Supplementary material for:
Influence of Static Eye and Head Position on Tone-Evoked Gaze Shifts
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Contribution of head to gaze shifts

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Abstract

To program eye-head gaze shifts to sounds, the orientation of eyes and head should be incorporated to specify the target relative to the eyes, and only head orientation should be incorporated to specify the target relative to the head. Here we test whether the eye and head motor systems employ different reference frames for gaze shifts evoked by broadband sounds and pure tones. The head-movement component of the gaze shift was modulated by initial head-orientation and sound frequency, but not by eye position. This demonstrates that eye and head are controlled separately by signals in an eye-centered and head-centered reference frame, respectively.

Introduction

Localizing sounds with eye-head gaze shifts requires a transformation into oculocentric commands for the eye (ΔG), and craniocentric signals for the head (ΔH; Goossens and Van Opstal, 1997) by:

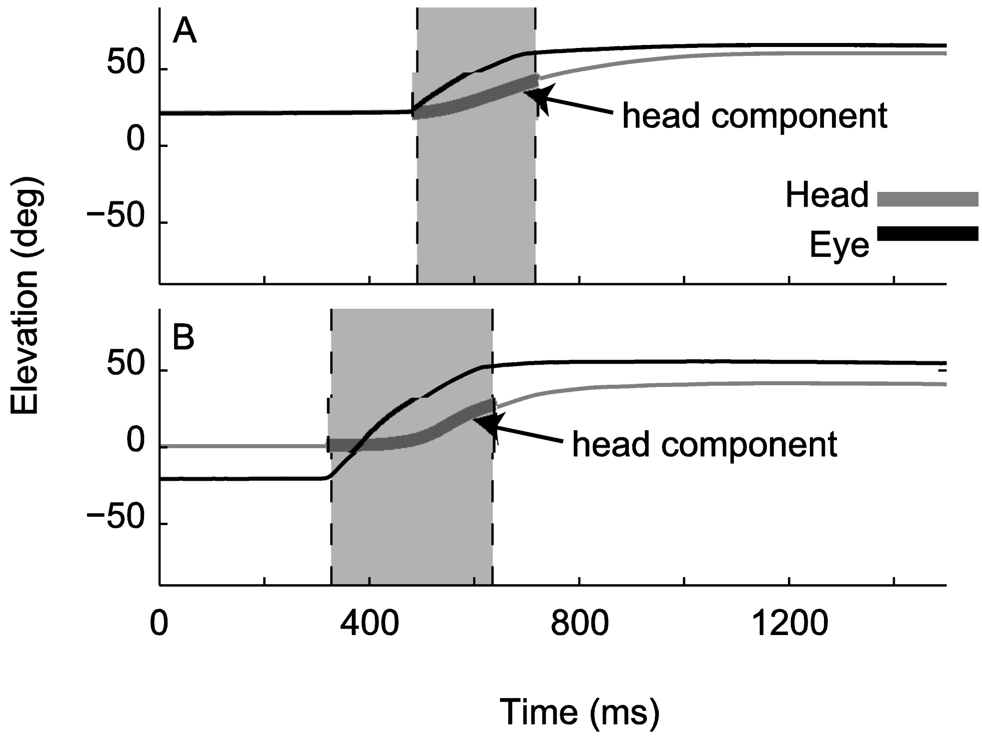
$$\Delta G = T_S - H_S - E_H \text{ and } \Delta H = T_S - H_S$$

with E_H, H_S, eye-in-head and head-in-space positions at gaze-shift onset, respectively We here provide the results of our data analysis of the head-movement responses, evoked from a wide variety of initial eye- and head positions (Fig. 2 in Van Grootel et al., 2011).

Methods

Head-movement contribution to gaze shift

The head-movement component was defined by the change in head posisition between the on- and offsets of the gaze shift, and was (semi-)automatically detected by a custom-made Matlab routine (Supplementary figure 1). Markings could be changed interactively by the experimenter, if needed.



Supplementary figure 1: *Definition of the head-movement component of a gaze shift. Gaze (black) and head (gray) trajectories of two example trials of listener MW.* ***A & B)*** *Same gaze shifts as presented in manuscript figure 3A and C, respectively. Dashed lines and grey box indicate the duration of the gaze shift. Thick grey line during this period defines the head-movement contribution. Note that the head continues to move after gaze-shift offset.*

Results

Sound localization

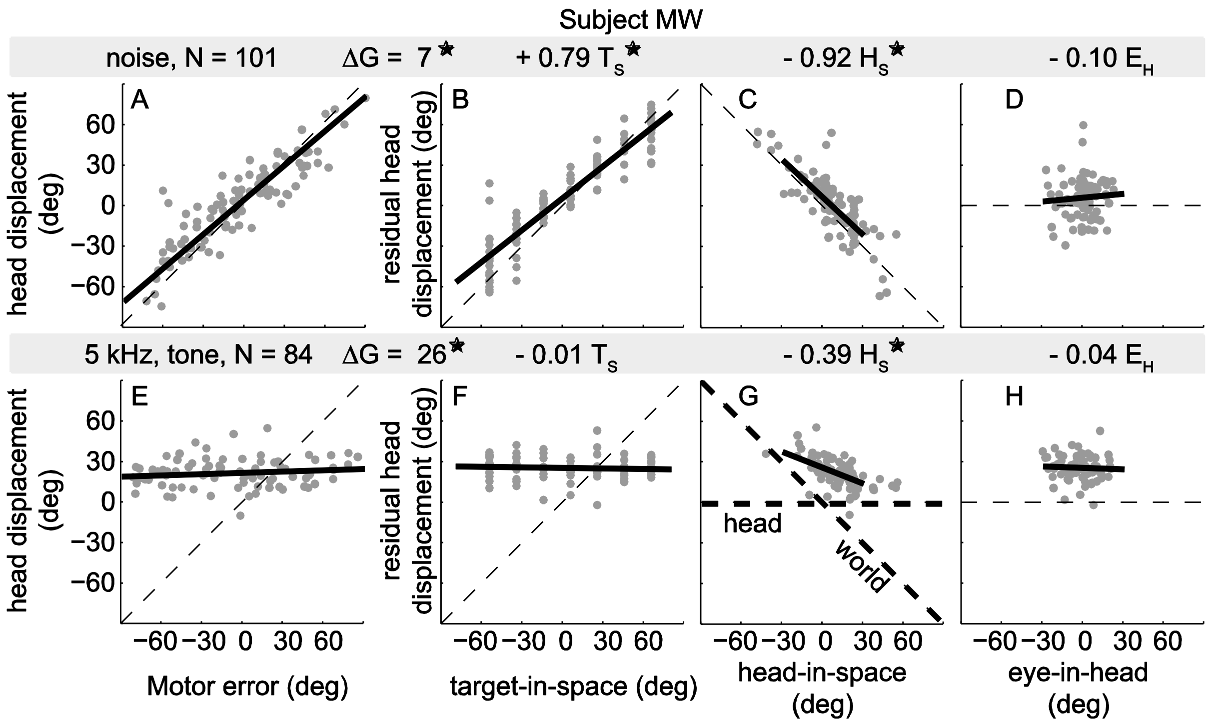
As for gaze shifts, we performed multiple linear regression on the head-movement component data (MLR) by fitting the following equations:

$$\Delta H = a \cdot T_s + b \cdot H_s + c \cdot E_H + d$$

$$\Delta H = k \cdot T_H + m \cdot E_H + n$$

for the world-centered and head-centered models, respectively. In supplementary figure 2 this is shown for subject MW, for broadband- and 5 kHz tone-evoked responses. Results were generally similar as for the gaze shifts (see manuscript figure 4). A minor difference was the slightly smaller target slope for broadband sounds (a, Fig. 4A). In stark contrast, however, the initial eye orientation had a negligible effect on head displacement (broadband: c=-0.10, t_{97}=0.55, P=0.58; tones: c=-0.04, t_{80}=-0.42, P=0.68).

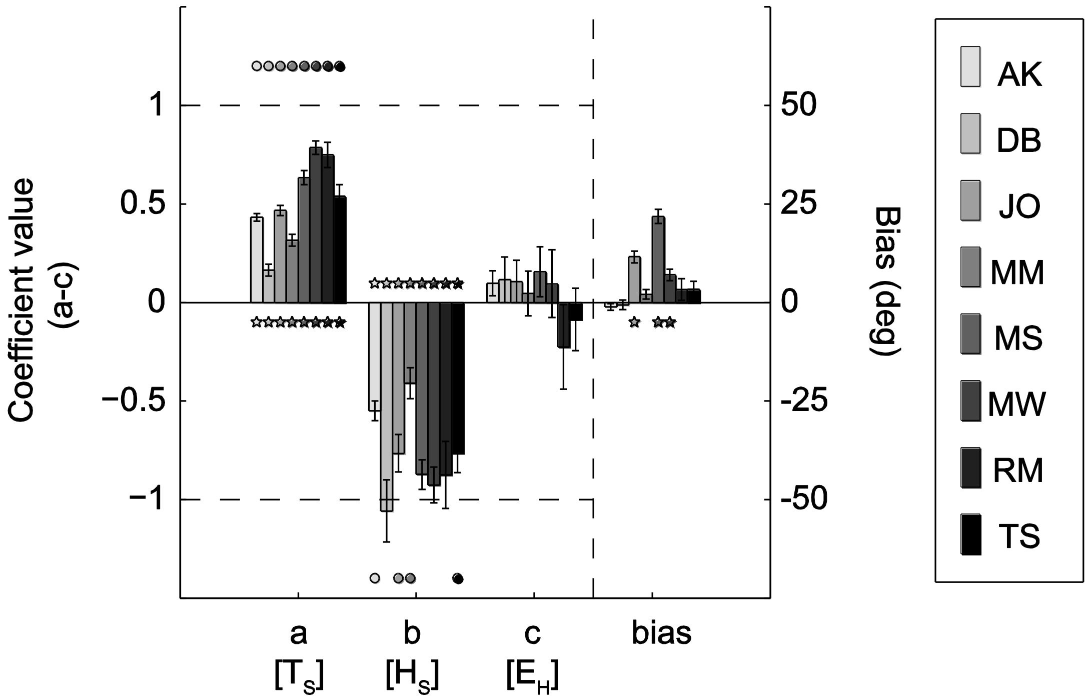
These data therefore suggest that while an *eye*-centered command controlled gaze shifts, a *head*-centered error signal drives the head movements.



Supplementary figure 2: *Elevation localization performance of head movements to (**A-C**) broadband noise and (**D-F**) a 5kHz tone of listener MW for all initial eye and head orientations. Same format as figure 4 in original manuscript. Solid black lines represent the slope and bias of the linear fit to the data (MLR, Eqn. 4). Thin dashed lines indicate the ideal response results according to the spatial model. Inside the gray bar the coefficients according to the MLR (Eqn. 4) are shown. Bias is the left-most value, followed by a, b and c. Significant values (different from 0) are indicated by an asterisk (*). **A)** Head displacements (ΔH) correlated well with the spatial target locations (T_S) for broadband sounds, but **D)** tone responses are not goal-directed. **B,E)** There was a systematic influence of initial H_S on ΔH, but **C,F)** the effect of E_H was absent.*

Reference frame for broad-band sounds

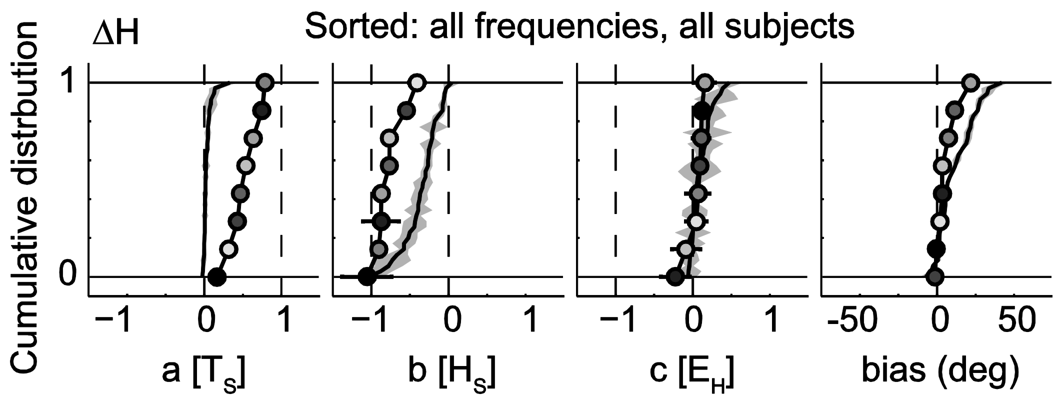
The MLR analysis for all subjects further corroborated this statement. The eye-in-head position did not contribute significantly to the head-movement responses (P>0.12).



Supplementary figure 3: *Results of MLR (Eqn. 4) for all listeners on head-movement components (ΔH) to broadband stimuli in elevation for different static initial eye and head orientations. Same format as manuscript figure 5. Data from all recording sessions were pooled. Response bias for each subject is indicated at the right-hand side. Note the different scale. Error bars correspond to one standard deviation. Dashed lines at +1 and -1 denote ideal target representation and full compensation of eye and head positions, respectively.*

Reference frame for pure tones

Supplementary figure 4 summarizes all broadband and tone results for the head-movement components, by presenting the regression coefficients (their means and standard deviations, obtained from bootstrapping) as cumulative distributions (for all subjects, experimental blocks and frequencies). Note that the eye contribution ($c[E_H]$) to the head displacement was always negligible.



Supplementary figure 4: *Regression coefficients of the head movements for all subjects to broad band noise (black lines and circles) and all tones (black lines and gray patch), presented as cumulative distribution (same format as panel C of manuscript figure 6).*

References

Goossens HHLM, Van Opstal AJ (1997) Human eye-head coordination in two dimensions under different sensorimotor conditions. Exp Brain Res 114:542-560.

Van Grootel TJ, Van Wanrooij MM, Van Opstal AJ (2011) Influence of static eye and head position on tone-evoked gaze shifts. J Neurosci, under review.