Horizontal-plane localization in single-sided deaf adults fitted with a bone-anchored hearing aid (Baha)

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Supplemental Digital Content 1
Analysis of Random Error ($\bar{s}$) and Constant Error ($\bar{C}$)

The overall rms error ($\bar{D}$) analyzed in the main article does not distinguish between random error ($\bar{s}$) and constant or bias error ($\bar{C}$). Random error ($\bar{s}$) is computed as the standard deviation of the subject's responses for a given source position (represented by the size of the error bars in Figure 4 in the main article), whereas constant error ($\bar{C}$) is represented by the rms difference between the mean response at each azimuth (the data points in Figure 4) and the diagonal representing perfect performance. The measures are related as follows (Rakerd & Hartmann 1986; Grantham 1995):

$$\bar{D}^2 = \bar{s}^2 + \bar{C}^2$$

To illustrate, Figure S-1 displays all three errors for our 12 subjects in one condition (Stimulus Condition 1, Baha off). We see that different subjects have different error patterns. For example, Subject S4 has an overall error of $\bar{D} = 48^\circ$, which is primarily composed of constant error ($\bar{C} = 46^\circ$) with relatively little contribution from random error ($\bar{s} = 13^\circ$). Subject S5, with a similar overall error ($\bar{D} = 48^\circ$) has about equal contributions from constant error ($\bar{C} = 35^\circ$) and random error ($\bar{s} = 34^\circ$). Thus, in order to have a complete description of localization performance for a given condition and a given individual, it is necessary to consider $\bar{s}$ and $\bar{C}$ in addition to $\bar{D}$. 
Fig. S-1. Overall error ($\overline{D}$), constant error ($\overline{C}$), and random error ($\overline{r}$), in degrees azimuth, for the 12 subjects in Stimulus Condition 1, Baha off. Left panel: SNHL group; right panel: CHL group. Within each panel, subjects are ordered according to the magnitude of $\overline{D}$.

Random Error • Average random error for all conditions and both groups is shown in Figure S-2. A 3-way ANOVA was carried out on random error, with Group as the between subjects factor and Stimulus Condition and Baha Mode as the repeated measures factors. The general trends noted for overall error (Figure 5 in the main article) were also evident for random error, but not all of the effects reached statistical significance. There was a significant interaction between Group and Baha Mode [$F(1, 10) = 8.308; p = 0.016; \eta^2 = 0.454$], again showing that the effect of the Baha device was different for the two groups. In addition, there was a significant interaction between Stimulus Condition and Baha Mode [$F(2, 20) = 3.965; p = 0.035; \eta^2 = 0.284$], but there were no other significant main effects or interactions.
Fig. S-2. Mean random error in the indicated stimulus conditions for the SNHL group (upper panel) and the CHL group (lower panel). LONG: stimulus duration = 1250 ms; SHORT: stimulus duration = 341 ms. Error bars indicate ± 1 standard error of the mean. Dashed lines indicate average performance from the four normal-hearing listeners in Stimulus Condition 3 (\(\bar{x} = 2.9^\circ\)).
As with the analysis of overall error (see Figure 5 in the main article), we conducted separate 2-way ANOVAs for the two groups to explore the Group x Baha Mode interaction. The only significant effect revealed from these analyses was a significant Stimulus Condition x Baha Mode interaction in the SNHL group \[ F(2,12) = 4.506; p = 0.035; \eta^2 = 0.429 \], indicating that for this group, the effect of Baha (On vs. Off) depended on the Stimulus Condition. Thus, although the direction of differences was generally the same for the random error as for overall error (i.e., reduced error scores for the CHL group and elevated errors for the SNHL group when using the Baha), these differences did not reach statistical significance.

**Constant Error** • A 3-way ANOVA (Group x Stimulus Condition x Baha Mode) was also carried out on the constant error. In this case there were significant main effects of Stimulus Condition \[ F(2,20) = 4.018, p = 0.034; \eta^2 = 0.287 \] and Baha Mode \[ F(1,10) = 5.581; p = 0.040; \eta^2 = 0.358 \]. However, the effect of most interest in the present context was the highly significant interaction between Baha Mode and Group \[ F(1,10) = 29.441; p < 0.001; \eta^2 = 0.746 \], indicating that the Baha affected performance differently for the CHL and the SNHL groups.

This Baha Mode x Group interaction was further explored by conducting separate 2-way ANOVAs (Stimulus Condition x Baha Mode) for the two groups. For the CHL group the average constant error was significantly smaller with Baha on \( \bar{C} = 14.9^\circ \) than with it off \( \bar{C} = 27.2^\circ \) \[ F(1,4) = 25.092; p = 0.007; \eta^2 = 0.863 \]. For the SNHL group, the average constant error was greater with Baha on \( \bar{C} = 35.2^\circ \) than with it off \( \bar{C} = 30.3^\circ \), but this difference did not reach statistical significance \[ F(1,6) = 5.770; p = 0.053 \]. Thus, the Baha significantly reduced constant error (response bias) in the CHL group, but did not have a statistically significant effect on constant error in the SNHL group.
The analysis of constant error $\bar{C}$ described above is based on unsigned constant error. That is, it reflects the rms average of the differences between the data points and the diagonal in Figure 4 in the main article, irrespective of the sign of the differences. For the present investigation, it is of interest to consider also the signed constant error, which takes account of the direction of the bias, considered across all source positions (in particular, whether the bias is toward or away from the normal-hearing ear). Figure S-3 plots the signed constant error for all subjects as scatter plots. In this figure, each subject appears as a data point in this space where the x-axis represents signed error with the Baha on, and the y-axis represents signed error with the Baha off. Positive error represents bias toward the subjects' normal ears.

Considering the CHL group (black data points), it can be seen that there is a considerable range of response bias observed when the Baha is off (the vertical spread of the data points spans up to 60°). However, with the Baha on, this group exhibits very little response bias (the black symbols are very close to the vertical dashed line representing no bias). On the other hand, the SNHL group exhibits as much or more range of response bias with the Baha on (horizontal spread) as with it off (vertical spread).
Fig. S-3. Signed constant error scores with Baha off (y-axes) vs. signed constant error scores with Baha on (x-axes). Positive error indicates bias toward each subject's normal ear. The three panels show performance in the three indicated stimulus conditions (see caption for Figure S-2). Each symbol represents one subject. Gray symbols: subjects with SNHL. Black symbols: subjects with CHL.

Constant Error (signed)

(positive error: bias toward normal ear)

Stimulus Condition

1. LONG (Head Moving)
2. LONG (Head Still)
3. SHORT
Taken together, the analyses of random and constant error indicate that the improvement in overall error ($\bar{D}$) in the CHL group when using the Baha device is due primarily to the reduction in response bias that occurs when using the device. Although this group also showed some reduction in random error when using the device, the latter reduction did not reach statistical significance. For the SNHL group, as described in the main article, there was a significant increase in overall error $\bar{D}$ when using the device. However, the increase of the component errors (random and constant) did not reach statistical significance, suggesting that the worsening of performance as measured by the overall error was based on some contribution from both components.

REFERENCES
