Brain co-registration to external Head coordinate system for M/EEG data analysis without MRI

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I BACKGROUND

Analyzing M/EEG data for investigating brain function is a well-established procedure. Recently, there has been growing interest in using anatomically informed source locations for this, e.g. to study brain network connectivity [1,2,3]. The accuracy of results relies on co-registration of anatomical MRI data with the external coordinate system [4], e.g. as supplied by the nasion/pre-auricular point coordinates (the Head coordinate system; figure 1). However, in many cases, anatomical MRI data are simply not available.
In this study, we investigated the feasibility of using mapping of sensory stimulation to known brain landmarks for obtaining co-registration without MRI.

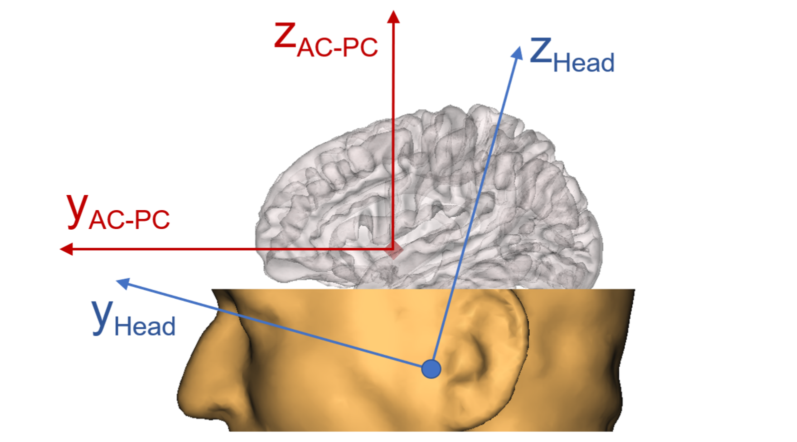

Fig. 1 Head coordinate system (blue) and AC-PC coordinate system (red).

II METHODS (1)

We first investigated the variability of brain center positioning and the main brain axes relative to external landmarks. The translation of the anterior commissure (AC) point with respect to the origin of the Head coordinate system was measured in 21 subjects, as well as the rotation of AC-PC coordinate system axes.

Figure 2 shows the distribution when transforming the same point from Head coordinates to brain (AC-PC) coordinates, using different co-registrations. Variability was analyzed for translation and rotation parameters (figure 3). In the following, we attempted an estimation of the three parameters with highest variability from experimental MEG data.

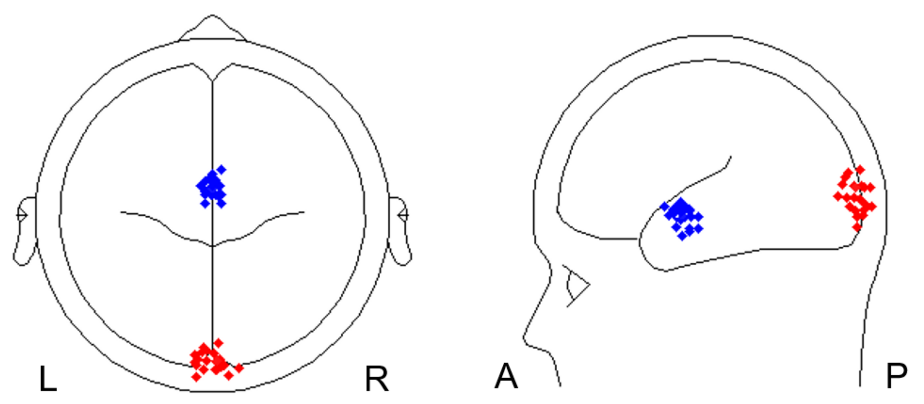

Fig. 2 Distribution of the same point in Head coordinates with different brain co-registrations. Blue: AC point. Red: Posterior point.

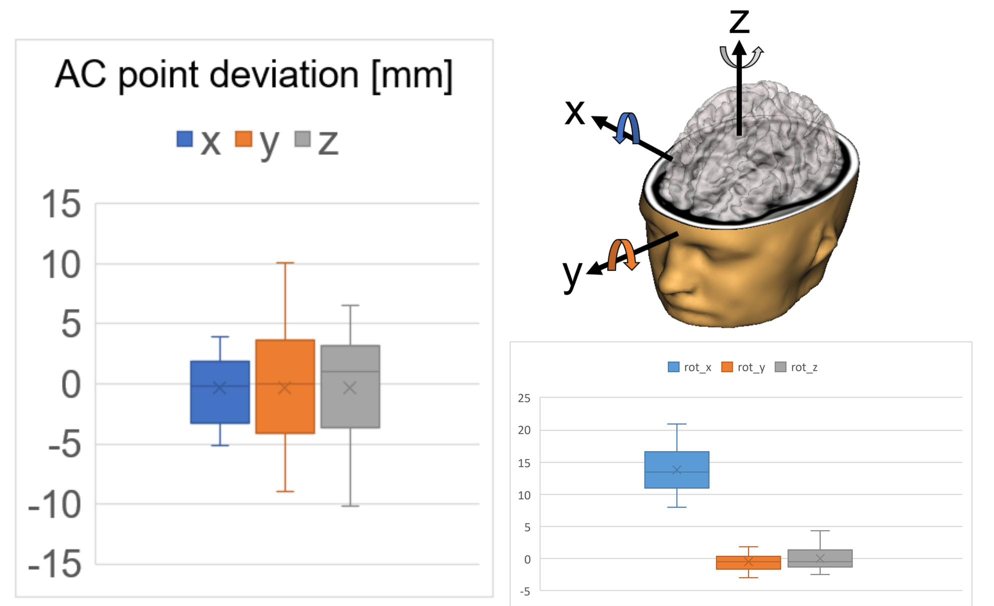

Fig. 3 Left: Of the translations, y and z had the highest variance. Right: Of the rotations, the x axis rotation had the highest variance.

III METHODS (2)

Auditory and visual stimulation activates the primary auditory and visual cortices. Their well-known anatomical locations can be used to approximate the co-registration. In 15 healthy volunteers, auditory and visual stimulation was recorded using a MEGIN Triux MEG system [5]. The location of primary auditory and visual areas was fitted by three regional sources using a default transformation (Head → AC-PC). This resulted in source coordinates HG_x, HG_y, HG_z (in left and right Heschl's gyrus) and $V1_x$, $V1_y$, $V1_z$ (in the visual area). Since the x values are reasonably well estimated by the default transformation (cf. figure 3), the focus was on the y and z coordinates.

A least-squares fit was applied to adapt the transformation parameters D_x, D_y, and rot_x of the equation below such that the source coordinates approached values listed in the literature (Table 1). Figure 4 shows an example.

$$\begin{pmatrix} 1 \\ x'_{AC-PC} \\ y'_{AC-PC} \\ z'_{AC-PC} \end{pmatrix} = \boldsymbol{T_c} T_{default} \begin{pmatrix} 1 \\ x_{Head} \\ y_{Head} \\ z_{Head} \end{pmatrix} \qquad \boldsymbol{T_c} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ D_y & 0 & \cos(rot_x) & \sin(rot_x) \\ D_z & 0 & -\sin(rot_x) & \cos(rot_x) \end{pmatrix}$$

Table 1 Heschl's gyrus coordinates [6] and V1 coordinates [7].

Landmark	Y (Talairach)	Z (Talairach)
Heschl's gyrus left	-20	11
V1 area	Variable by subject	4 ± 3

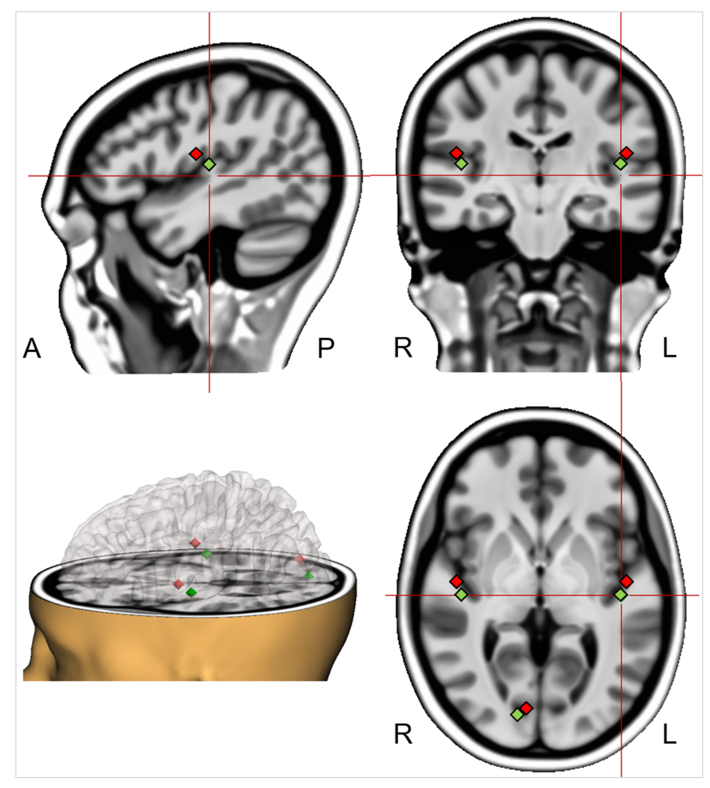

Fig. 4 Fitting auditory and visual cortex before (red sources) and after (green sources) optimizing the transformation, superimposed on an averaged brain.

Finally, reconstruction of source activity before and after co-registration was tested using a source montage [8] based on the automated anatomical labeling (AAL) atlas [6] (figure 5). Averages of auditory stimulation were used and the magnitude of reconstructed source activation in the left and right Heschl's gyrus regions of the AAL atlas were analyzed using the software BESA Statistics 2.1 [9].

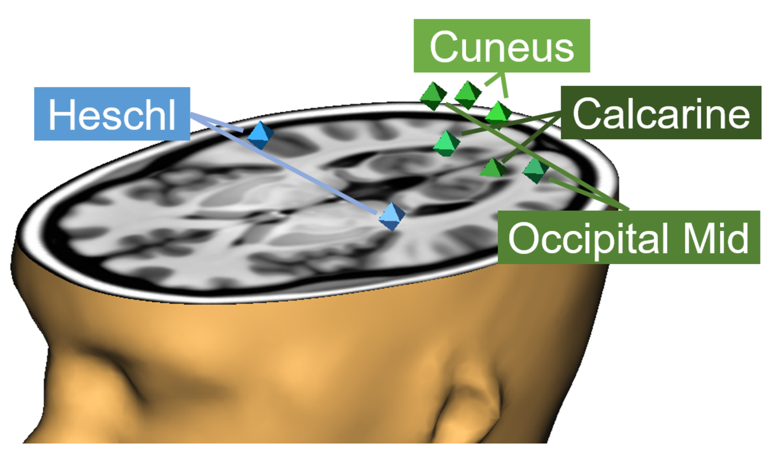

Fig. 5 Source montage based on AAL.

IV RESULTS

Figure 6 shows the distribution of fitted locations for Heschl's gyrus and V1 before and after the optimization. A clear improvement is visible.
Figure 7 shows a statistical comparison of signal magnitude obtained from the 15 subjects using an AAL-based source montage in Heschl's gyrus. A highly significant increase was found in right Heschl's gyrus between 0–100 ms after stimulus, followed by a trend from 115–147 ms. Another trend was seen in left Heschl's gyrus (33–68 ms). No other clusters reached significance.

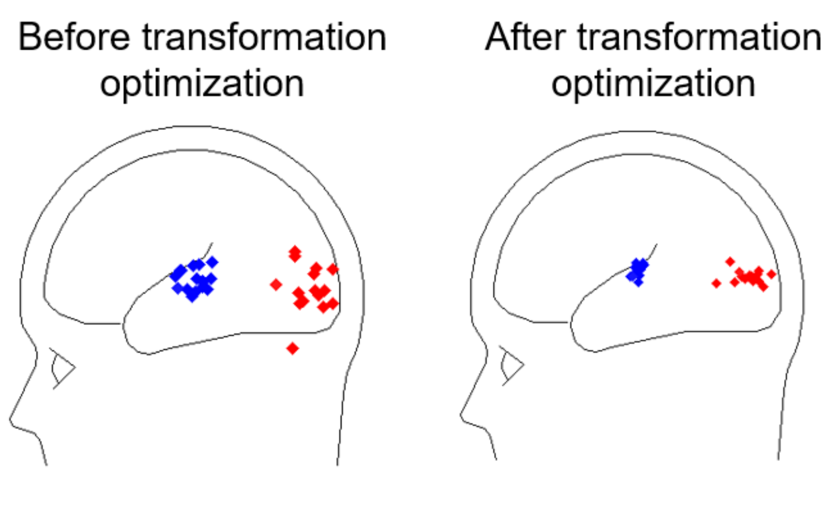

Fig. 6 Fitted locations for Heschl's gyrus (blue) and V1 (red).

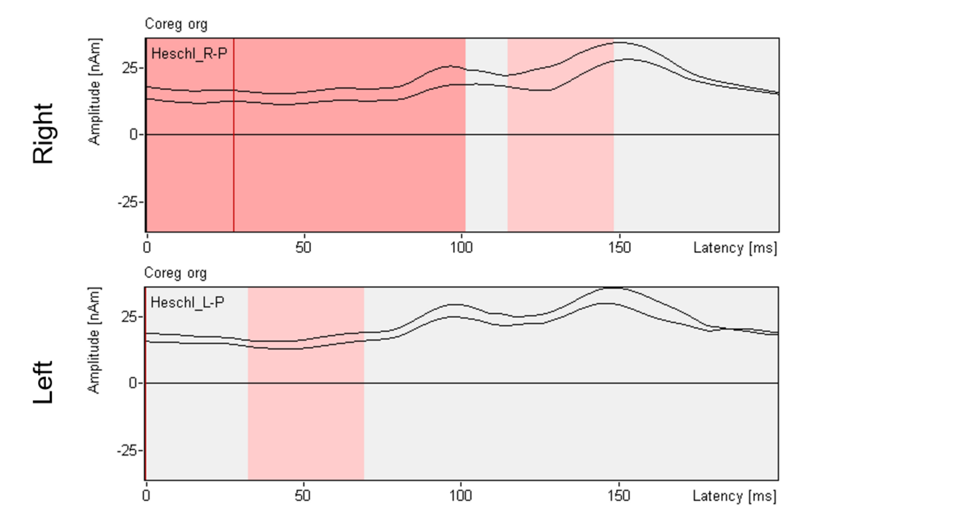

Fig. 7 Cluster permutation statistics on the two Heschl's gyrus sources between 0–200 ms after stimulus. After co-registration the power increases in the sources, highly significant in right Heschl's gyrus, not reaching full significance in left Heschl's gyrus.

V CONCLUSIONS and OUTLOOK

The transformation optimization allows to obtain better source current reconstructions from seeded locations. This can enable source-level connectivity studies in the future, investigating task-related connectivity at different frequency levels.
However, fitting of the visual component was less robust than the auditory one. Adding another stimulus type, e.g. sensory stimulation of median nerve, may further increase the accuracy of this method.

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