The Auditory System and Human Sound-Localization Behavior
Answers Exercises Chapter 12: Plasticity.

Exercise 12.1:
In the case of inverted ears, the cues become:

$$ILD'(\alpha) = ILD(-\alpha) \quad \text{and} \quad ITD'(\alpha) = ITD(-\alpha)$$

With the head stationary at target presentation, a sound presented at a rightward azimuth angle in the frontal hemifield appears to originate from a location corresponding to a leftward azimuth angle in the frontal hemifield (note that the pinna cues remain intact, so that there is no 'cone of confusion'). The stimulus-response relationship will therefore look like

$$R(\alpha) = g \cdot T(\alpha) + b \quad \text{with} \quad g \approx -1 \quad \text{and} \quad b \approx 0$$

But what happens when the head moves toward this sound source, e.g. by making a rightward rotation, i.e.

$$\frac{d\alpha}{dt} > 0 \quad \text{causing} \quad I_{RE} \uparrow \quad \text{and} \quad I_{LE} \downarrow$$

However, because of the inverted ears, the perceived changes in sound level become

$$I'_{RE} \downarrow \quad \text{and} \quad I'_{LE} \uparrow$$

This change in perceived sound levels could correspond to a change in azimuth for movement to the left to a leftward target, however, the brain 'knows' that the head is moving rightward! (we did not invert the neck muscles.....). Thus, for the brain the question becomes:

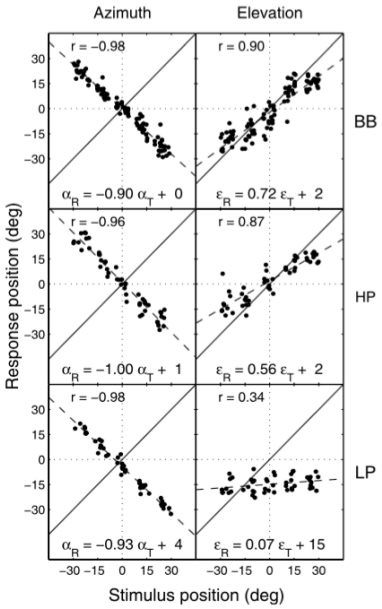
Wich target location causes $d\alpha/dt < 0$ for a rightward head rotation??

The only solution that is compatible with this percept is a sound location that is 180 deg mirror-symmetric with respect to the left-front location, which is to the $right\text{-}back$ location! Therefore, the system is now confronted with two incompatible sound-source locations:

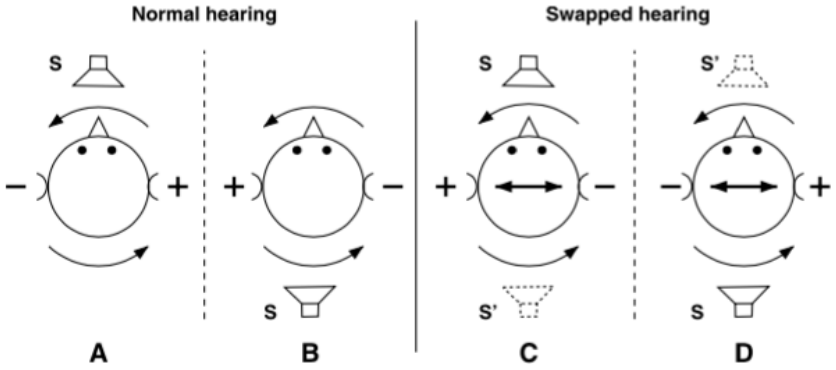
1. When the head is not moving: left and frontal

2. When the head moves: right and back

Because these two locations are mutually exclusive, the auditory system will not adapt to inverted ears. The figures below are taken from Hofman et al., J Neurosci Meth 113: 167-179, 2002.



Result of swapped hearing for broadband, high-pass filtered (>3 kHz) and low-pass filtered (<1.5 kHz) sounds: the azimuth gain is inverted (gain close to -1), elevation localization is normal.



Explanation for the ambiguous percept during head rotations. The +/- signs indicate increase/decrease in perceived sound level at the ear for a leftward head rotation.