

Diffusion Measures of Subcortical Using High-Field MRI

◯ Cell to In-vivo 이미징 핵심연구지원센터

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Background & Introduction

- Deep brain structures such as the subthalamic nucleus and globus pallidus internal have shown to be effective targets of deep brain stimulation in treating Parkinson's Disease [Krause et al., Journal of Neurology, Neurosurgery & Psychiatry 2001].
- Accurate segmentations of deep brain targets ex-vivo is important in providing accurate locations of deep brain targets, as well as for observing effects of Parkinson's disease and deep brain stimulation surgery [Behrens et al., Neuroimage 2007].
- However, popular segmentation toolboxes such as FSL and Freesurfer cannot automatically segment particular deep brain structures, such as STN, RN. Additionally, the same toolboxes cannot segment GPI and GPE separately.
- □ The intention of this study was to utilize Lead-DBS, an open source toolbox designed to

Results (II): Subcortical diffusion measures



provide precise locations of anatomical structures for deep brain stimulation surgery, to segment subthalamic nucleus (STN), red nucleus (RN), globus pallidus internal (GPI) and globus pallidus external (GPE) [Horn A and Kühn AA, Neuroimage, 2015].

□ In addition, we compare the diffusion measures of 3T and 7T mean, whole-brain structural connectome with PPMI normative connectome using x-direction sampling [Marek et al., Progress in neurobiology, 2011; Ewert et al., Neuroimage, 2017].

Materials and Methods

q-sampling o







Figure 1. Basic processing Lead-connectome pipeline. Minimally preprocessed human connectome project images are co-registered to the structural T1w image using SPM. Structural images are registered to templates using ANTs registration, generating inverse transforms to translate MNI PD25 template to b0 space. DSI Studio is used to apply Q-sampling on diffusion images to reconstruct diffusion orientations and generate diffusion network statistics of

segmented ROIs and ROI diffusion connectivity

- ✤ Figure 3. Results of 3T and 7T Lead-DBS segmentations of the same subject (HCP) Subject ID: 196144) overlaid on 3T and 7T b0 images.

ROI	Mean 3T FA	Mean 7T FA	Student T Test p 3T FA > 7T FA	Mean 3T M D (×10 ⁻³)	Mean 7T MD (×10 ^{−3})	Student T Test p 3T MD > 7T MD
Left amygdala	0.189	0.184	0.645	0.748	0.669	0.098
Left caudate	0.164	0.175	0.719	0.679	0.620	0.359
Left globus pallidus externus	0.242	0.189	0.013	0.514	0.424	0.032
Left globus pallidus internus	0.250	0.196	0.597	0.525	0.433	0.890
Left hippocampus	0.168	0.157	0.351	0.788	0.712	0.632
Left nucleus accumbens	0.169	0.149	0.701	0.677	0.659	0.215
Left putamen	0.188	0.175	0.471	0.627	0.569	0.032
Left red nucleus	0.329	0.304	0.332	0.554	0.457	0.394
Left substantia nigra	<mark>0.346</mark>	<mark>0.343</mark>	<mark>0.001</mark>	<mark>0.584</mark>	<mark>0.409</mark>	<mark>0.006</mark>
Left subthalamic nucleus	0.347	0.294	0.030	0.534	0.426	0.635
Left thalamus	0.269	0.248	0.753	0.631	0.583	0.252
Right amygdala	0.169	0.175	0.509	<mark>0.757</mark>	<mark>0.667</mark>	<mark>0.001</mark>
Right caudate	0.177	0.161	0.017	0.677	0.608	0.748
Right globus pallidus externus	0.230	0.250	0.176	0.532	0.384	0.207
Right globus pallidus internus	0.200	0.215	0.070	0.511	0.377	0.162
Right hippocampus	0.169	0.156	0.578	0.767	0.709	0.847
Right nucleus accumbens	0.171	0.147	0.490	0.665	0.642	0.810
Right putamen	0.200	0.186	0.325	0.629	0.546	0.941
Right red nucleus	0.320	0.323	0.357	0.550	0.433	0.082
Right substantia nigra	0.480	0.400	0.743	0.535	0.397	0.001
Right subthalamic nucleus	0.402	0.325	0.692	0.493	0.405	<0.001
Right thalamus	0.272	0.254	0.595	0.636	0.573	0.472
ROI	Mean 3T AD (Mean 7T AD (×10 ⁻³)	Student T Test p	Mean 3T RD	Mean 7T RD (Student T Test p
	~10)		31 AD > 71 AD	$(\times 10^{-1})$	×10 °)	31 RD > /1 RD
Left amvodala	0.897	0.798	0.084	0.673	×10 ⁻³) 0.605	31 RD > 71 RD 0.126
Left amygdala Left caudate	0.897	0.798	0.084 0.400	0.673	×10 °) 0.605 0.566	31 RD > 71 RD 0.126 0.343
Left amygdala Left caudate Left globus pallidus externus	0.897 0.788 0.636	0.798 0.730 0.500	0.084 0.400 0.043	0.673 0.625 0.452	×10 °) 0.605 0.566 0.386	31 RD > 71 RD 0.126 0.343 0.033
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus	0.897 0.788 0.636 0.657	0.798 0.730 0.500 0.513	0.084 0.400 0.043 0.636	0.673 0.625 0.452 0.460	×10 ⁻³) 0.605 0.566 0.386 0.393	31 RD > 71 RD 0.126 0.343 0.033 0.943
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus	0.897 0.788 0.636 0.657 0.922	0.798 0.730 0.500 0.513 0.824	0.084 0.400 0.043 0.636 0.570	0.673 0.625 0.452 0.460 0.722	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens	0.897 0.788 0.636 0.657 0.922 0.788	0.798 0.730 0.500 0.513 0.824 0.756	0.084 0.400 0.043 0.636 0.570 0.375	0.673 0.625 0.452 0.460 0.722 0.621	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656 0.611	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left putamen	0.897 0.788 0.636 0.657 0.922 0.788 0.751	0.798 0.730 0.500 0.513 0.824 0.756 0.675	0.084 0.400 0.043 0.636 0.570 0.375 0.040	0.673 0.625 0.452 0.460 0.722 0.621 0.565	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656 0.611 0.516	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left putamen Left red nucleus	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751	0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018	0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left red nucleus Left red nucleus	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.751 0.813	0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.568	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066	0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.470	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left red nucleus Left substantia nigra Left substantia nigra	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717	0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.568 0.568 0.560	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067	0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.455 0.470 0.442	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804	0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.568 0.568 0.560 0.731	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873	0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.455 0.470 0.442 0.544	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.510	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.749 0.159
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.888	0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.605 0.568 0.568 0.560 0.731 0.789	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873 0.013	0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.455 0.470 0.442 0.544 0.544	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.510 0.607	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.985 <0.001 0.749 0.159 0.002
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left red nucleus Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right caudate	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.888 0.800	0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.568 0.568 0.560 0.731 0.789 0.708	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873 0.013 0.751	0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.455 0.455 0.470 0.442 0.544 0.544 0.691 0.615	×10 ⁻³) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.510 0.607 0.559	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.985 <0.001 0.749 0.159 0.159 0.002 0.925
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right caudate	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.888 0.800 0.655	0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.568 0.568 0.560 0.731 0.789 0.708 0.479	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873 0.013 0.751 0.477	$(\times 10^{-1})$ 0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.455 0.470 0.442 0.544 0.691 0.615 0.470	×10 3) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.510 0.607 0.559 0.336	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.985 <0.001 0.749 0.159 0.159 0.002 0.925 0.186
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right amygdala Right caudate	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.804 0.888 0.800 0.655 0.612	$\begin{array}{c} (.1.6 \) \\ 0.798 \\ 0.730 \\ 0.500 \\ 0.513 \\ 0.824 \\ 0.756 \\ 0.675 \\ 0.605 \\ 0.605 \\ 0.568 \\ 0.560 \\ 0.731 \\ 0.789 \\ 0.708 \\ 0.708 \\ 0.479 \\ 0.450 \end{array}$	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873 0.013 0.751 0.477 0.800	$(\times 10^{-1})$ 0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.455 0.470 0.442 0.544 0.691 0.615 0.470 0.470 0.470 0.470 0.615 0.470 0.460	$\times 10^{-5}$) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.510 0.607 0.559 0.336 0.340	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.985 <0.001 0.749 0.159 0.159 0.159 0.002 0.925 0.186 -0.065 $$
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right amygdala Right caudate Right globus pallidus externus Right globus pallidus internus	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.804 0.888 0.800 0.655 0.612 0.898	$(.110^{-1})$ 0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.605 0.568 0.560 0.731 0.789 0.708 0.708 0.479 0.450 0.821	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873 0.013 0.751 0.477 0.800 0.925	$(\times 10^{-1})$ 0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.455 0.470 0.442 0.544 0.691 0.615 0.470 0.470 0.470 0.460 0.701	$\times 10^{-5}$) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.510 0.607 0.559 0.336 0.340 0.654	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.985 <0.001 0.749 0.159 0.159 0.159 0.002 0.925 0.186 0.065 0.788
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left putamen Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left subthalamic nucleus Left thalamus Right amygdala Right amygdala Right caudate Right globus pallidus externus Right globus pallidus internus Right hippocampus	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.804 0.888 0.800 0.655 0.612 0.898 0.774	$\begin{array}{c} (.1.6 \) \\ 0.798 \\ 0.730 \\ 0.500 \\ 0.513 \\ 0.824 \\ 0.756 \\ 0.675 \\ 0.605 \\ 0.605 \\ 0.568 \\ 0.560 \\ 0.731 \\ 0.789 \\ 0.708 \\ 0.708 \\ 0.708 \\ 0.479 \\ 0.450 \\ 0.821 \\ 0.734 \end{array}$	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873 0.013 0.751 0.477 0.800 0.925 0.872	$(x + 10^{-1})$ 0.673 0.625 0.452 0.460 0.722 0.621 0.565 0.455 0.455 0.470 0.442 0.544 0.691 0.615 0.470 0.460 0.701 0.611	$\times 10^{-5}$) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.510 0.607 0.559 0.559 0.336 0.340 0.654 0.597	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.985 <0.001 0.749 0.159 0.159 0.159 0.002 0.925 0.186 0.065 0.788 -0.603
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left putamen Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right amygdala Right caudate Right globus pallidus externus Right globus pallidus internus Right hippocampus Right nucleus accumbens	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.804 0.888 0.800 0.655 0.612 0.898 0.774 0.762	$(.110^{-1})$ 0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.605 0.568 0.560 0.731 0.789 0.789 0.708 0.708 0.479 0.450 0.821 0.734 0.655	0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873 0.013 0.751 0.477 0.800 0.925 0.872 0.537	$(x + 10^{-1})$ 0.673 0.625 0.452 0.460 0.722 0.621 0.621 0.565 0.455 0.470 0.442 0.544 0.691 0.615 0.470 0.470 0.460 0.701 0.611 0.563	\times 10 ° 3) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.359 0.510 0.607 0.559 0.336 0.340 0.654 0.597 0.492	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.985 <0.001 0.749 0.159 0.159 0.159 0.002 0.925 0.186 0.065 0.788 0.603 0.743
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right amygdala Right caudate Right globus pallidus externus Right globus pallidus internus Right globus pallidus internus Right hippocampus Right nucleus accumbens Right putamen Right putamen	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.888 0.800 0.655 0.612 0.898 0.774 0.762 0.738	$\begin{array}{c} (.1.6 \) \\ 0.798 \\ 0.730 \\ 0.500 \\ 0.513 \\ 0.824 \\ 0.756 \\ 0.675 \\ 0.675 \\ 0.605 \\ 0.568 \\ 0.560 \\ 0.731 \\ 0.789 \\ 0.708 \\ 0.708 \\ 0.708 \\ 0.479 \\ 0.450 \\ 0.479 \\ 0.450 \\ 0.821 \\ 0.734 \\ 0.655 \\ 0.581 \end{array}$	$\begin{array}{c} 0.084\\ 0.400\\ 0.043\\ 0.636\\ 0.570\\ 0.375\\ 0.040\\ 0.018\\ 0.066\\ 0.067\\ 0.873\\ 0.067\\ 0.873\\ 0.013\\ 0.751\\ 0.477\\ 0.800\\ 0.925\\ 0.872\\ 0.872\\ 0.537\\ 0.004 \end{array}$	$(x + 10^{-1})$ 0.673 0.625 0.452 0.460 0.722 0.621 0.621 0.565 0.455 0.470 0.442 0.544 0.691 0.615 0.470 0.470 0.460 0.701 0.611 0.563 0.456	\times 10 ° 3) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.359 0.510 0.607 0.559 0.336 0.340 0.654 0.597 0.492 0.360	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.749 0.749 0.159 0.159 0.002 0.925 0.186 0.065 0.186 0.065 0.788 0.603 0.743 0.297
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right amygdala Right caudate Right globus pallidus externus Right globus pallidus internus Right globus pallidus internus Right hippocampus Right nucleus accumbens Right nucleus accumbens Right putamen Right red nucleus	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.888 0.800 0.655 0.612 0.898 0.774 0.762 0.738 0.850	$(.110^{-1})$ 0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.605 0.568 0.560 0.731 0.789 0.789 0.708 0.708 0.708 0.708 0.708 0.479 0.450 0.821 0.734 0.734 0.655 0.581 0.589	31 AD > 71 AD 0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.040 0.018 0.066 0.067 0.873 0.013 0.751 0.477 0.800 0.925 0.872 0.537 0.004 0.004	$(\times 10^{-1})$ 0.673 0.625 0.452 0.460 0.722 0.621 0.621 0.565 0.455 0.470 0.442 0.544 0.691 0.615 0.470 0.470 0.460 0.701 0.611 0.563 0.456 0.377	\times 10 ° 3) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.510 0.607 0.559 0.559 0.336 0.340 0.654 0.597 0.492 0.360 0.301	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.749 0.159 0.159 0.002 0.925 0.186 0.002 0.925 0.186 0.065 0.788 0.603 0.743 0.297 0.432
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left nucleus accumbens Left putamen Left red nucleus Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right amygdala Right caudate Right globus pallidus externus Right globus pallidus internus Right globus pallidus internus Right hippocampus Right nucleus accumbens Right nucleus accumbens Right nucleus accumbens Right nucleus accumbens Right nucleus accumbens Right substantia nigra Right substantia nigra		$(.110^{-1})$ 0.798 0.730 0.500 0.513 0.824 0.756 0.675 0.605 0.568 0.568 0.560 0.731 0.789 0.789 0.708 0.708 0.708 0.708 0.479 0.450 0.821 0.734 0.734 0.655 0.581 0.589 0.548	31 AD > 71 AD 0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.040 0.018 0.066 0.067 0.873 0.013 0.751 0.477 0.800 0.925 0.872 0.537 0.004 0.001	$(\times 10^{-1})$ 0.673 0.625 0.452 0.460 0.722 0.621 0.621 0.565 0.455 0.470 0.442 0.544 0.691 0.615 0.470 0.470 0.460 0.701 0.460 0.701 0.611 0.563 0.456 0.377 0.384	\times 10 °) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.510 0.607 0.559 0.559 0.336 0.340 0.340 0.654 0.597 0.492 0.360 0.301 0.334	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.749 0.159 0.002 0.925 0.159 0.002 0.925 0.186 0.065 0.788 0.603 0.743 0.297 0.432 0.037
Left amygdala Left caudate Left globus pallidus externus Left globus pallidus internus Left hippocampus Left nucleus accumbens Left putamen Left putamen Left substantia nigra Left substantia nigra Left subthalamic nucleus Left thalamus Right amygdala Right caudate Right globus pallidus externus Right globus pallidus internus Right globus pallidus internus Right hippocampus Right nucleus accumbens Right nucleus accumbens Right nucleus accumbens Right nucleus Right red nucleus Right substantia nigra Right substantia nigra Right substantia nigra	0.897 0.788 0.636 0.657 0.922 0.788 0.751 0.751 0.813 0.717 0.804 0.888 0.800 0.655 0.612 0.898 0.774 0.762 0.738 0.738 0.850 0.711 0.814	0.798 0.730 0.500 0.513 0.824 0.756 0.605 0.605 0.568 0.560 0.731 0.789 0.708 0.479 0.450 0.821 0.734 0.581 0.581 0.589 0.548	31 AD > 71 AD 0.084 0.400 0.043 0.636 0.570 0.375 0.040 0.018 0.066 0.067 0.873 0.013 0.751 0.477 0.800 0.925 0.872 0.537 0.004 0.001 <0.001 <0.001 <0.001 <0.001	(×10 ⁻¹) 0.673 0.625 0.452 0.460 0.722 0.621 0.621 0.565 0.455 0.455 0.470 0.442 0.544 0.691 0.615 0.470 0.460 0.701 0.460 0.701 0.460 0.701 0.563 0.456 0.377 0.384 0.547	×10 3) 0.605 0.566 0.386 0.393 0.656 0.611 0.516 0.383 0.329 0.359 0.359 0.359 0.510 0.607 0.559 0.336 0.340 0.340 0.654 0.597 0.492 0.360 0.301 0.334 0.334	31 RD > 71 RD 0.126 0.343 0.033 0.943 0.742 0.162 0.090 0.985 <0.001 0.749 0.159 0.002 0.925 0.186 0.065 0.186 0.065 0.788 0.603 0.743 0.603 0.743 0.297 0.432 0.037 0.861

Data Analysis performed on preprocessed 3T and 7T T1 and DTI images of four patients obtained from Human Connectome Project (HCP) [Van Essen et al., Neuroimage, 2013].

Parameter	Value	Parameter	Value
Sequence	Spin-echo EPI	Sequence	Spin-echo EPI
TR	5520 ms	TR	7000 ms
TE	89.5 ms	TE	71.2 ms
flip angle	78 deg	flip angle	90 deg
refocusing flip angle	160 deg	refocusing flip angle	180 deg
For the second s	240x420 (DO x DE)	FOV	210x210 (RO x PE)
FOV	210x180 (RO x PE)	matrix	200x200 (RO x PE)
matrix	168x144 (RO x PE)	slice thickness	1.05 mm, 132 slices, 1.05 mm isotropic voxels
slice thickness	1.25 mm, 111 slices, 1.25 mm isotropic voxels	Multiband factor	2
Multiband factor	3	Image Acceleration factor (iPAT)	3
Echo spacing	0.78 ms	Echo spacing	0.82 ms
BW	1488 Hz/Px	BW	1388 Hz/Px
Phase partial Fourier	6/8	Phase partial Fourier	6/8
b-values	1000, 2000, and 3000 s/mm2	b-values	1000, 2000 s/mm2

- **Lead-DBS** ANTs atlas based segmentation using MNI PD25 atlas [Avants et al., Medical image] analysis, 2008; Xiao et al., Data in brief, 2017].
- **DSI Studio and q-sampling** for generating diffusion measures of between each segmented structure [Yeh et al., Neuroimage, 2010].
- **Student-t test** used to determine significant difference with p <0.05; FDR correction with **Benjamini-Hochberg procedure**

Results (I): Subcortical structure segmentation





Table 1. Significant mean differences of 11 subcortical diffusion measures (FA, MD, RD, ••• and AD).

□ The left substantia nigra showed significant differences in FA, MD, and RD; the right amygdala showed significant differences in MD and RD; the right red nucleus showed significant differences in AD; and the right substantia nigra and the right subthalamic nucleus showed significant differences in MD and AD.



Figure 2. Basic processing Lead-connectome pipeline. Minimally preprocessed human connectome project images are co-registered to the structural T1w image using SPM.

- ✤ Figure 4. Connectivity matrices of significant, FDR-corrected mean differences of diffusion measures, FA, MD, QA, between 3T and 7T connectomes.
- □ We found that there were significant differences in the left SN, right amygdala, right SN, right RN, and right STN when comparing diffusion measures of 3T and 7T structures.
- □ In Figure 4, positive values represent higher value of 3T mean diffusion measure while negative values represent higher value of 7T mean diffusion measure.
- □ Connectivity between ROIs showed more significant increases in FA, MD, and QA in 3T diffusion images when compared with 7T diffusion images.
- **T** 7T were relatively new compared to 3T scanners, meaning that there was little time for the project to experiment with custom hardware or protocols to optimize 7T protocols.
- □ In the future, improvements to 7T hardware and acquisition protocols should lead to a more accurate representation of a connectome
- Acknowledgments. This research supported by Basic Science Research Capacity Enhancement Project ••• through Republic of Korea Basic Science Institute (National research Facilities and Equipment Center), grant funded by the Ministry of Education. (grant No. 2021R1A6C101A432)