Auditory Cortex in Musicians with Absolute Pitch
Deformation-based Shape Analysis

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Introduction

Absolute pitch (AP): an ability to recognize and reproduce pitches of Western musical scale without an external reference tone (Miyazaki, 1988)

Structural differences in auditory cortex (see Table 1)

- *Region-of-interest (ROI)-based studies*: increased leftward asymmetry of planum temporale (PT) due to smaller area of the right PT and larger volume of the right Heschl's gyrus (HG)
- *Voxel-/vertexwise analyses*: no differences in cortical thickness (CT) or gray matter density in superior temporal gyrus (STG) in some studies
- Inconsistency may be due to methodological limits

Aim of the study:
To localize precise strcutnual differences in auditory cortex using deformation-based shape analysis (Kim et al., 2012) that combines manual ROI and vertex-wise analysis

Study	Method	N (AP / NAP)	Findings
Schlaug et al., 1995	ROI-area	[illegible]	Smaller right PT
Zatorre et al., 1998	ROI-vol	[illegible]	Larger left PT
Keenan et al., 2001	ROI-area	[illegible]	Smaller right PT
Luders et al., 2004	VBM	[illegible]	Leftward asymmetry in PT/HG
Bermudez & Zatorre, 2005	VBM	[illegible]	No difference found in STG
Bermudez et al., 2009	CT/VBM	[illegible]	No difference found in STG
Wengenroth et al., 2013	ROI-vol	[illegible]	Larger right HG
Dohn et al., 2013	CT	[illegible]	Thicker bilateral STG [illegible]

Table 1. AP-related structural findigins in superior temporal gyrus (STG)

Methods

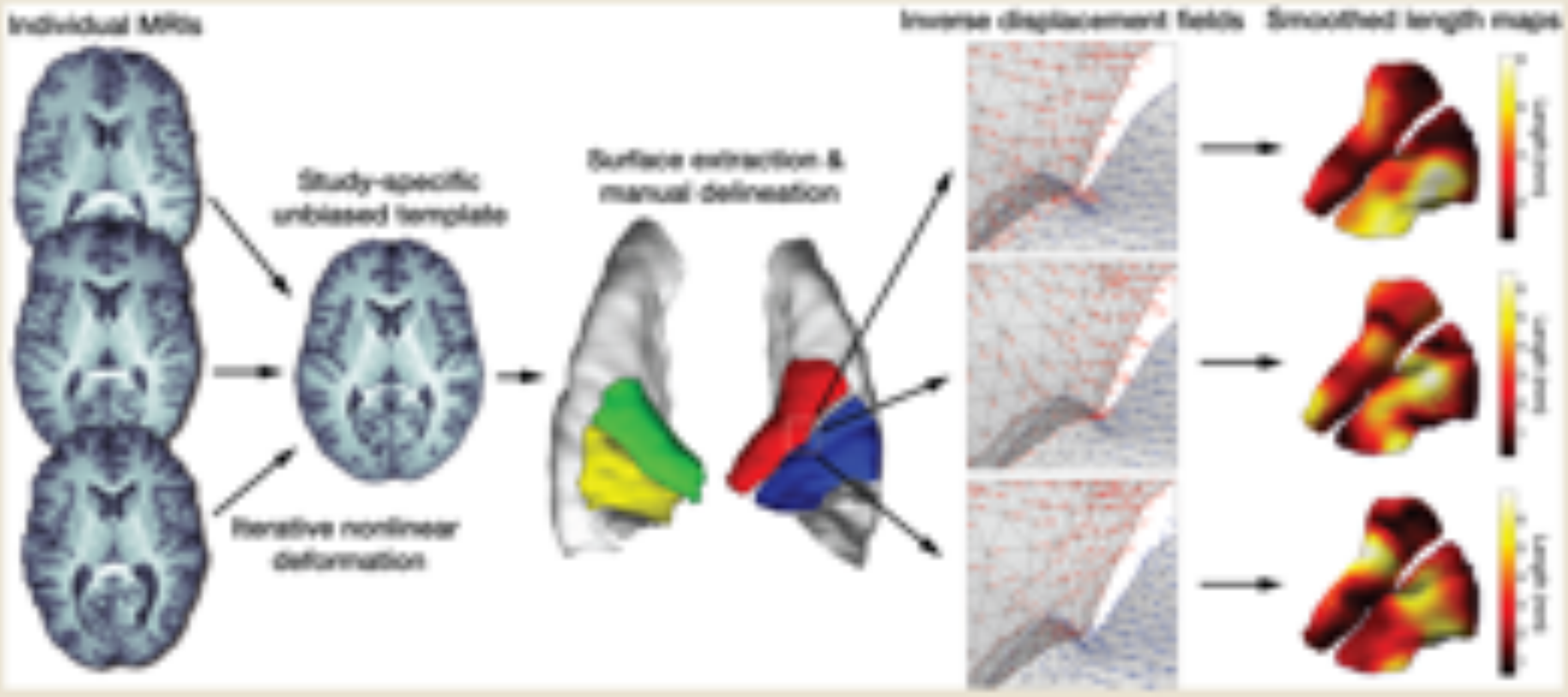
Magnetic resonance imaging
T1-weighted 3D MPRAGE images at 1-mm isovoxel resolution using 3T scanners (MAGNETOM Trio and Verio, Siemens, Germany)

Subjects†
17 AP musicians (6 females), 25.8 ± 3.7 y.o.
17 non-AP (NAP) musicians (5 females), 25.4 ± 4.0 y.o.

†The musicians participated in either of two experiments performed by J.S. and K.S., respectively, at Max Planck Institute for Human Cognitive and Brain Sciences (Leipzig, Germany).

Study-specific template creation
Using Advanced Normalization Tools (ANTS) (Avants et al., 2008), iterative averaging and registrations were done as
- *First four iterations*: randomly chosen 10 subjects
- *Last two iterations*: all 34 subjects

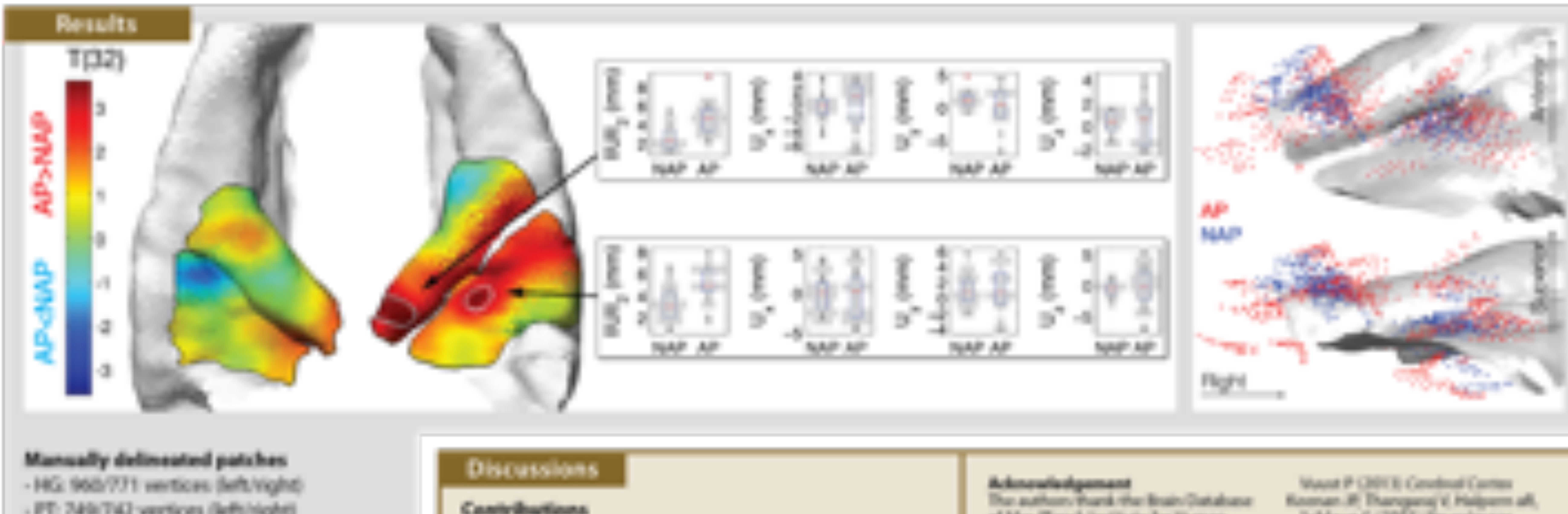
Surface extration and ROI delineation
Cortical surfaces were extracted using Freesurfer. On the template surfaces, manual delineation of HG and PT was made by a human rater (S.-G.K) with the help from a German Radiologist (A.V.)



Inverse displacement field
The inverse displacement field describes the necessary deformation that is required to warp the template structure to match an individual structure. Thus the length of displacement is the distance from the template and used as the response variable of the current study.

Statistical inference
- *Two-sample t-tests over HG and PT*: to find group differences between the musicians with/without AP.
- *Multiple comparisons correction*: based on random field theory (RFT) was applied using the SurfStat MATLAB toolbox (Worsley et al., 2009). For the Gaussian assumption of RFT, the length maps were iteratively smoothed by a 2D Gaussian kernel with the full width at half maximum (FWHM) of about 3 mm. The family-wise rate error at vertex-level was determined as 0.05.

Results



Manually delineated patches
- HG: 960/771 vertices (left/right)
- PT: 749/742 vertices (left/right)

Significant group differences (AP>NAP)
- *The right HG*: medial region, max T(32) = 3.685, corrected p-value = 0.034
- *The right PT*: anterior region, max T(32) = 3.605, corrected p-value = 0.036

Variance of displacement component for x-/y-/z-coordiantes: greater in AP than NAP in most of components (see insets for Ux, Uy, Uz and scatterplots over surfaces)

Template creation with all 34 subjects through full iterations: also similar results (QR)

Discussions

Contributions
- We applied shape analysis to the auditory cortex in musicians with and without AP.
- We found significantly larger length of displacement from the template to the individuals in AP than NAP on the right HG and the right PT.
- It suggests that the morphological characteristics of AP are confined within some regions of the auditory cortex.

Limitation & future works
- Beyond local morphology (e.g. expansion/contraction), the topology of HG may largely differ across subjects, especially in musicians.
- We may be able to take varying topology into account in the future, possibly using spectral methods such as Reeb graph based on Laplace-Beltrami eigenvectors.

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Resources
ANTS, http://picsl.upenn.edu/software/ants/
FreeSurfer, http://surfer.nmr.mgh.harvard.edu/
SurfStat MATLAB toolbox, http://www.math.mcgill.ca/~keith/surfstat/

References
Avants BB, Epstein CL, Grossman M, Gee JC (2008) Medical Image Analysis
Bermudez P, Zatorre RJ (2005) PNAS
Bermudez P, Lerch JP, Evans AC, Zatorre RJ (2009) Cerebral Cortex
Dohn A, Garza-Villarreal EA, Chakravarty MM, Hansen M, Lerch JP, Vuust P (2013) Cerebral Cortex
Keenan JP, Thangaraj V, Halpern AR, Schlaug G (2001) NeuroImage
Luders E, Gaser C, Jancke L, Schlaug G (2004) NeuroImage
Miyazaki K (1988) Perception and Psychophysics
Schlaug G, Jancke L, Huang Y, Steinmetz H (1995) Science
Kim SG, Chung MK, Schaefer SM, van Reekum C, Davidson RJ (2012) MMBIA
Wengenroth M, Blatow M, Heinecke A, Reinhardt J, Stippich C, Hofmann E, Schneider P (2013) Cerebral Cortex
Worsley KJ, Taylor JE, Carbonell F, Chung MK, Duerden E, Bernhardt B, Lyttelton O, Boucher M, Evans AC (2009) NeuroImage
Zatorre RJ, Perry DW, Beckett CA, Westbury CF, Evans AC (1998) PNAS