SUPPLEMENTARY ONLINE MATERIAL

S1 – Univariate analysis.

S2 – Example of between-subject MVPA.

S3 – What is the locus of neuroplastic changes happening within the AC of congenitally deaf individuals?

Fig. S1 – Univariate whole-brain analysis of the representation of the azimuth and medial planes

S1. Univariate analysis.

We performed univariate analysis on our visual data within the deaf and hearing groups. We first did a region-of-interest univariate analysis over the data from our experiment, and showed that for deaf but not hearing participants, the contrast between the inner-most and the outer-most annuli yielded activation in AC (bilateral, t (3080) = 1.85, p = 0.064; right hemisphere AC, t (3080) = 1.97, p = 0.048). Moreover, the contrast between locations within the azimuth plane (i.e., left vs right) yielded marginally significant activations in right AC (t (3080) = 1.90, p = 0.058), whereas the contrast between positions within the medial plane (i.e., up vs. down) did not (t (3080) = 0.66, p = 0.511).

We then performed whole-brain analyses. For the deaf, but not for the hearing, contrasting left *versus* right presentations (i.e., the azimuth plane condition) led to activation within superior temporal and parietal regions. Contrasting superior *versus* inferior visual presentations (i.e., the medial plane) led to a much less widespread pattern of activation throughout temporal and parietal cortices, within both deaf and hearing participants. Finally, contrasting central to peripheral locations showed a widespread activation in superior parietal regions for both groups, and some temporal and temporo-parietal activation (more in the right hemisphere) for the deaf.

These data show, as demonstrated before (e.g., Finney et al., 2001), that there is a neural processing advantage for items presented in the periphery within the auditory cortex of deaf individuals, and that this is especially prevalent within the right auditory cortex. These data also hint at the fact that this advantage may be restricted to items presented within the azimuth plane.

S2. Example of between-subject MVPA.

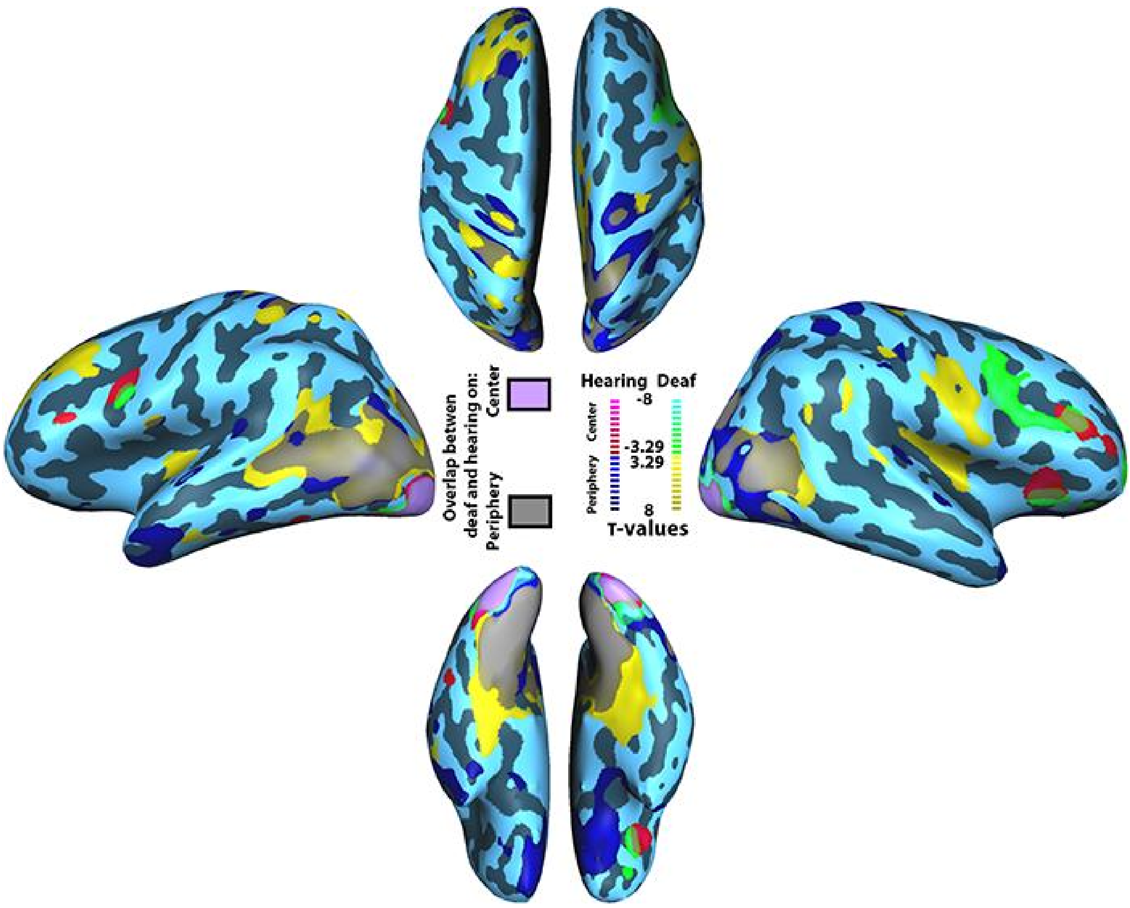
To better explain the way in which we analyzed our between-subject MVPA data, we will present an example for within-group classification performed over data from the AC of congenitally deaf individuals regarding the classification “center versus periphery”. We conducted MVPA to investigate the possibility of dissociating activation patterns arising as a response to centrally presented visual stimuli (i.e., the 2 most central rings) from those arising as a response to peripherally presented visual stimuli (i.e., the two most peripheral rings). We trained the classifier to predict whether the activation patterns were related with “central” or “peripheral” visual stimuli on beta values from 8 deaf participants (10 beta values times 2 categories times 8 subjects for a total of 160 pattern vectors), and tested the model over beta values from the remaining 2 deaf participants (10 beta values times 2 categories times 2 subject for a total of 40 pattern vectors; Haxby *et al*., 2001, 2011).

S3. What is the locus of neuroplastic changes happening within the AC of congenitally deaf individuals?

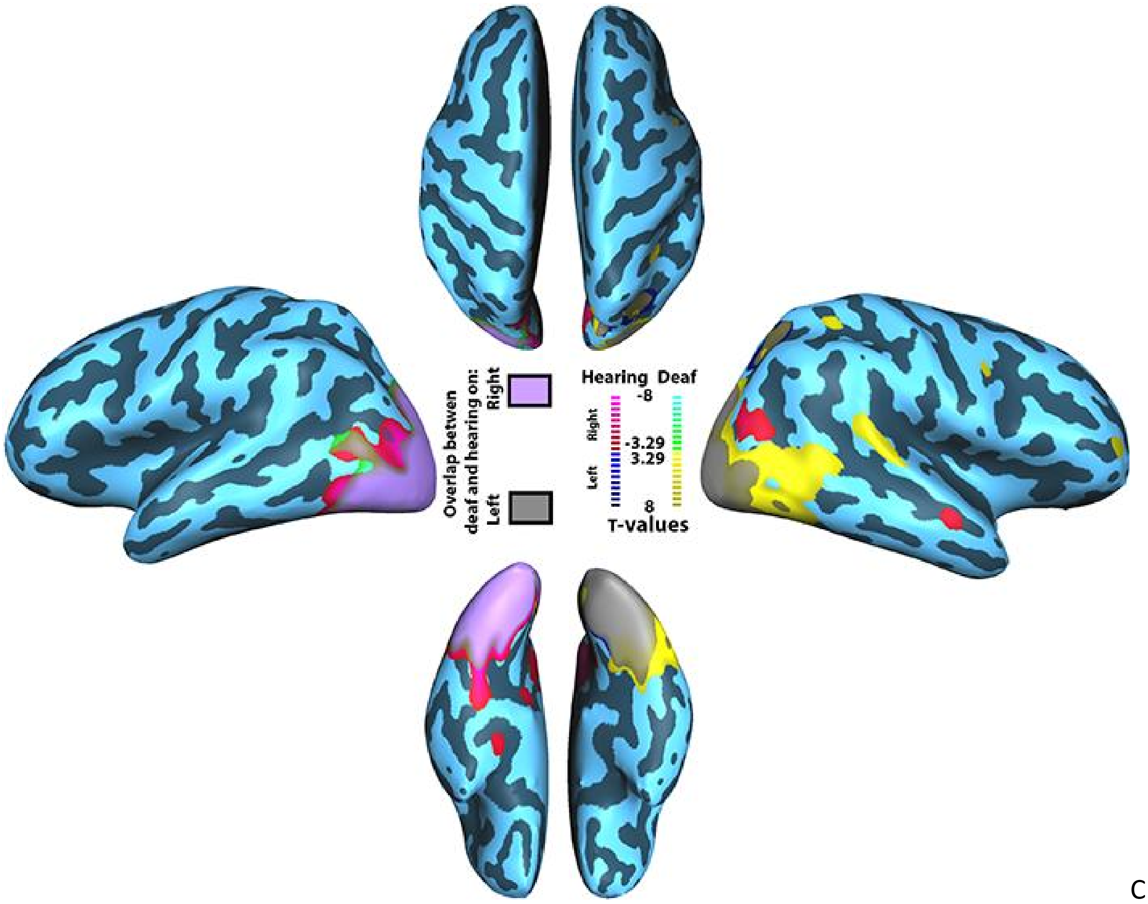
Prior findings implicate several auditory areas, but leave the role of PAC, and in particular A1, underdetermined in congenitally deaf humans. Some reports showed that A1 responds to visual stimulation both in human and non-human subjects (e.g., Finney et al., 2001; Hunt et al., 2006; Roe et al., 1990). Many others, however, have failed to show any visual responses in A1 (e.g., Hickok et al., 1997; Kral et al., 2003; Nishimura et al., 1999; Stewart and Starr, 1970). Moreover, it seems that A1 in deaf animals still responds to electric stimulation of the auditory nerve (e.g., Hartmann et al., 1997), suggesting that A1 may not go through massive reorganization under deafness. Nevertheless, given the coordinates of our auditory region, it seems that our activation is within PAC, alongside activation in non-core auditory regions.

Fig. S1 – Univariate whole-brain analysis of the representation of center and periphery, as well as the azimuth and medial planes. Contrast (t-values) maps for the contrasts of interest. (A) Contrast maps for center versus periphery locations across the whole-brain for deaf and hearing participants; (B) Contrast maps for left versus right locations across the whole-brain for deaf and hearing participants; and (C) Contrast maps for up versus down locations across the whole-brain for deaf and hearing participants. Contrast maps are cluster corrected 0.001.

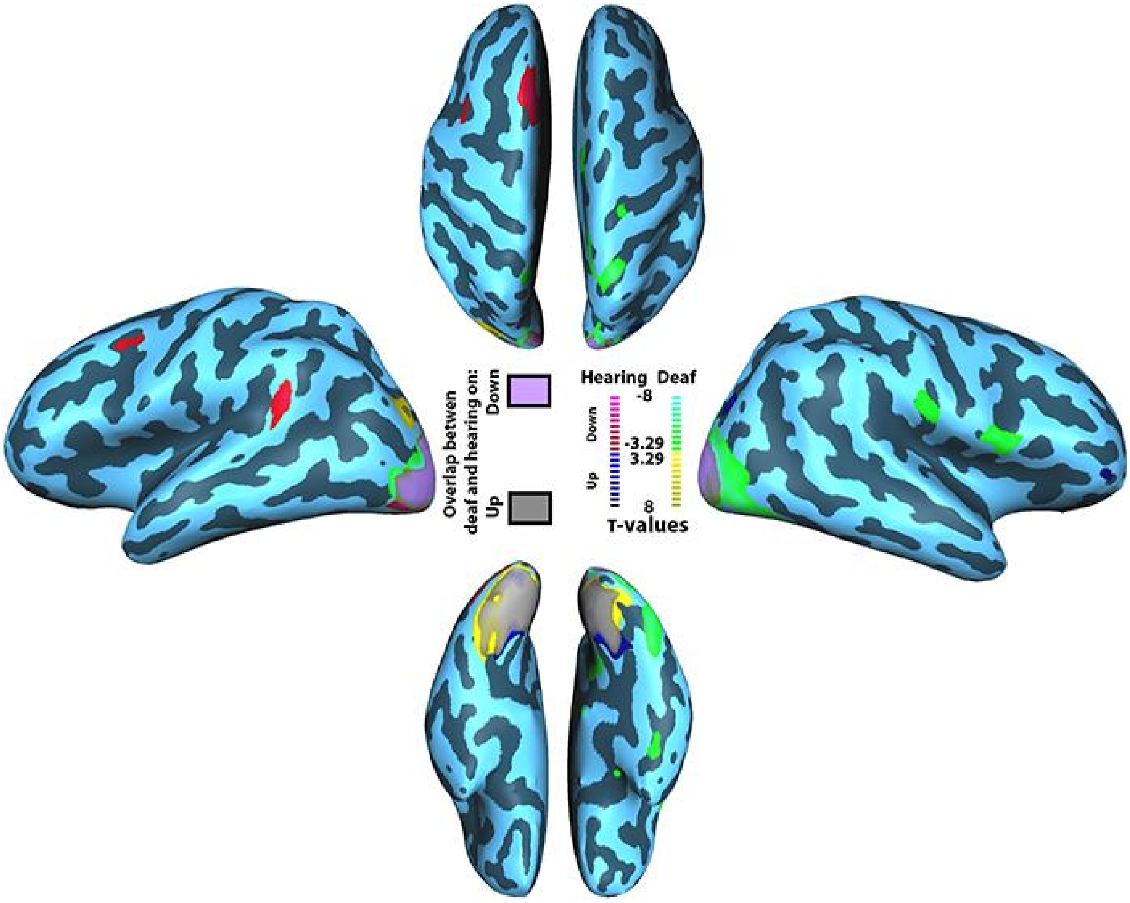
A.



B.


Overlap betwen
deaf and hearing on:
Right
Left
Hearing Deaf
-8
-3.29
3.29
8
Right
Left
T-values

C.


Overlap betwen deaf and hearing on:
Down
Up
Hearing Deaf
Down
Up
-8
-3.29
3.29
8
T-values

REFERENCES

Barone, P., Lacassagne, L. & Kral, A. (2013). Reorganization of the connectivity of cortical field DZ in congenitally deaf cat. *PLoS One* doi: 10.1371/journal.pone.0060093

Bavelier, D. & Neville, H. (2002). Cross-modal plasticity: where and how? *Nat Rev Neurosci, 3*, 443-452.

Bavelier, D., Tomann, A., Hutton, C., Mitchell, T., Corina, D., Liu, G. & Neville, H. (2000). Visual attention to the periphery is enhanced in congenitally deaf individuals. *J Neurosci, 20*, 1–6.

Bosworth, R.G. & Dobkins, K.R. (2002). Visual field asymmetries for motion processing in deaf and hearing signers. *Brain Cogn, 49*, 170–181.

Brainard, M.S. & Knudsen, E.I. (1993). Experience-dependent plasticity in the inferior colliculus: a site for visual calibration of the neural representation of auditory space in the barn owl. *J Neurosci, 13*, 4589–4608.

Da Costa, S., van der Zwaag, W., Marques, J.P., Frackowiak, R.S., Clarke, S. & Saenz, M. (2011). Human primary auditory cortex follows the shape of Heschl's gyrus. *J Neurosci, 31*, 14067-14075.

Fine, I., Finney, E.M., Boynton, G.M. & Dobkins, K.R. (2005). Comparing the effects of auditory deprivation and sign language within the auditory and visual cortex. *J Cogn Neurosci, 17*, 1621–1637.

Finney, E.M., Fine, I. & Dobkins, K.R. (2001). Visual stimuli activate auditory cortex in the deaf. *Nat Neurosci, 4*, 1171–1173.

Ghazanfar, A.A., & Schroeder, C.E. (2006). Is neocortex essentially multisensory? *Trends Cogn Sci*, 10, 278-285.Gougoux, F., Lepore, F., Lassonde, M., Voss, P., Zatorre, R.J. & Belin, P. (2004). Neuropsychology: pitch discrimination in the early blind. *Nature, 430*, 309.

Hartmann, R., Shepherd, R.K., Heid, S. & Klinke, R. (1997).Response of the primary auditory cortex to electrical stimulation of the auditory nerve in the congenitally deaf white cat. *Hear Res, 112*, 115-133.

Haxby, J.V., Gobbini, M.I., Furey, M.L., Ishai, A., Schouten, J.L & Pietrini, P. (2001). Distributed and overlapping representations of faces and objects in ventral temporal cortex. *Science, 293*, 2425–2430.

Haxby, J.V., Guntupalli, J.S., Connolly, A.C., Halchenko, Y.O., Conroy, B.R., Gobbini, M.I., Hanke, M., & Ramadge, P.J. (2011). A Common, High-Dimensional Model of the Representational Space in Human Ventral Temporal Cortex. *Neuron, 72*, 404–416.

Hickok, G., Poeppel, D., Clark, K., Buxton, R.B., Rowley, H.A. & Roberts, T.P. (1997). Sensory mapping in a congenitally deaf subject: MEG and fMRI studies of cross-modal non-plasticity. *Hum Brain Mapp, 5*, 437-444.

Hunt, D.L., Yamoah, E.N. & Krubitzer, L. (2006). Multisensory plasticity in congenitally deaf mice: how are cortical areas functionally specified? *Neurosci, 139*, 1507-1524.

Karns, C.M., Dow, M.W. & Neville, H.J. (2012). Altered cross-modal processing in the primary auditory cortex of congenitally deaf adults: a visual-somatosensory fMRI study with a double-flash illusion. *J Neurosci, 32*, 9626-38.

Kral, A., Schröder, J.H,. Klinke, R., & Engel, A.K. (2003). Absence of cross-modal reorganization in the primary auditory cortex of congenitally deaf cats. *Exp Brain Res, 153*, 605-613.

Kriegeskorte, N., Goebel, R., & Bandettini, P. (2006). Information-based functional brain mapping. *PNAS USA, 103*, 3863-3868.

Levanen, S. & Hamdorf, D. (2001). Feeling vibrations: enhanced tactile sensitivity in congenitally deaf humans. *Neurosci Lett, 301*, 75–77.

Lomber, S.G., Meredith, M.A. & Kral, A. (2010). Crossmodal plasticity in specific auditory cortices underlies visual compensations in the deaf. *Nat Neurosci, 13*, 1421 – 1427.

Meredith, M.A., Kryklywy, J., McMillan, A.J., Malhotra, S., Lum-Tai, R. & Lomber, S.G. (2011). Crossmodal reorganization in the early deaf switches sensory, but not behavioral roles of auditory cortex. *Proc Natl Acad Sci USA, 108*, 8856–8861.

Meredith, M.A. & Lomber, S.G. (2011). Somatosensory and visual crossmodal plasticity in the anterior auditory field of early-deaf cats. *Hear Res, 280*, 38-47.

Meyer, K., Kaplan, J.T., Essex, R., Webber, C., Damasio, H., & Damasio, A. (2010). Predicting visual stimuli on the basis of activity in auditory cortices. *Nat. Neurosci.*, 13, 667–668.Neville, H.J. & Lawson, D. (1987a). Attention to central and peripheral visual space in a movement detection task: an event-related potential and behavioral study. II. Congenitally deaf adults. *Brain Res, 405*, 268–283.

Neville, H.J. & Lawson, D. (1987b). Attention to central and peripheral visual space in a movement detection task: an event-related potential and behavioral study. III. Separate effects of auditory deprivation and acquisition of a visual language. *Brain Res, 405*, 284–294.

Nishimura, H., Hashikawa, K., Doi, K., Iwaki, T., Watanabe, Y., Kusuoka, H., Nishimura, T. & Kubo, T. (1999). Sign language 'heard' in the auditory cortex. *Nature, 397*, 116.

Penhune, V.B., Zatorre, R.J., MacDonald, J.D. & Evans, A.C. (1996). Interhemispheric anatomical differences in human primary auditory cortex: probabilistic mapping and volume measurement from magnetic resonance scans. *Cereb Cortex, 6*, 661-672.

Rajan, R., Aitkin, L.M. & Irvine, D.R. (1990). Azimuthal sensitivity of neurons in primary auditory cortex of cats. II. Organization along frequency-band strips. *J Neurophysiol, 64*, 888-902.

Reynolds, H.N. (1993). Effects of foveal stimulation on peripheral visual processing and laterality in deaf and hearing subjects. *Am J Psychol, 106*, 523–540.

Roe, A.W., Pallas, S.L., Hahm, J.O. & Sur, M. (1990). A map of visual space induced in primary auditory cortex. *Science, 250*, 818-820.

Sadato, N., Pascual-Leone, A., Grafman, J., Ibañez, V., Deiber, M.P., Dold, G., & Hallett, M. (1996). Activation of the primary visual cortex by Braille reading in blind subjects. *Nature, 380*, 526–528.

Sandmann, P., Dillier, N., Eichele, T., Meyer, M., Kegel, A., Pascual-Marqui, R.D., Marcar, V.L., Jancke, L. & Debener, S. (2012). Visual activation of auditory cortex reflects maladaptive plasticity in cochlear implant users. *Brain, 135*, 555-568.

Schneider, K.A., Richter, M.C., & Kastner, S. (2004). Retinotopic organization and functional subdivisions of the human lateral geniculate nucleus: A high-resolution functional magnetic resonance imaging study. *J Neurosci*, *24*, 8975–8985.

Scott, G.D., Karns, C.M., Dow, M.W., Stevens, C. & Neville, H.J. (2014). Enhanced peripheral visual processing in congenitally deaf humans is supported by multiple brain regions, including primary auditory cortex. *Front Hum Neurosci, 8*, 177.

Sereno, M.I., Dale, A.M., Reppas, J.B., Kwong, K.K., Belliveau, J.W., Brady, T.J., Rosen, B.R. & Toote;;, R.B. (1995). Borders of multiple visual areas in humans revealed by functional magnetic resonance imaging. *Science, 268*, 889–893.

Shiell, M. M., Champoux, F., & Zatorre, R. J. (2015). Reorganization of Auditory Cortex in Early-deaf People: Functional Connectivity and Relationship to Hearing Aid Use. *Journal of Cognitive Neuroscience, 27*(1), 150-163.

Smith, A.M., Lewis, B.K., Ruttimann, U.E., Ye, F.Q., Sinnwell, T.M., Yang, Y., Duyn, J.H. & Frank, J.A. (1999). Investigation of low frequency drift in fMRI signal. *Neuroimage, 9*, 526-533.

Stewart, D.L. & Starr, A. (1970). Absence of visually influenced cells in auditory cortex of normal and congenitally deaf cats. *Exp Neurol, 28*, 525-528.

Talairach, J. & Tournoux, P. (1988). *Co-planar stereotaxic atlas of the human brain*. Thieme, New York.

Van Boven, R.W., Hamilton, R.H., Kauffman, T., Keenan, J.P. & Pascual-Leone, A. (2000). Tactile spatial resolution in blind braille readers. *Neurology, 54*, 2230–2236.

Vetter, P., Smith, F.W., & Muckli, L. (2014) Decoding sound and imagery content in early visual cortex. *Cur Biol.*, 24, 1256-1262.Watanabe, M., Cheng, K., Murayama, Y., Ueno, K., Asamizuya, T., Tanaka, K. & Logothetis, N. (2011). Attention but not awareness modulates the BOLD signal in the human V1 during binocular suppression. *Science, 334*, 829-831.

Watkins, K.E., Shakespeare, T.J., O'Donoghue, M.C., Alexander, I., Ragge, N., Cowey, A. & Bridge, H. (2013). Early auditory processing in area V5/MT+ of the congenitally blind brain. *J Neurosci, 33*, 18242-18246.

Wong, C., Chabot, N., Kok, M.A. & Lomber, S.G. (2013). Modified Areal Cartography in Auditory Cortex Following Early- and Late-Onset Deafness. *Cereb Cortex* doi: 10.1093/cercor/bht026.

Zhang, X., Zhaoping, L., Zhou, T. & Fang, F. (2012). Neural activities in V1 create a bottom-up saliency map. *Neuron, 73*, 183-192.

FIGURE LEGENDS

Figure 1. Stimuli used in the experiments. (**A**) stimuli used for visual field location classification; and (**B**) stimuli used for eccentricity classification.

Figure 2. Auditory and visual cortex. (**A**) Regions within auditory cortex (AC), defined in hearing participants, and primary visual cortex used for the classification. (**B**) The auditory cortex ROI includes de Heschl's Gyrus (Brodmann Area 41), but does not include other auditory regions of interest such as Brodmann Areas 42 and 22. *t* map corresponds to the AC ROI contrast of white noise vs. silence . HG – Heschl's Gyrus; SF – Sylvian Fissure; STG – Superior Temporal Gyrus; STS – Superior Temporal Sulcus.

Figure 3. Percent correct performance for real and surrogate data in auditory cortex (bilaterally) and visual cortex. (**A**) Percent correct performance for quadrant classification in AC; and (**B**) Percent correct performance for the classification of the contrasts left vs. right and up vs. down in AC; (**C**) Percent correct performance for quadrant classification in V1; and (**D**) Percent correct performance for the classification of the contrasts left vs. right and up vs. down in V1. Bars correspond to performance with real data, and black dashes (**-**) correspond to performance with the surrogate data. Dashed lines correspond to different confidence intervals for the estimate of the mean of the surrogate data. Red error bars correspond to the SEM of the classification data, whereas black error bars correspond to the SEM of the surrogate data. Within-group classification performance for deaf individuals is above chance for quadrant classification, demonstrating that visual location is represented in the AC of congenitally deaf individuals. Stimuli within the azimuth, when compared to stimuli within the meridian plane, seem to drive responses in AC of congenitally deaf individuals. Results in V1 show highly significant classification performance across classifiers.

Figure 4. Whole-brain searchlight classification accuracy for center/periphery locations, and locations within the azimuth and meridian planes. (A) Decoding performance effect maps (z-values) for decoding center versus periphery locations across the whole-brain for deaf and hearing participants; **(B)** Decoding performance effect maps (z-values) for decoding left versus right locations across the whole-brain for deaf and hearing participants; and **(C)** Decoding performance effect maps

(z-values) for decoding up versus down across the whole-brain for deaf and hearing participants. z-values (calculated against surrogate data) above 3.9 correspond to p-values equal to or less than 0.0001; Decoding performance for the deaf group is represented in yellow, whereas for the hearing group it is represented in blue. Overlap in decoding ability for both groups in represented in silver gray.

Figure 1. Stimuli used in the experiments.

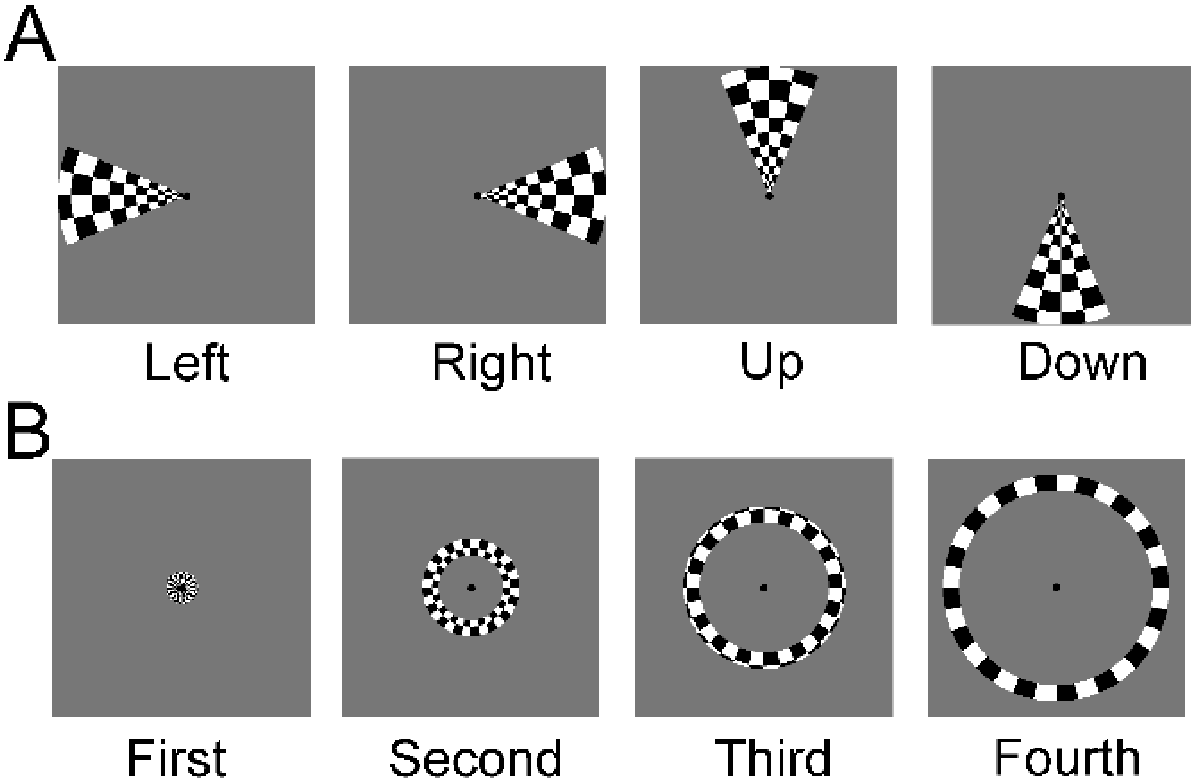


Figure 2. Auditory and visual cortex.

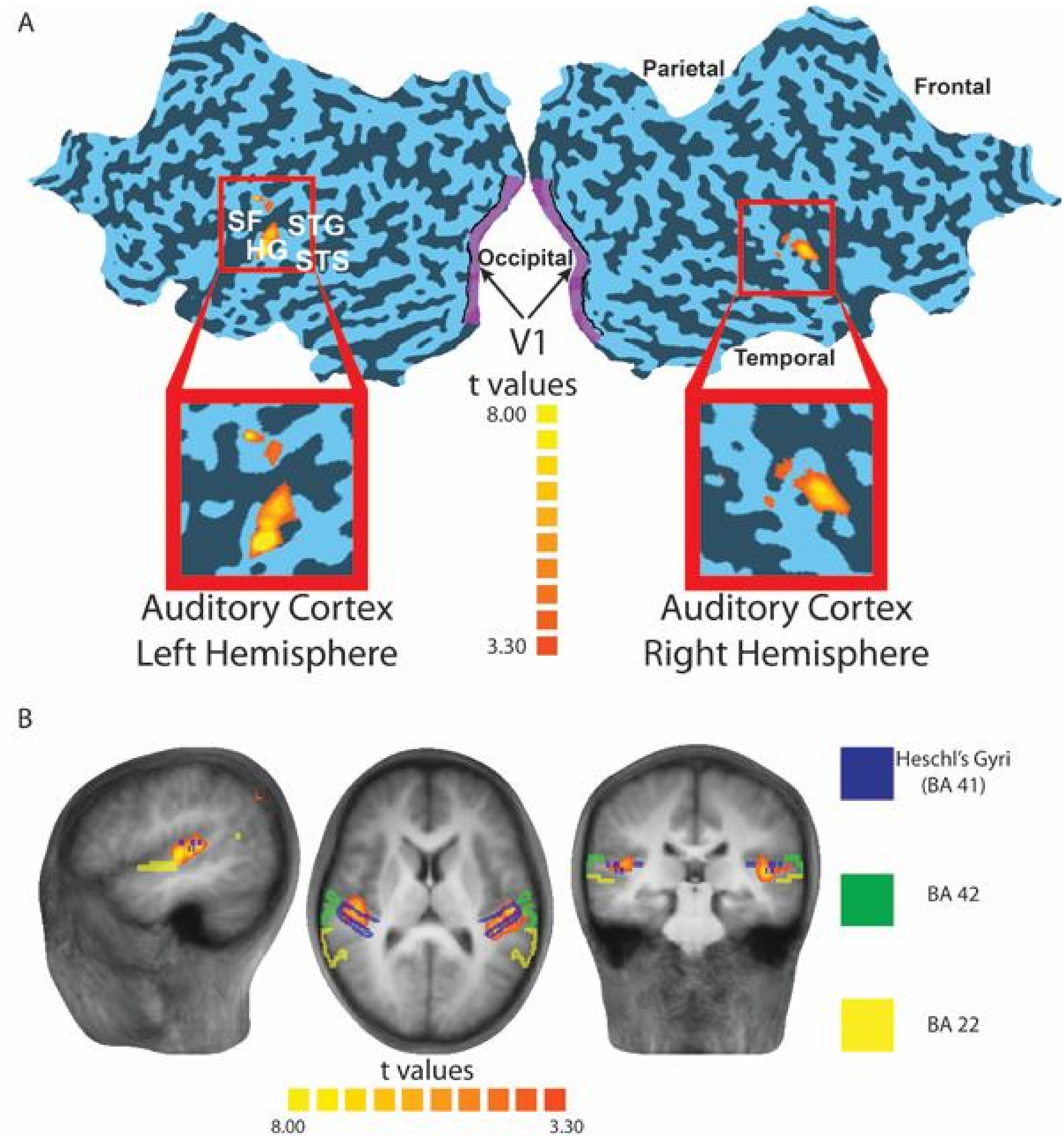


Figure 3. Percent correct performance for real and surrogate data in auditory cortex (bilaterally) and visual cortex.

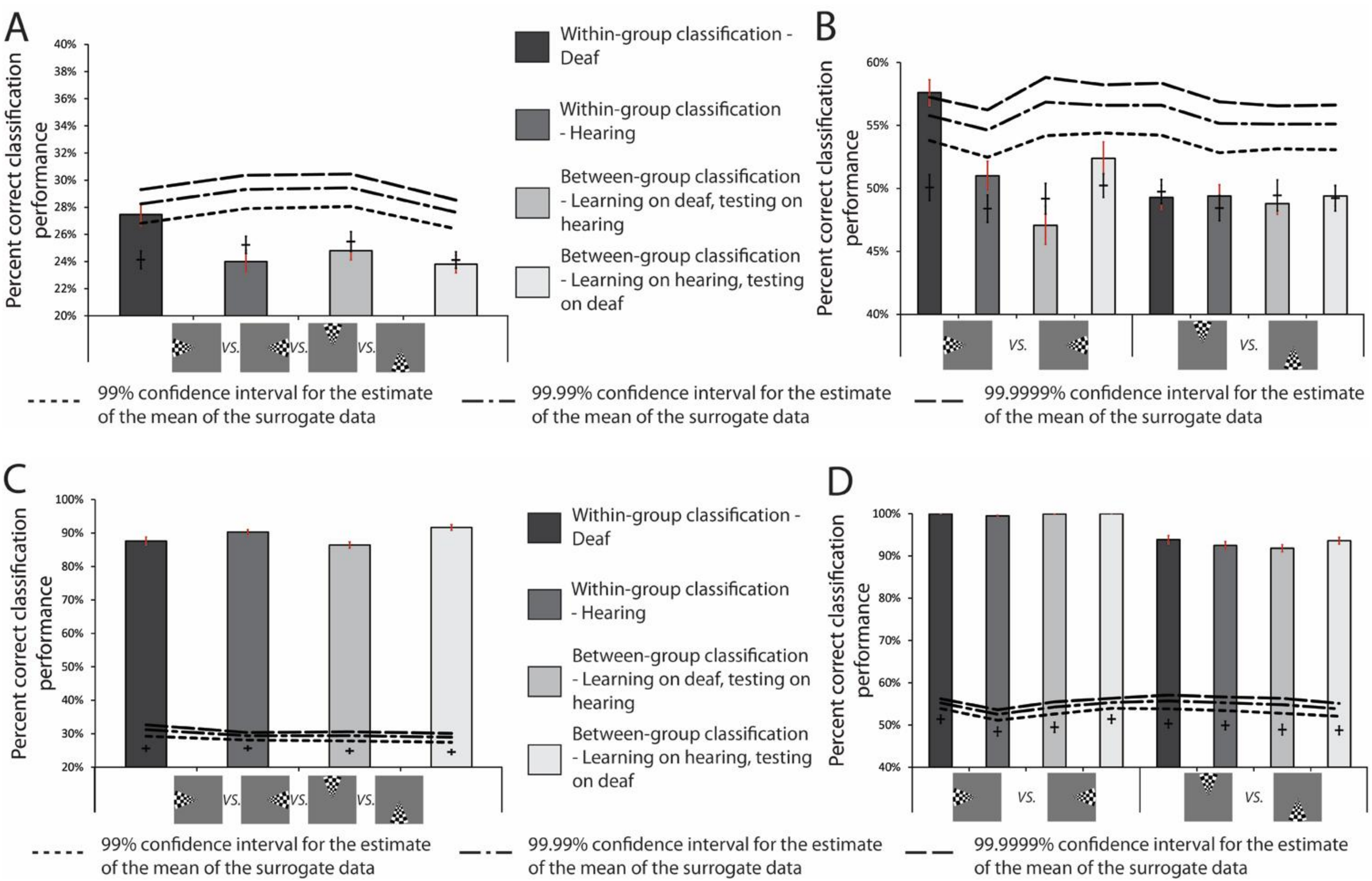
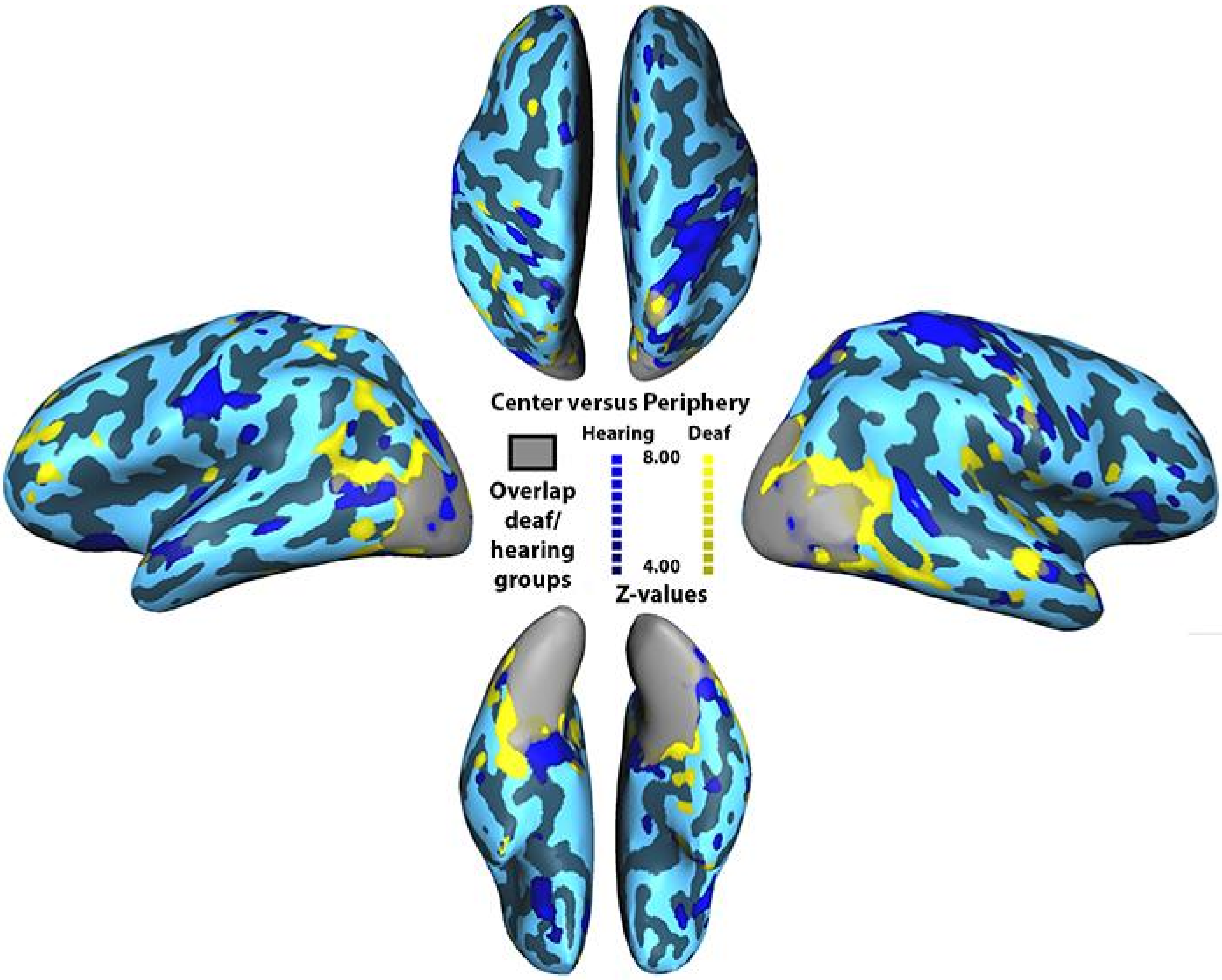
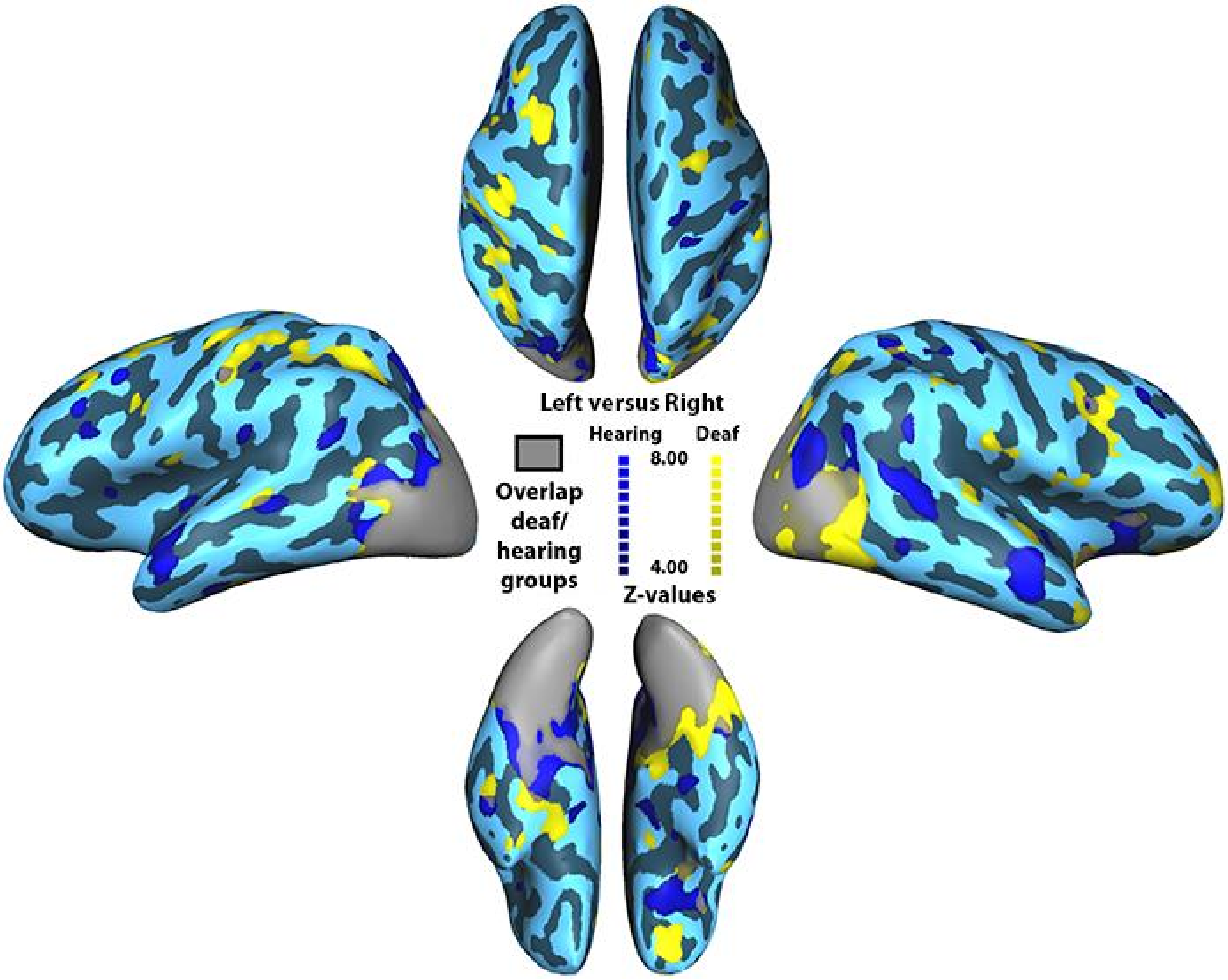


Figure 4. Whole-brain searchlight classification accuracy for center/periphery locations, and locations within the azimuth and meridian planes.

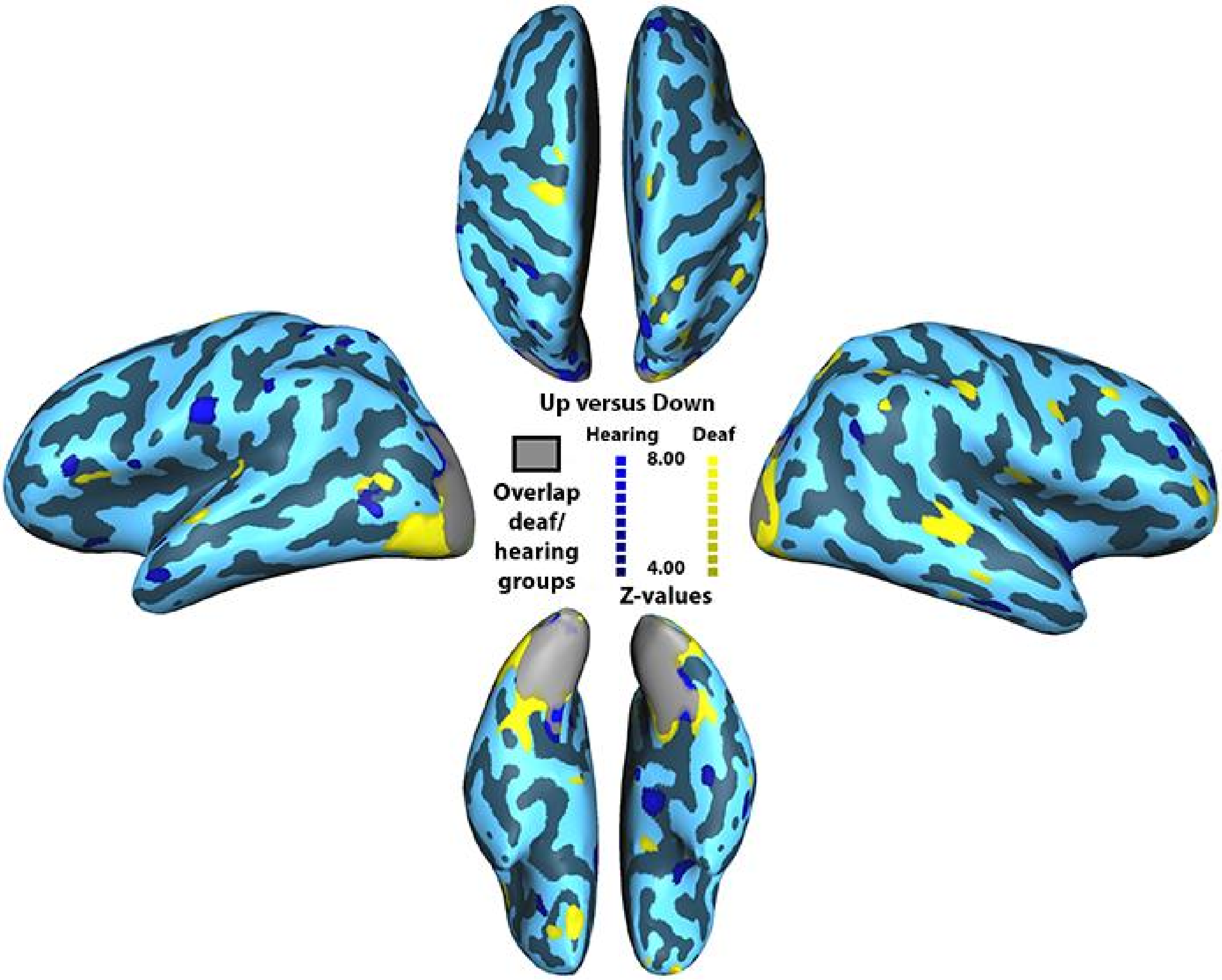
A.



B.


Left versus Right
Hearing
Deaf
8.00
4.00
Z-values
Overlap deaf/ hearing groups

C.


Up versus Down
Hearing
Deaf
8.00
4.00
Z-values
Overlap deaf/ hearing groups