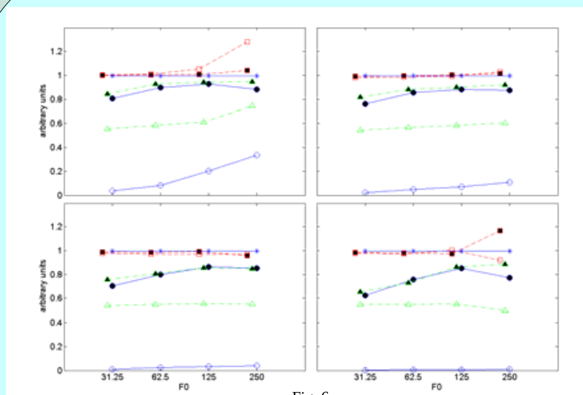

Fig. 6

Fig.6: Ratios of the main (P1) and secondary peaks (P2) of the time waves for the 48 conditions. The conditions in the panels are represented in a similar fashion as in Fig. 3. The blue, green and red lines correspond to the phase shifts 0, 1/3 π and 1/2 π. The open symbols present the ratios for waves without attenuation; the filled symbols present the ratios for waves with attenuations of the odd harmonics at threshold. The ratios for waves with a complete octave shift are indicated with stars.

For waves without attenuation, (open symbols) the phase shifts produce a large effect. The ratios are 0, 0.5 and 1 for shifts of 0, 1/3 π and 1/2 π, respectively. The closed symbols show that the peaks at threshold are not similar in height, except for a phase shift of 1/2 π as expected.

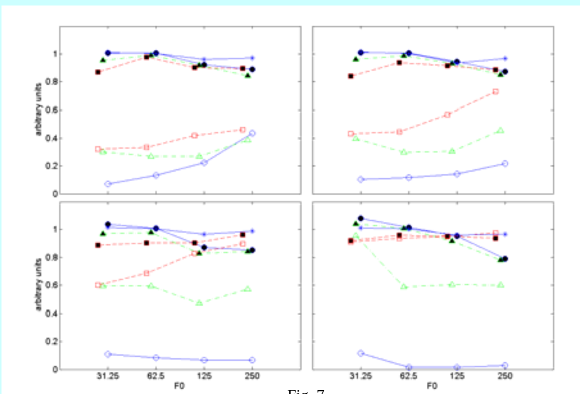

Fig. 7

Fig.7: Ratios of the main (P1) and secondary peaks (P2) of the temporal profiles for the 48 conditions. The description of the symbols is the same as in Fig. 6.

Ratios for waves without attenuation (open symbols) show an effect of phase, frequency region, and F0. The closed symbols show ratios close to one, indicating that the peaks of the temporal profile are similar in height at threshold.

The ratios based on the peaks of the temporal profile explain the results of the experiment better than the ratios based on the peaks of the time waves. The ratios of the solid symbols shown in Fig. 7, suggest that the tone height we perceive is related to the relative heights of the main and secondary peaks in the temporal profile.