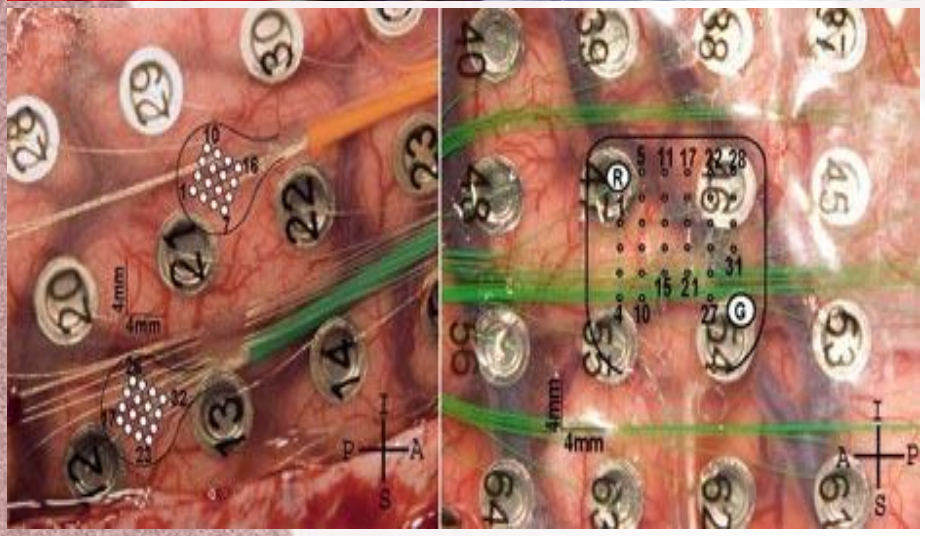
Neural Cortex Circuit Simulation

- University of Washington
- Department of Neurosurgery
- Ojemann Laboratory
- Jean-Paul Wiegand

Laboratory Goal

- To utilize high gamma brainwaves in order to improve upon current brain-computer interfaces (BCI's)
- Electroencephalography (EEG)
- Investigating mirror motor neuron response to hand movements vs. tree movements
- High gamma may be accurately task-specific; beta wave suppression
- Electrocorticography (ECoG)
- Investigating multimodal BCI control
- Comparing BCI and motor movement learning curves

Measuring the Brain



- EEG
- Passive vs. active
- 10'20
- 24-channels
- Measures EPSP's of pyramidal cells
- ECoG
- 8x8 Adtech arrays
- 2.3mm electrode, 1cm spacing
- Primarily over motor cortex
- Also measures EPSP's pyramidal cells

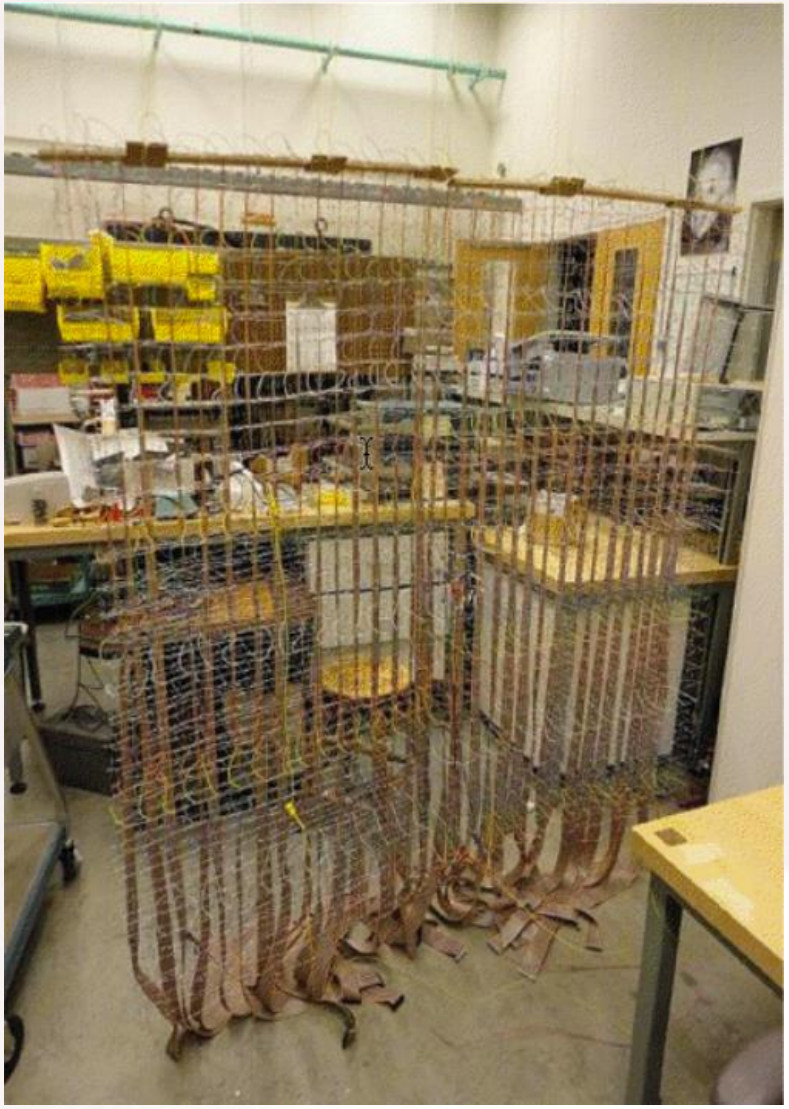
Problem

- EEG readings are obscured
- An electrode on the scalp obtains signals from roughly 6 square cm, and these are obscured by CSF, the skull and skin. Necessary brain mapping onto a model may be extremely inaccurate.
- ECoG electrode acts as capacitor
- When a metal electrode is placed in water that contains ions, and a voltage applied, ions in the water move to counter the electric field. The result is a “double layer” between the metal electrode with one sign of charge on it and the layer of counter ions a short distance away from it. Charge layers (or plates) separated by a distance act like a capacitor. Since C=1/d, and d is small, this capacitance is large.

Questions

- "What do ECoG electrodes do?"
- "What voltage do they measure?"
- "How does the voltage they measure compare with the cortex voltages without electrodes?"
- "How do they change the current flow?"

Cortex Circuit Simulation



- Analog computer
- 4x32x32, 1000ohm resistors
- Simulates 3cm of cortex, pyramidal neuron action, and a electrode [array]
- Voltage in: 1volt (for convenience), AC current
- Use 3x3 wired alligator clips for electrodes
- Lock-in amplifier (little interference)

Other methods

- Electrode arrays on salty jello model cortex and CSF
- Electrode arrays in electrolytic tank
- Pre-written computer software

Data

							0.5002	0.5002	0.5002	0.5002									
				0.5002	0.5002	0.5003	0.5003	0.5003	0.5003	0.5003	0.5002								
				0.5002	0.5003	0.5003	0.5003	0.5003	0.5003	0.5003	0.5002	0.5002	0.5002						
				0.5002	0.5003	0.5003	0.5004	0.5004	0.5004	0.5004	0.5003	0.5003	0.5002	0.5002	0.5002				
			0.5002	0.5003	0.5004	0.5004	0.5005	0.5006	0.5007	0.5007	0.5005	0.5005	0.5004	0.5003	0.5002	0.5001			
	0.5002	0.5002	0.5003	0.5004	0.5004	0.5006	0.5007	0.5010	0.5012	0.5013	0.5011	0.5009	0.5007	0.5005	0.5004	0.5002	0.5001		
	0.5002	0.5003	0.5003	0.5004	0.5006	0.5009	0.5013	0.5019	0.5024	0.5027	0.5023	0.5018	0.5008	0.5008	0.5005	0.5004	0.5002		
	0.5002	0.5003	0.5004	0.5005	0.5009	0.5014	0.5024	0.5037	0.5051	0.5059	0.5050	0.5036	0.5014	0.5013	0.5008	0.5005	0.5002		
0.5002	0.5002	0.5003	0.5004	0.5007	0.5013	0.5024	0.5043	0.5073	0.5112	0.5137	0.5111	0.5073	0.5024	0.5023	0.5012	0.5007	0.5003	0.5002	0.5002
0.5002	0.5002	0.5004	0.5005	0.5010	0.5019	0.5037	0.5074	0.5141	0.5243	0.5328	0.5242	0.5140	0.5042	0.5036	0.5018	0.5009	0.5004	0.5002	0.5002
0.5002	0.5003	0.5004	0.5007	0.5012	0.5024	0.5052	0.5113	0.5244	0.5488	0.5781	0.5487	0.5242	0.5064	0.5051	0.5023	0.5008	0.5005	0.5003	0.5002
0.5002	0.5003	0.5004	0.5007	0.5013	0.5027	0.5062	0.5140	0.5331	0.5785	**0.6628**	0.5781	0.5328	0.5079	0.5058	0.5026	0.5012	0.5006	0.5003	0.5002
	0.5002	0.5004	0.5006	0.5012	0.5026	0.5061	0.5117	0.5249	0.5498	0.5787	0.5490	0.5142	0.5065	0.5051	0.5023	0.5011	0.5006	0.5003	0.5002
	0.5002	0.5003	0.5005	0.5010	0.5020	0.5040	0.5079	0.5151	0.5265	0.5339	0.5146	0.5082	0.5042	0.5037	0.5018	0.5009	0.5005	0.5003	0.5002
	0.5002	0.5002	0.5004	0.5007	0.5012	0.5025	0.5046	0.5080	0.5123	0.5144	0.5115	0.5074	0.5043	0.5023	0.5012	0.5007	0.5005	0.5003	0.5002
			0.5003	0.5005	0.5009	0.5015	0.5025	0.5040	0.5055	0.5062	0.5052	0.5037	0.5024	0.5014	0.5008	0.5005	0.5004	0.5002	0.5002
			0.5002	0.5004	0.5005	0.5009	0.5013	0.5020	0.5026	0.5028	0.5024	0.5018	0.5013	0.5008	0.5005	0.5004	0.5003	0.5002	0.5002
			0.5002	0.5003	0.5004	0.5005	0.5007	0.5010	0.5012	0.5013	0.5012	0.5010	0.5007	0.5005	0.5004	0.5003	0.5002	0.5002	
			0.5002	0.5002	0.5003	0.5004	0.5004	0.5005	0.5006	0.5007	0.5006	0.5005	0.5004	0.5003	0.5002	0.5002			
					0.5002	0.5002	0.5003	0.5004	0.5004	0.5004	0.5004	0.5003	0.5002	0.5002					
							0.5002	0.5002	0.5002	0.5003	0.5002	0.5002	0.5002						
										0.5002									

Data

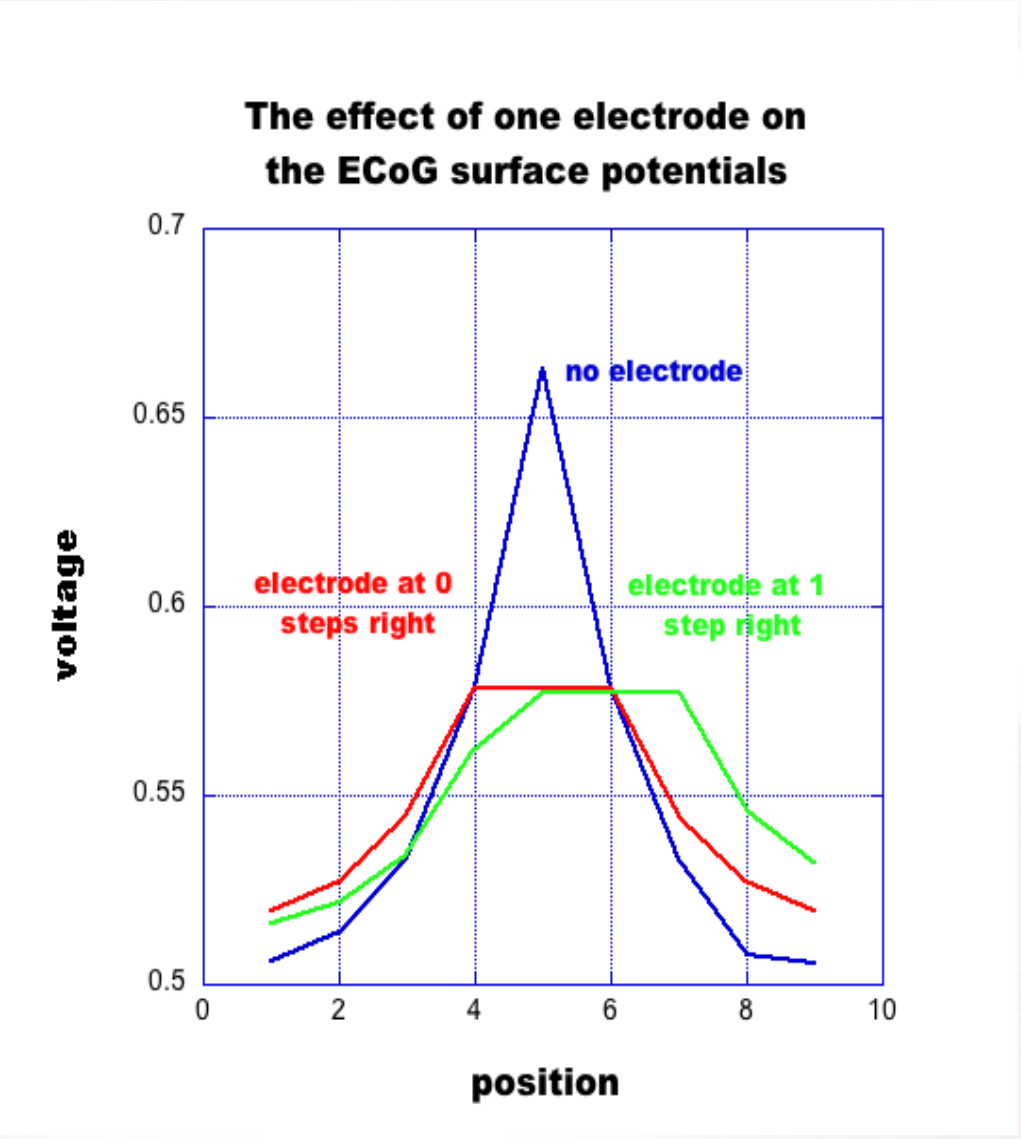
0 Steps Right

	A	B	C	D	E	F	G	H	I
1	0.5149	0.5159	0.5173	0.5188	0.5194	0.5188	0.5173	0.5159	0.5149
2	0.5159	0.5181	0.5214	0.5256	0.5272	0.5256	0.5214	0.5181	0.5159
3	0.5173	0.5215	0.5293	0.5412	0.5447	0.5412	0.5293	0.5215	0.5173
4	0.5188	0.5256	0.5413	*0.5784*	*0.5784*	*0.5784*	0.5412	0.5256	0.5188
5	0.5196	0.5273	0.5449	*0.5784*	**0.5784**	*0.5784*	0.5447	0.5272	0.5194
6	0.5198	0.5259	0.5416	*0.5784*	*0.5784*	*0.5784*	0.5413	0.5256	0.5188
7	0.5176	0.5219	0.5302	0.5432	0.5456	0.5415	0.5294	0.5215	0.5173
8	0.5160	0.5183	0.5220	0.5265	0.5277	0.5258	0.5215	0.5181	0.5159
9	0.5149	0.5160	0.5176	0.5192	0.5197	0.5189	0.5174	0.5159	0.5149
10									

1 Step Right

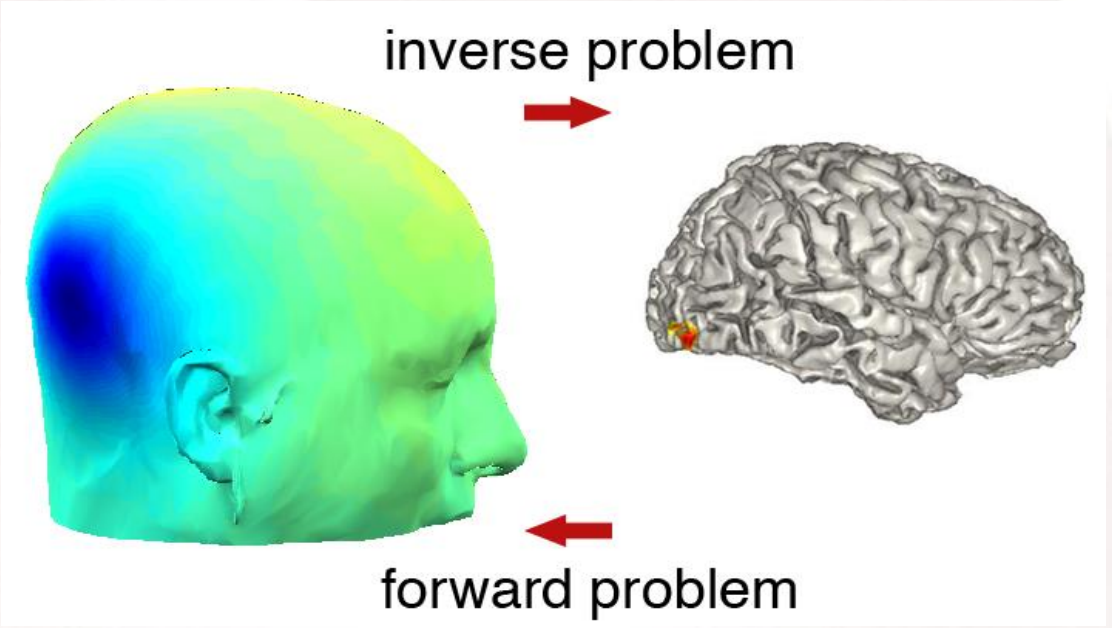
	A	B	C	D	E	F	G	H	I
1	0.5143	0.5152	0.5168	0.5189	0.5211	0.5223	0.5226	0.5221	0.5213
2	0.5145	0.5161	0.5190	0.5234	0.5279	0.5295	0.5290	0.5262	0.5237
3	0.5150	0.5177	0.5234	0.5329	0.5439	0.5453	0.5430	0.5334	0.5272
4	0.5156	0.5200	0.5299	0.5494	*0.5775*	*0.5775*	*0.5775*	0.5439	0.5309
5	0.5162	0.5215	0.5347	0.5621	**0.5775**	*0.5775*	*0.5775*	0.5462	0.5321
6	0.5165	0.5203	0.5304	0.5502	*0.5775*	*0.5775*	*0.5775*	0.5439	0.5309
7	0.5153	0.5182	0.5244	0.5350	0.5448	0.5455	0.5431	0.5334	0.5271
8	0.5146	0.5164	0.5196	0.5244	0.5284	0.5297	0.5291	0.5262	0.5237
9	0.5144	0.5154	0.5171	0.5193	0.5214	0.5225	0.5227	0.5221	0.5213
10									

Data Analysis



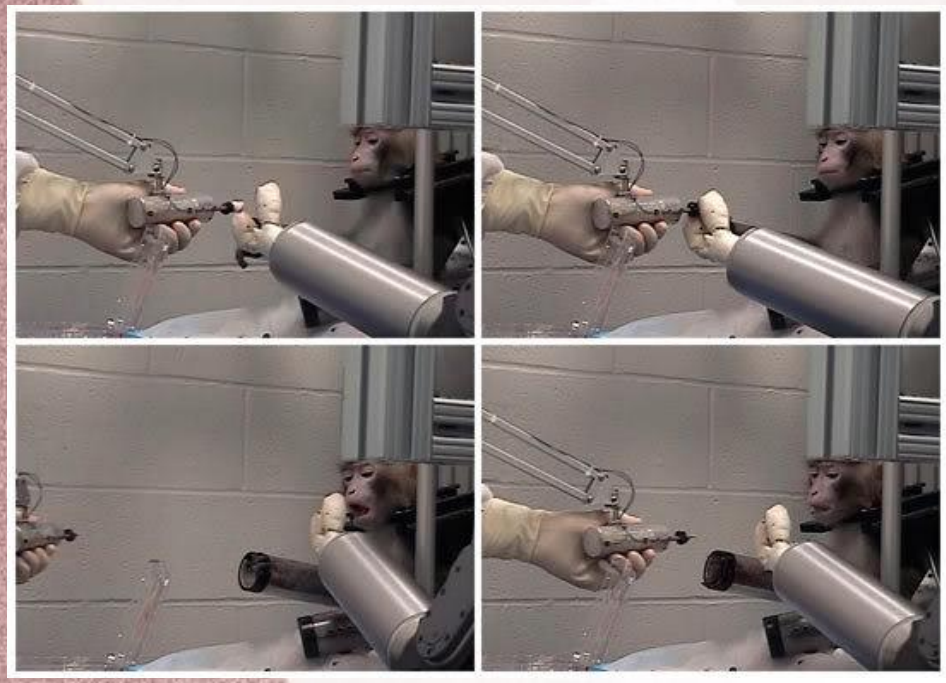
Conclusions

- From the data collected:
- We have determined how an electrode placed on the surface of the cortex changes the distribution of voltages on the surface and how the voltage measured using the electrode is related to the voltages that would be present without the electrode present.
- Accurate brain signal mapping is necessary for function localization, and will become more necessary for a realistic BCI



Future questions

- Effects of long-term electrodes?
- Changes in brain function?
- Electrode stimulation?
- Effects of long-term BCI use?



References

- Chauveau N, Morucci J.P., Franceries X, Celsis P, Rigaud B. Resistor mesh model of a spherical head: Part 1: Applications to scalp potential interpolation. Med. Biol. Eng. Comput., 2005, 43, 694-702
- Chauveau N, Morucci J.P., Franceries X, Celsis P, Rigaud B. Resistor mesh model of a spherical head: Part 2: A review of applications to cortical mapping. Med. Biol. Eng. Comput., 2005, 43, 703-711.
- Darvas F, Pantazis D, Kucukaltun-Yildirim E, Leahy RM. Mapping human brain function with MEG and EEG: methods and validation. NeuroImage 23 (2004) S289 – S299
- Franceries X, Doyon B, Chauveau N, Rigaud B, Celsis P, Morucci JP. Solution of Poisson's equation in a volume conductor using resistance mesh models: Application to event related potential imaging. J. Applied Phys., 2002, 93, 3578-3588
- Zhi-zun Z, Pockett S, Brennan BJ, Chun-huan X, Bold GE. Physical characteristics of simulated human brain. J. Chinese Clinical Medicine, 2007, 2, 231-235

Thanks

- Jeff G. Ojemann, M.D.
- Larry Sorensen, Ph.D.
- Felix Darvas, Ph.D.
- Tim Blakely, B.S.
- Stavros Zanos, M.D.
- Kai Miller, Ph.D.