

# fMRI Biomarker for Deep Brain Stimulation

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# Parkinson's Disease, a Movement Disorder

- Parkinson's disease is a chronic and progressive movement disorder, meaning that symptoms continue and worsen over time.
- Nearly one million people in the US are living with Parkinson's disease.
- The cause is unknown and there is presently no cure.
- But there are treatment options such as medication and surgery to manage its symptoms.

# Deep Brain Stimulation (DBS)

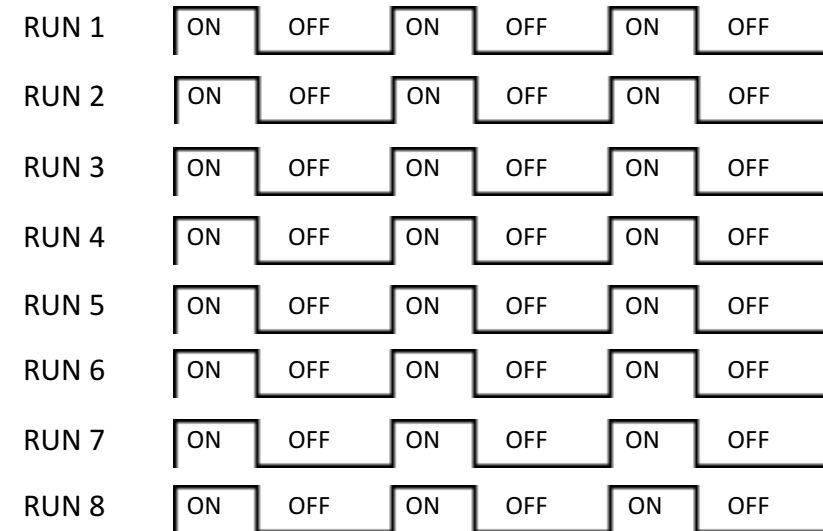
- DBS is a surgical procedure used to treat a variety of disabling neurological symptoms—most commonly the debilitating symptoms of Parkinson's disease, such as tremor.
- The therapeutic mechanisms of DBS are not well understood and objective biomarkers for guiding DBS lead targeting and stimulation programming are lacking.

# Research Question

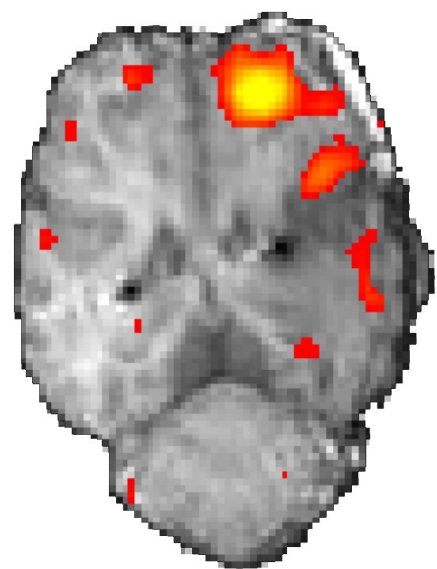
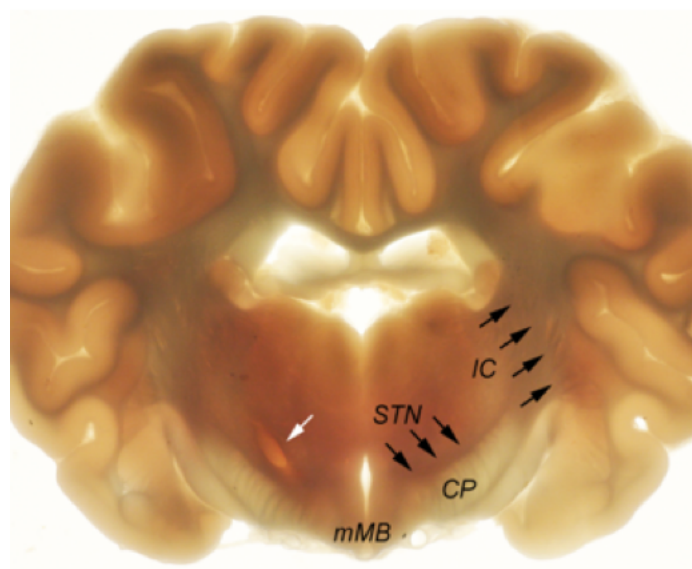
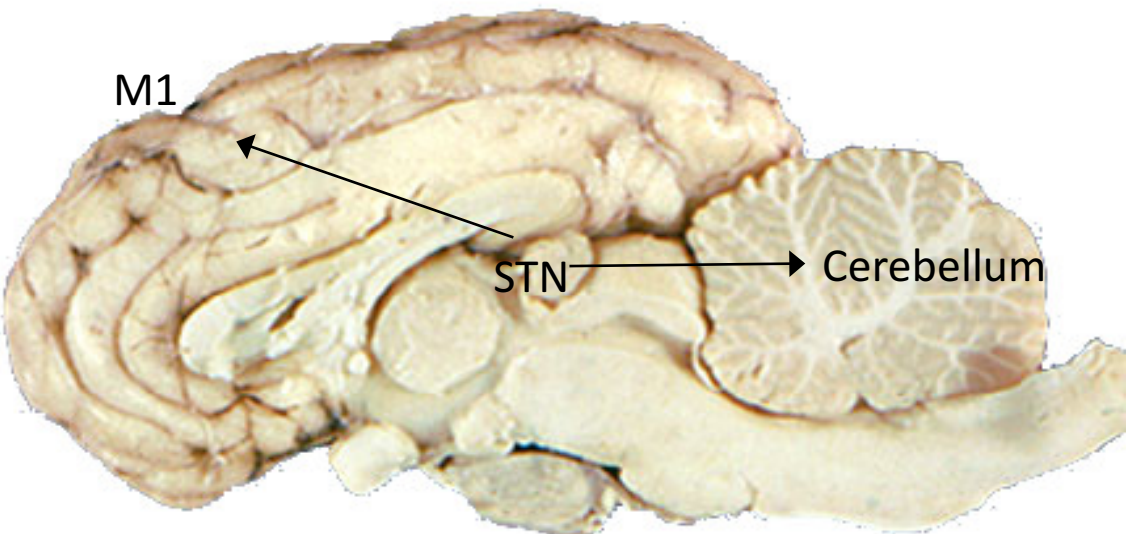
- Whether fMRI signals can be used to distinguish between DBS parameters relevant to brain physiology of the movement system.
- And if so, whether fMRI may be used as a brain biomarker at the time of DBS implantation of individual patients.

# Experimental Design

- 3 subjects.
- Electrode stimulation sites: deep, middle, superficial.
- Voltages (V): 1, 3, 5, 7.
- Brain areas:
  - Left motor cortex, right motor cortex,
  - Left cerebellum, right cerebellum.
- Combinations:
  - Subject 1, stimulation site deep, 3V, left motor.
- Block design: DBS on, off, on, off, on, off for each run.
- 8 runs per combination, 135 signals per run.

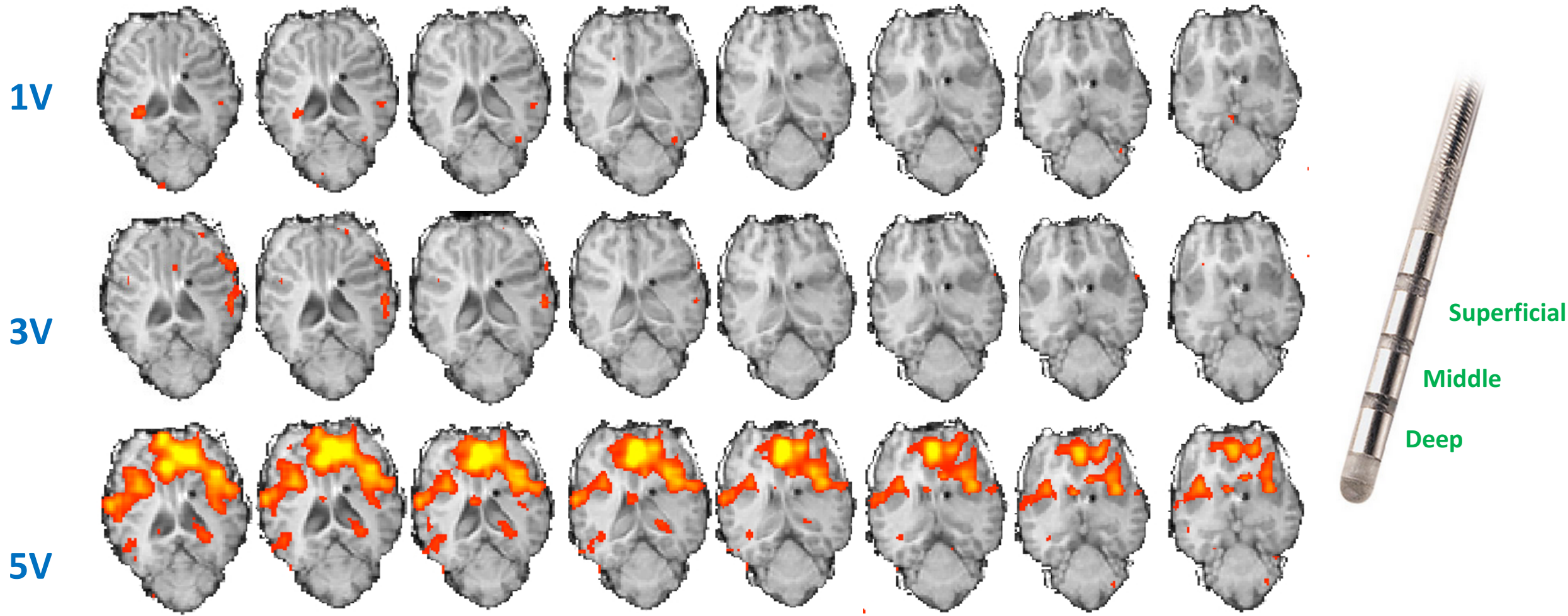


Electrode Stimulation Sites



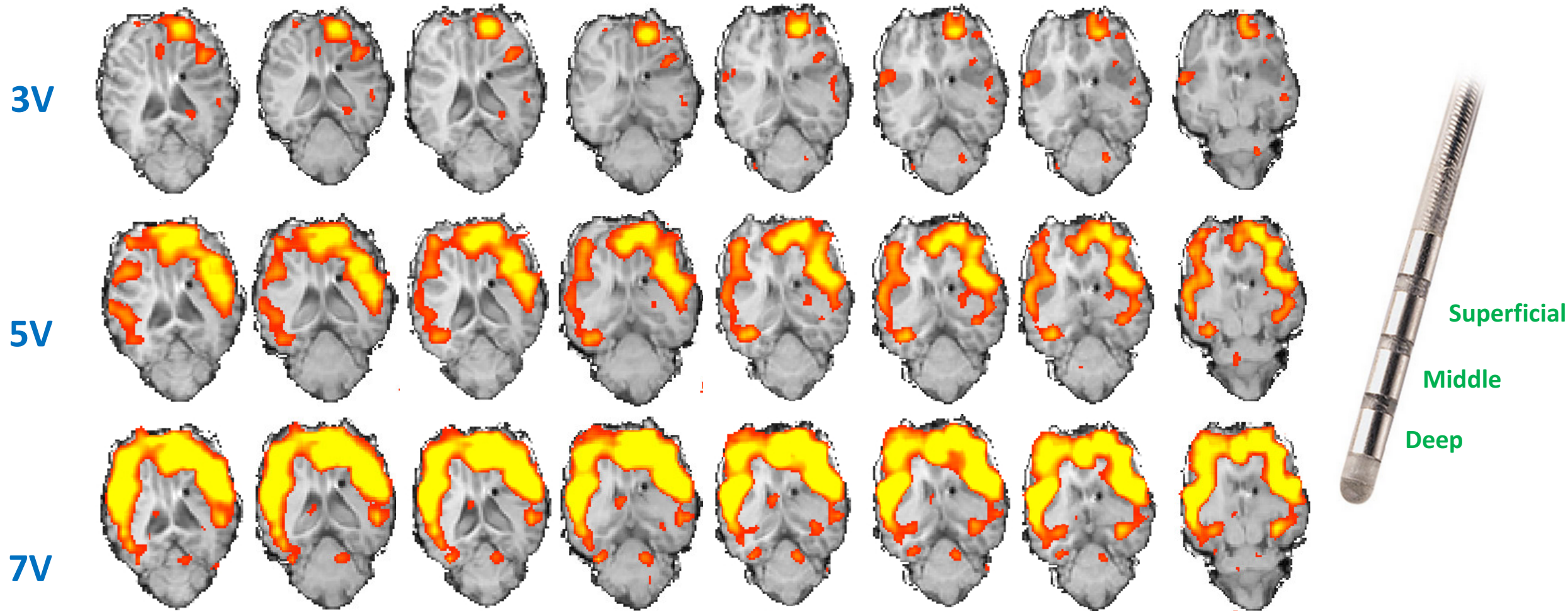
Subject 1, middle site, 3V

## 635 Deep Stimulation Site: Activation maps for voltage levels





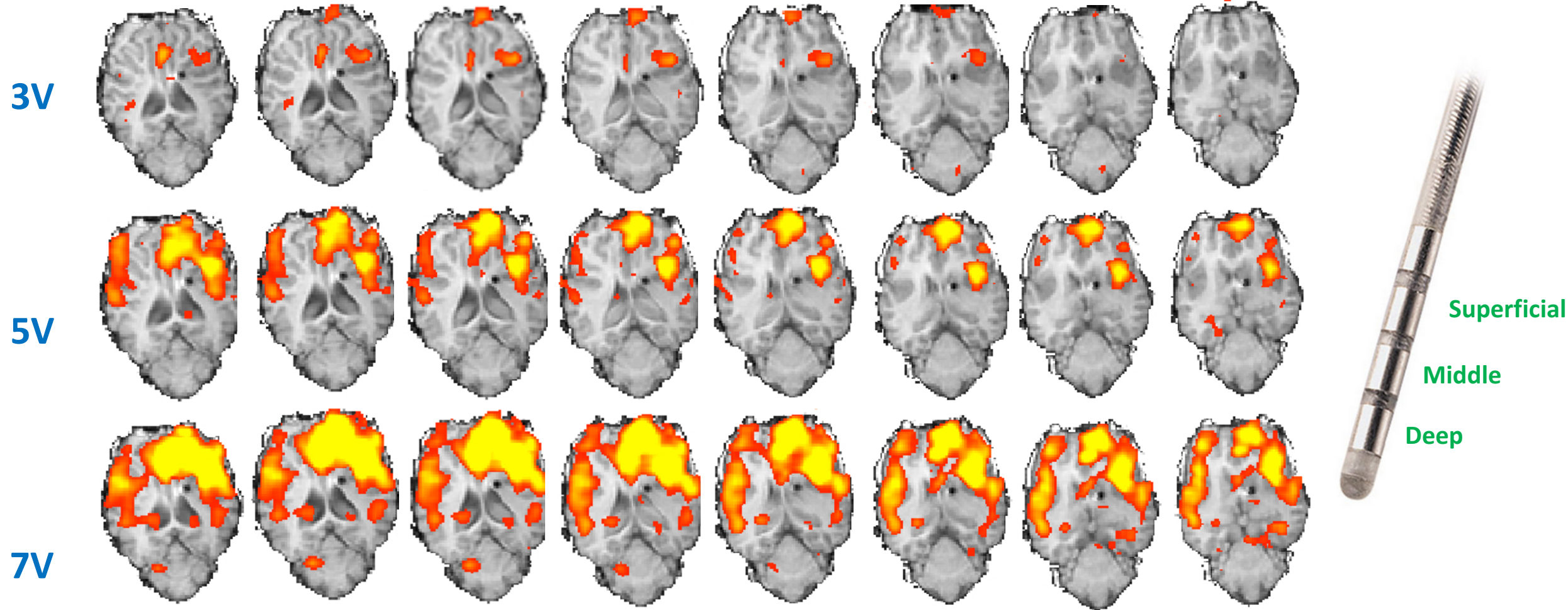
## 635 Middle Stimulation Site: Activation maps for voltage levels



*superior to inferior axial slices*



## 635 **Superficial** Stimulation Site: Activation maps for voltage levels



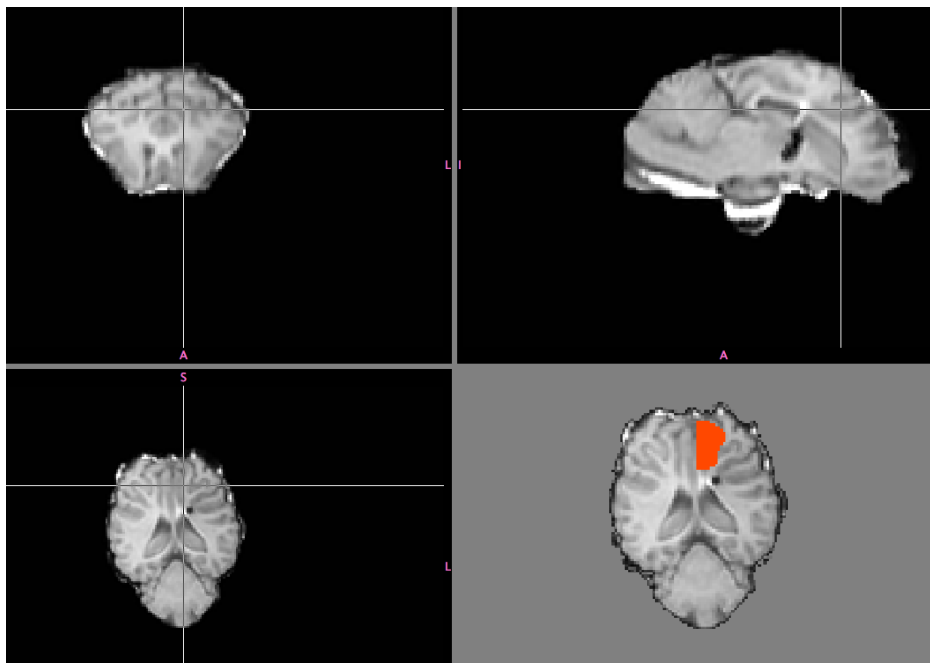
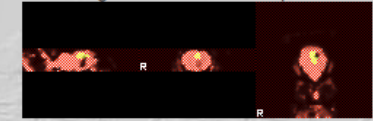


Image of mask in native space:



PE/COPE values converted into % (VARCOPE into %<sup>2</sup>).

Mean time series (masked/weighted). Masked time series plots.

stats image	# voxels	image statistics							positi					
		min	10%	mean	median	90%	max	stddev	vox (FMRI space)			mm (standard space)		
stats/pe1	122	-1.1	-0.09003	0.08279	0.07174	0.3045	0.6173	0.1965	40	43	9	13.6	-94.4	13.9
stats/pe2	122	-1.487	-0.6496	0.1332	0.1046	0.7868	3.834	0.7085	41	42	10	11.0	-98.2	11.5
stats/pe3	122	-4.78	-0.8875	-0.3257	-0.1426	0.4351	0.8615	0.8519	40	40	9	14.6	-96.9	5.3
stats/pe4	122	-4.35	-0.7326	-0.112	0.104	0.5111	1.042	0.8159	41	43	10	10.6	-97.4	14.4
stats/pe5	122	-3.573	-0.6729	0.008554	0.1079	0.7228	3.273	0.8209	41	43	10	10.6	-97.4	14.4
stats/pe6	122	-1.401	-0.4292	0.09303	0.03506	0.4889	4.179	0.6304	40	43	9	13.6	-94.4	13.9
stats/pe7	122	-1.826	-0.906	-0.2505	-0.2844	0.4029	3.267	0.6472	42	41	10	8.3	-99.1	8.3
stats/cope1	122	-1.592	-0.1433	0.1198	0.1038	0.4407	0.8933	0.2844	40	43	9	13.6	-94.4	13.9
stats/varcope1	122	0.01275	0.017	0.04758	0.02459	0.04939	0.8901	0.09858	41	42	10	11.0	-98.2	11.5
stats/tstat1	122	-2.222	-0.8384	0.6894	0.6213	2.222	3.877	1.289	39	43	12	16.5	-103.0	16.7
stats/zstat1	122	-2.197	-0.8356	0.68	0.6196	2.197	3.762	1.271	39	43	12	16.5	-103.0	16.7

														Visible: 14
roi	contact	voltage	dbi_onOff	block	run1	run2	run3	run4	run5	run6	run7	run8		
1.00	1.00	1.00	1.00	1.00	19248.46	19911.70	20758.04	20615.81	22833.51	22875.68	20399.84	22043.66		
1.00	1.00	1.00	1.00	1.00	19419.69	19992.02	20690.92	20495.07	22845.86	22775.90	20430.17	21896.22		
1.00	1.00	1.00	1.00	1.00	19245.24	19944.49	20690.78	20596.65	22869.15	22692.50	20369.37	21802.72		
1.00	1.00	1.00	1.00	1.00	19403.75	19871.95	20768.26	20516.90	22807.54	22767.94	20320.21	21564.71		
1.00	1.00	1.00	1.00	1.00	19299.47	20064.37	20784.67	20533.17	22840.56	22780.74	20369.19	21974.82		
1.00	1.00	1.00	1.00	1.00	19407.31	19941.08	20644.64	20587.55	22754.92	22794.75	20250.13	21950.00		
1.00	1.00	1.00	1.00	1.00	19397.34	19977.29	20792.74	20526.22	22730.83	22708.02	20400.43	22238.42		
1.00	1.00	1.00	1.00	1.00	19277.09	19964.01	20764.68	20500.09	22832.36	22790.54	20364.32	22078.29		
1.00	1.00	1.00	1.00	1.00	19447.65	19998.81	20769.21	20504.18	22669.75	22741.15	20287.94	21726.05		
1.00	1.00	1.00	1.00	1.00	19300.96	19938.87	20721.44	20539.93	22752.33	22662.91	20500.06	22060.77		
1.00	1.00	1.00	1.00	1.00	19418.87	20009.56	20775.90	20507.25	22832.12	22604.87	20409.14	21966.79		
1.00	1.00	1.00	1.00	1.00	19348.72	19925.06	20767.88	20625.30	22724.95	22733.55	20534.38	22112.05		
1.00	1.00	1.00	1.00	1.00	19397.29	19929.55	20741.80	20528.29	22675.88	22808.62	20483.05	21898.12		
1.00	1.00	1.00	1.00	1.00	19254.15	19980.77	20768.43	20446.34	22894.52	22753.69	20333.08	21728.95		
1.00	1.00	1.00	1.00	1.00	19319.87	20149.43	20719.62	20487.54	22755.04	22698.48	20410.35	21862.82		
1.00	1.00	1.00	1.00	1.00	19259.47	19941.53	20798.68	20532.24	22759.91	22646.29	20286.41	22042.01		
1.00	1.00	1.00	1.00	1.00	19304.60	19984.93	20859.34	20466.20	22693.33	22762.25	20509.66	22179.97		
1.00	1.00	1.00	1.00	1.00	19361.46	20011.44	20769.81	20635.99	22708.02	22777.39	20332.59	21824.27		
1.00	1.00	1.00	1.00	1.00	19226.43	19900.27	20705.30	20490.61	22776.53	22791.04	20331.65	21749.71		
1.00	1.00	1.00	1.00	1.00	19419.38	19889.25	20834.62	20594.59	22809.43	22673.51	20565.05	21811.15		
1.00	1.00	1.00	1.00	1.00	19217.92	19985.76	20777.67	20521.81	22742.88	22928.13	20429.19	22131.27		
1.00	1.00	1.00	1.00	1.00	19261.00	19940.56	20770.09	20527.49	22866.65	22666.91	20517.66	21930.01		
1.00	1.00	1.00	1.00	1.00	19332.70	19948.71	20755.99	20541.34	22912.54	22774.42	20494.10	22084.44		
1.00	1.00	1.00	1.00	2.00	19324.98	20094.58	20854.88	20608.02	22687.11	22744.88	20306.26	21859.02		
1.00	1.00	1.00	1.00	2.00	19355.84	19859.92	20789.04	20610.05	22829.11	22785.63	20523.03	21959.62		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	ind	ind2	ind3	ind4	col	p.compl	n.unq	class	mn	med	mx	x y	pred	check.ass
2	1	1	1	1	subj	100	3	factor	76	635	985	c	N	N
3	1	2	2	2	area	100	4	factor	1	2.5	4	c	Y	N
4	1	3	3	3	dbiOnOff	100	2	factor	1	1	2	z	Y	N
5	1	4	4	4	block	100	6	factor	1	3	6	z	N	N
6	1	5	5	5	contact	100	3	factor	1	2	3	z	Y	N
7	1	6	6	6	voltage	100	3	factor	3	4	7	z	Y	N
8	1	7	7	7	freq	100	4	factor	5	75	180	z	Y	N
9	1	8	8	8	run1	100	8640	numeric	1691	12494.4	38914.1	y	N	Y
10	1	9	9	9	run2	100	8640	numeric	1284.1	12231.1	39016.2	y	N	Y
11	1	10	10	10	run3	100	8640	numeric	4912.4	11964.7	38752.7	y	N	Y
12	1	11	11	11	run4	87.5	7561	numeric	4723.8	11182.2	37412.6	y	N	Y
13	1	12	12	12	run5	81.2	7021	numeric	1923.9	10966.1	38367.7	y	N	Y
14	1	13	13	13	run6	73.4	6346	numeric	2259.2	10837.8	37587.7	y	N	Y
15	1	14	14	14	run7	32.8	2836	numeric	1225.6	6775.7	11846.8	y	N	Y
16	1	15	15	15	run8	25	2161	numeric	1258.7	6420.4	11005.5	y	N	Y
17	2	16	1	16	subj	100	3	factor	76	635	985	c	N	N
18	2	17	2	17	area	100	6	factor	1	3	9	c	Y	N
19	2	18	3	18	contact	100	3	factor	1	2	3	z	Y	N
20	2	19	4	19	volt	100	4	factor	1	5	7	z	Y	N
21	2	--	5	20	freq	100	1	factor	--	--	--	z	Y	N
22	2	20	6	21	dbiOnOff	100	2	factor	1	1	2	z	Y	N
23	2	21	7	22	block	100	6	factor	1	3	6	z	N	N
24	2	22	8	23	run1	100	13769	numeric	1672.4	22774.5	36760.5	y	N	Y
25	2	23	9	24	run2	100	13769	numeric	7841.8	22663.4	36084.2	y	N	Y
26	2	24	10	25	run3	100	13770	numeric	9804.8	22107.7	36363	y	N	Y
27	2	25	11	26	run4	96.1	13231	numeric	9860.7	21937.7	35730.5	y	N	Y
28	2	26	12	27	run5	96.1	13231	numeric	8869.7	22862.8	35923.1	y	N	Y
29	2	27	13	28	run6	92.2	12690	numeric	9192.7	23526.5	36513	y	N	Y
30	2	28	14	29	run7	88.2	12150	numeric	10684.5	23543.7	35981.8	y	N	Y
31	2	29	15	30	run8	86.3	11880	numeric	9424.6	23883.7	36129.3	y	N	Y