Cytoarchitectonic mapping of the human olfactory tubercle and terminal islands

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INTRODUCTION:
The olfactory tubercle and terminal islands are part of the basal forebrain, a brain area characterized by great structural heterogeneity. The connectivity and function of the olfactory tubercle have been evaluated using diffusion imaging and fMRI, however the precise boundaries within 3D space are still not clarified (Zelano et al., 2007; Echevarria-Cooper et al., 2022). In addition, it is particularly challenging to study these aspects of terminal islands due to their small size, complex shape and scattered arrangement in the basal forebrain (Meyer et al., 1989). Therefore, we have generated cytoarchitectonic maps of the olfactory tubercle and terminal islands in order to determine their localization in the stereotaxic space and intersubject variability. Moreover, we provided a 3D reconstruction of the Great Terminal Island (GTI) in the BigBrain, to define its anatomical features.

METHODS:
Cytoarchitectonic mapping was performed in ten human postmortem brains. The olfactory tubercle and terminal islands were traced in histological serial sections stained for cell bodies based on cytoarchitectonic criteria in both hemispheres (Amunts et al., 2020). Serial mappings were reconstructed and warped to the MNI "Colin27" and MNI ICBM2009c reference spaces in order to gain probability maps of olfactory tubercle and terminal islands. These maps capture the localization of these regions considering intersubject variations in space (Evans et al., 2012). Furthermore, a 3D reconstruction of the GTI was performed in the BigBrain space using a deep learning-assisted workflow (Schiffer et al., 2021). The method is based on convolutional neural networks (CNNs) trained on manual expert annotations on every 15th section in the BigBrain to predict the delineations of the GTI on every section in rostro-caudal extent (Amunts et al., 2013). Following the quality check, annotations were 3D reconstructed, transferred to the BigBrain space at 20 µm resolution isotropic and a surface was generated. Computations were performed on the supercomputer JURECA-DC at Jülich Supercomputing Centre (JSC).

RESULTS:
The olfactory tubercle showed medium spiny neurons, which is also characteristic for the ventral striatum, but in comparison with the latter with less heterogeneous neuropil. Terminal islands appeared as clusters of small cells of various size and shape embedded in the olfactory tubercle and the neighboring structures. The superposition of the cytoarchitectonic maps in the reference brains resulted in high degree of intersubject variability. High-resolution 3D reconstruction of the Great Terminal Island in the BigBrain

revealed its narrow, slightly curved shape containing two rugged surfaces. A lateral concave surface bordered nucleus accumbens while a medial convex surface bordered septal nuclei, diagonal band of Broca and subcallosal area in dorsoventral direction. Finally, a dorsal semi-portion was more massive and elongated at the caudal end (Figure).

CONCLUSION:

The new maps provide detailed anatomical information of a complex region of the basal forebrain. A 3D reconstruction of the Great Terminal Island revealed its complex shape. The new maps will support future neuroimaging studies to assess the connectivity and functions of the basal forebrain areas in both healthy and diseased brains. Maps are openly available through the Julich-Brain atlas available via EBRAINS, the research platform of the HBP (https://ebrains.eu/service/human-brain-atlas/).

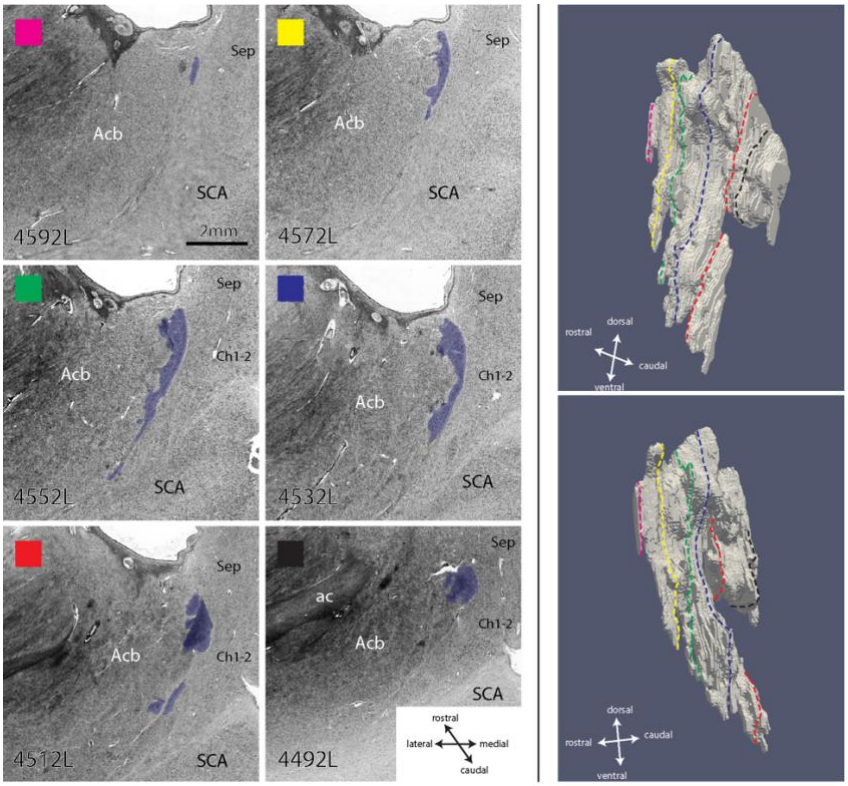

Figure: Successive coronal sections showing the rostro-caudal sequence of the Great Terminal Island (GTI) and its relations to the neighboring structures (left and middle column). Color coded annotations are indicated in the 3D reconstruction model (right column). The complex shape of the GTI reveals a concave lateral surface with various protrusions. The dorsal part of the GTI is more massive compared to the ventral portion of the island. Acb, nucleus accumbens; ac, anterior commissure; Ch1-2, magnocellular cell groups in the diagonal band; SCA, subcallosal area; Sep, septal nuclei.

Keywords: olfactory tubercle, terminal islands, Great terminal island, cytoarchitecture, probabilistic maps, BigBrain, deep learning

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