An auditory illusion

I HERE report a novel and striking auditory illusion, which provides a paradox for theories of pitch perception and auditory localisation[1,2]; and which varies in correlation with the handedness of the listener. The stimulus configuration which produced the illusion consisted of a sequence of tones, alternating in pitch between 400 Hz and 800 Hz (Fig. 1*a*). Each tone lasted 250 ms, with no gap between tones. The sequence was presented at equal amplitude to both ears simultaneously; however, when one ear received 400 Hz the other received 800 Hz, and *vice versa*. Thus the same two-tone combination was presented constantly, but the ear of input for each component switched every 250 ms.

It is easy to imagine how this pattern should sound if perceived correctly. However, 86 subjects listened to a 20-s presentation of this sequence, and none obtained the correct percept. Instead, various illusory percepts were reported (Table 1), the most common being a single tone oscillating from ear to ear, whose pitch also oscillated from one octave to the other in synchrony with the localisation shift (Fig. 1*b*). Two subjects with absolute pitch identified these oscillating pitches as G_4 (392 Hz) and G_5 (784 Hz); these are closest on the musical scale to the 400 Hz and 800 Hz presented. The percept depicted by one of these subjects is shown on Fig. 2.

Table 1 Categories of illusory percept

	Octave (%)	Single (%)	Complex (%)
Right handers (*n* = 53)	58	25	17
Left handers (*n* = 33)	52	9	39

Figures show the percentages of right or left-handed subjects obtaining a given percept. The two groups of subjects differed significantly in the relative distribution of their percepts ($\chi^2 = 6.8$, d.f. = 2, $P < 0.05$). Octave indicates the illusion of a single tone oscillating from ear to ear, whose pitch oscillates synchronously from one octave to another. Single pitch indicates the illusion of a single tone oscillating from ear to ear, whose pitch either remains constant or shifts very slightly. Complex comprises various complex percepts, such as two alternating pitches in one ear, with a third pitch intermittently in the other; or two alternating pitches oscillating from ear to ear and two further pitches alternating at twice the speed localized at the back of the head. This group of percepts tends to be quite idiosyncratic and unstable; however, no subject reported the stimulus correctly.

This synchronous alternation of apparent pitch and localisation is paradoxical. The perception of alternating pitches can be explained by assuming that the listener processes the input to one ear and ignores the other. But then both the alternating pitches should seem to be localised in the same ear. Alternatively, the oscillation of a single tone from ear to ear can be explained by supposing that the listener suppresses the input to each ear in turn. But then the pitch of this tone should not change with a change in its apparent localisation.

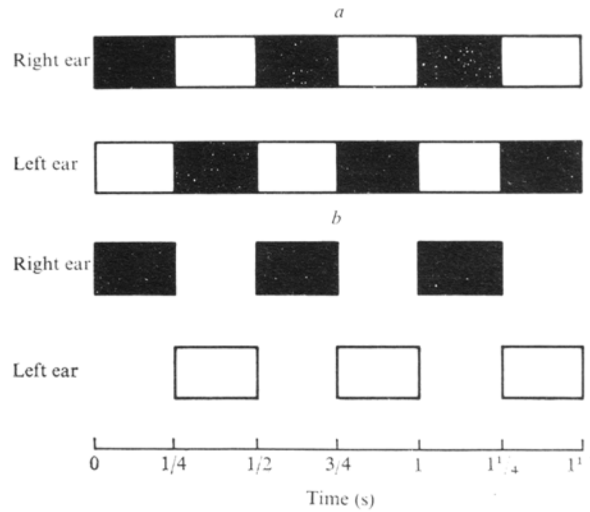

Fig. 1 *a*, Representation of the stimulus configuration which produces the illusion. Filled boxes represent tones of 800 Hz and unfilled boxes tones to 400 Hz. The tones were sinusoids, and their phase relationship varied randomly. They were played to subjects at a level of 75 dB SPL. *b*, Representation of the illusory percept most commonly obtained.

A further surprise involves the patterns of apparent localisation for the two pitches at the two ears in right and left-handed subjects. Right handers had a highly significant tendency to hear the high tone in the right ear and the low tone in the left ($P < 0.001$, two-tailed on a binomial test), and also to maintain a given localisation pattern when the placement of the earphones was reversed ($P < 0.001$, two-tailed on a binomial test). Left handers did not localise the tones preferentially either way, however, though they showed a marginally significant tendency to retain a given localisation pattern when the earphones were reversed ($P = 0.05$, two-tailed on a binomial test). This difference between right and left handers is consistent with findings relating patterns of hemispheric dominance to handedness[3,4] and so suggests that we tend to localise the high tone to the side producing the most effective input to the dominant hemisphere[5-7] and the low tone to the other side.

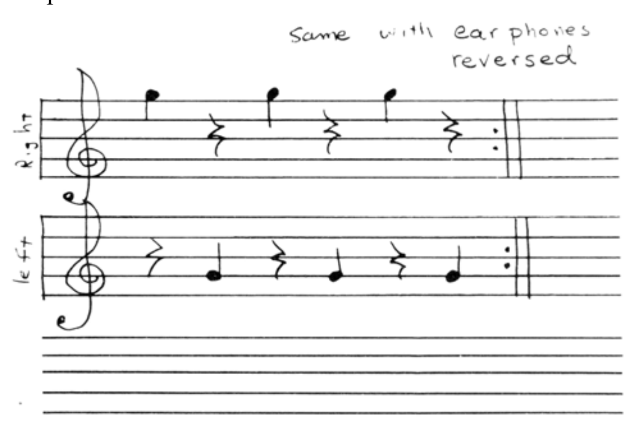

Fig. 2 Percept of the stimulus depicted by a subject with absolute pitch. The writing is that of the subject herself. Her statement: `Same with earphones reversed' shows that the high tones were localised in the right ear and the low tones in the left, irrespective of the positioning of the earphones.

Table 2 Patterns of apparent localisation for the two pitches at the two ears in subjects who obtained the octave illusion

	RR	LL	Both
Right Handers	25	5	1
Left Handers	6	7	4

Each subject was twice given a 20-s presentation of the stimulus sequence, with earphones placed one way initially and then reversed. The order of earphone placement was strictly counterbalanced for both right and left-handed subjects. Figures show the number of right or left-handed subjects obtaining a given localisation pattern. RR, high tone localised in the right ear and low tone in the left on both stimulus presentations. LL, high tone localised in the left ear and low tone in the right on both stimulus presentations. Both, high tone localised in the right ear and low tone in the left on one stimulus presentation; and high tone localised in the left ear and low tone in the right on the other.

The localisation patterns on Table 2 are based on the two initial presentations of the sequence; however, with continued listening these patterns sometimes reverse, as in reversals of ambiguous figures in vision[8]. Thus these localisation patterns represent strong tendencies, rather than absolute rules.

The question arises whether a given localisation pattern depends on absolute or relative pitch levels in the stimulus configuration. To determine this, I selected twelve right handers who had consistently localised the 800 Hz tone in the right ear, and the 400 Hz tone in the left, showing no tendency to reverse this pattern over several listening sessions. These subjects were presented with tape segments consisting of tones alternating between 400 Hz and 800 Hz, between 200 Hz and 400 Hz, and between 800 Hz and 1,600 Hz, the other parameters being identical. These sequences were presented for 20 s each in counterbalanced order, with earphone positions also counter-balanced. Except for one subject's report on the 200 Hz-400 Hz sequence, the higher of the two tones in each pattern was always localised in the right ear and the lower in the left. I conclude that these localisation patterns depend on the pitch relationships between the competing tones, and not on a pattern of ear preference at different pitch levels. Further, when I presented the two sequences channelled through spatially separated loud-speakers instead of earphones, the illusion was still obtained; even though both sequences were now presented to both ears, with only localisation cues to distinguish them.

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