Dry and Mobile EEG Systems for Real-world Neuroimaging

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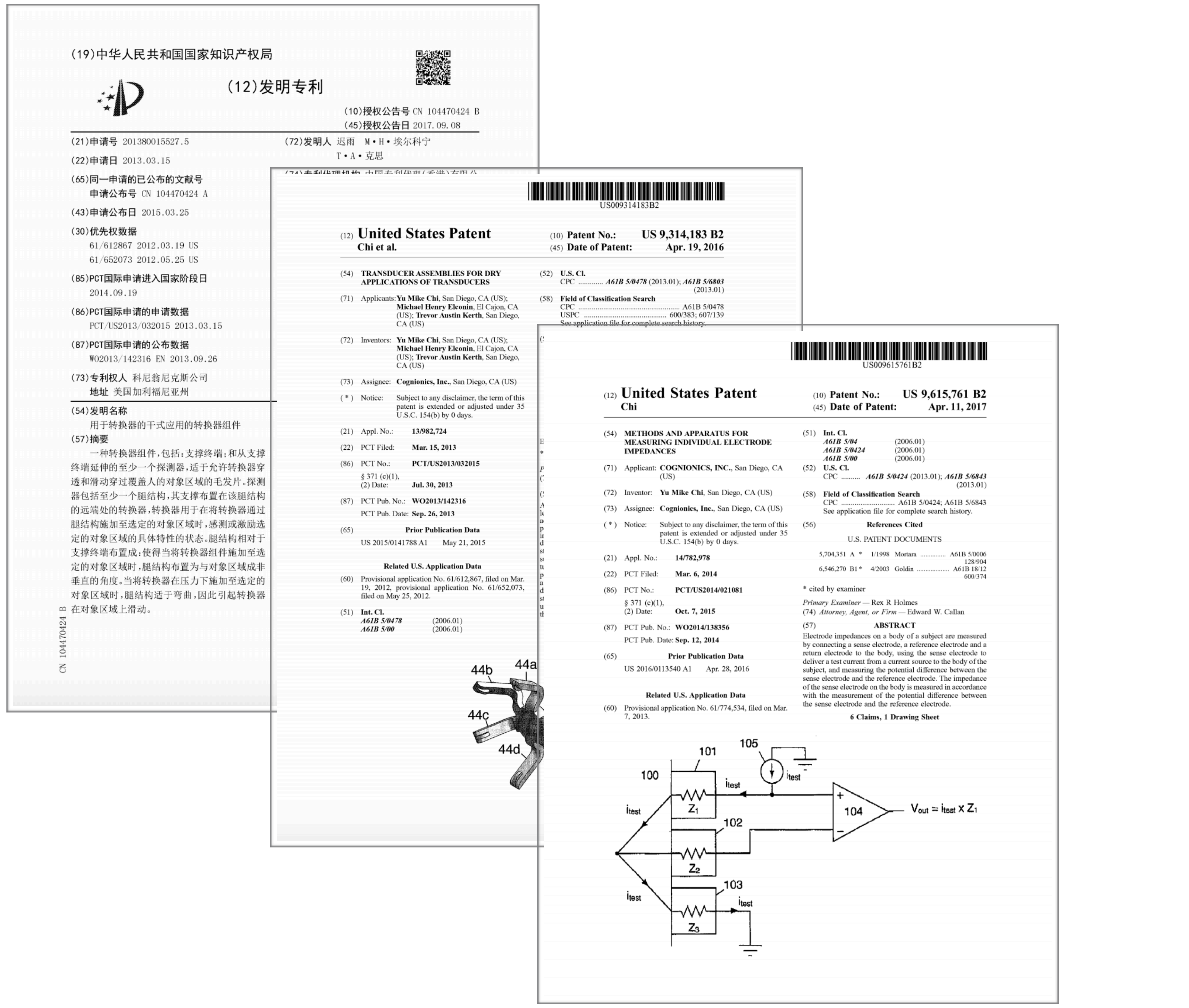
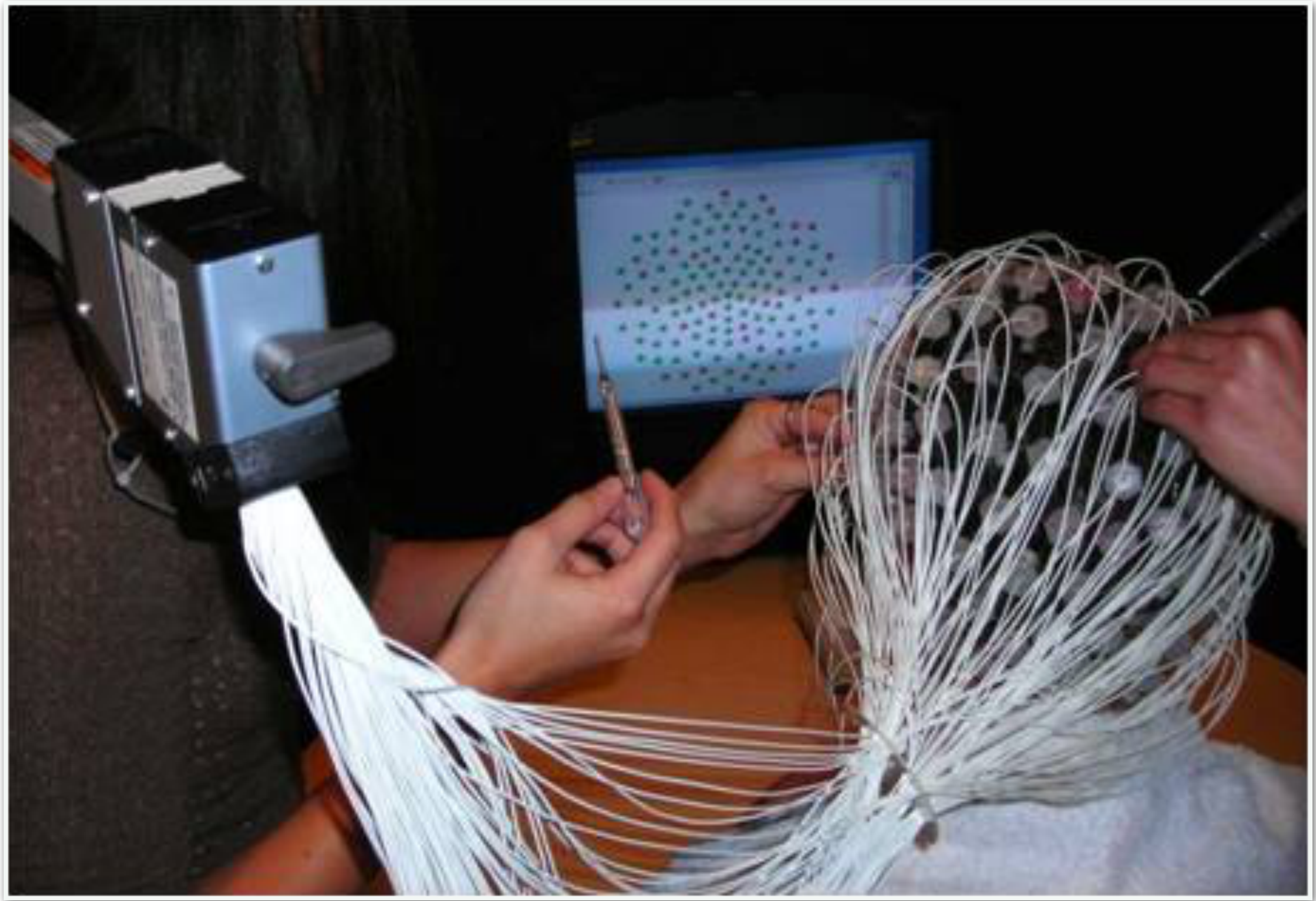
Company History

- UCSD spin-off, founded in 2011
- Funded by DARPA, NASA, NSF, Air Force, Navy, Army and the NIH
- 9000 sq. ft. R&D office in San Diego
- Main product line of high-end research EEG systems range from 2 to 128 channels
- 60% of business serving high-end academic and commercial neuroscience research
- 30% of business serving “pre-clinical” practitioners
- 10% licensing technology and OEM manufacturing
- Multiple issued patents covering sensors, mechanics and electronics related to mobile EEG



Enabling Real-world EEG



Team Neurodynamics
@ JUMP

DARPA Phase II SBIR
BrainFlight with JHU APL

Accessories

Dev-Kit

8/20/32 Channel

Quick-20

Self-donning Dry Headset
20/8 Channel

Quick-30

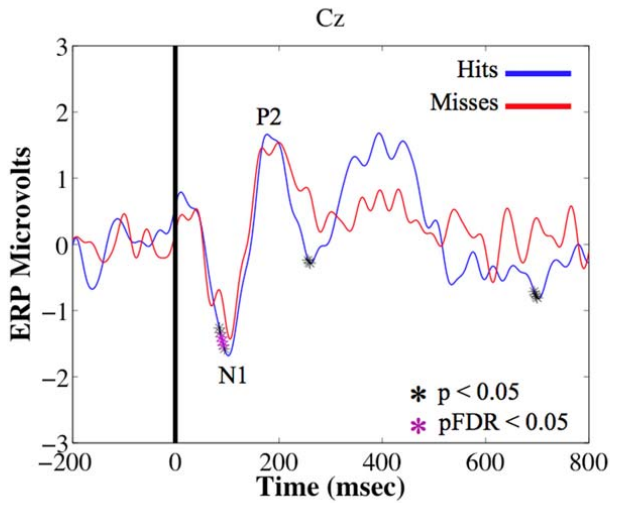
Self-donning Dry Headset
30 Channel

Mobile-128

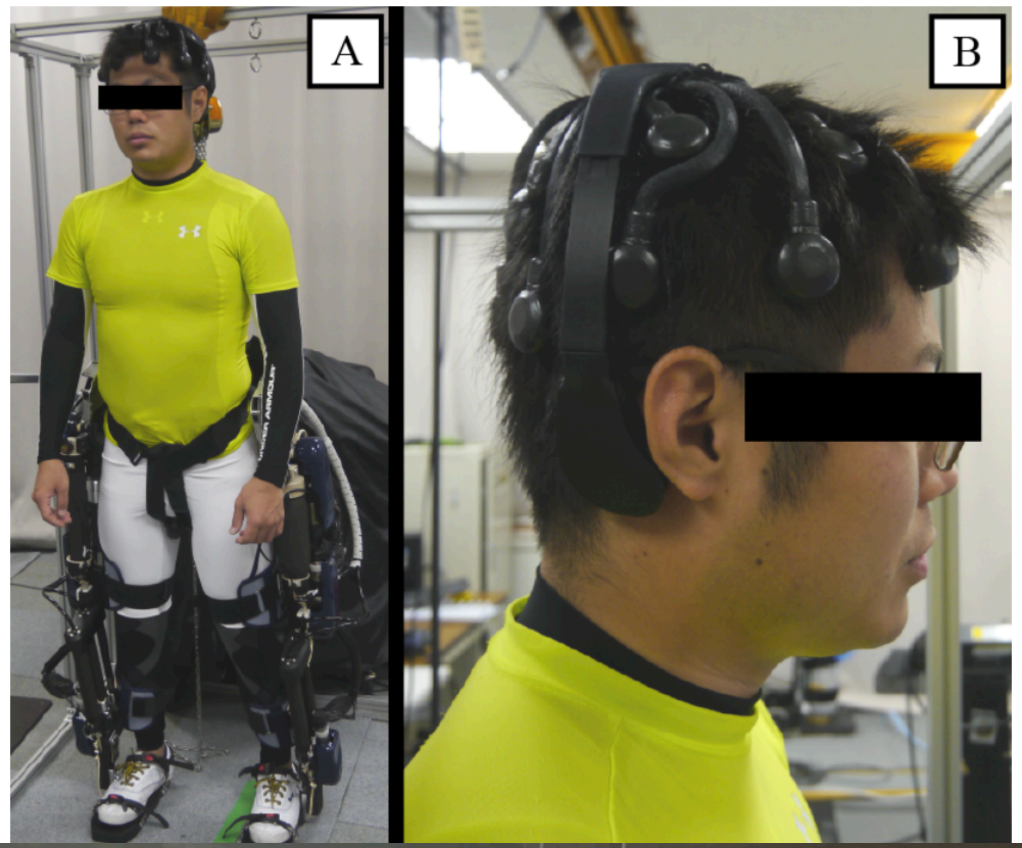
Wearable Active Wet
64/128-Channel

Dry Electrode Applications

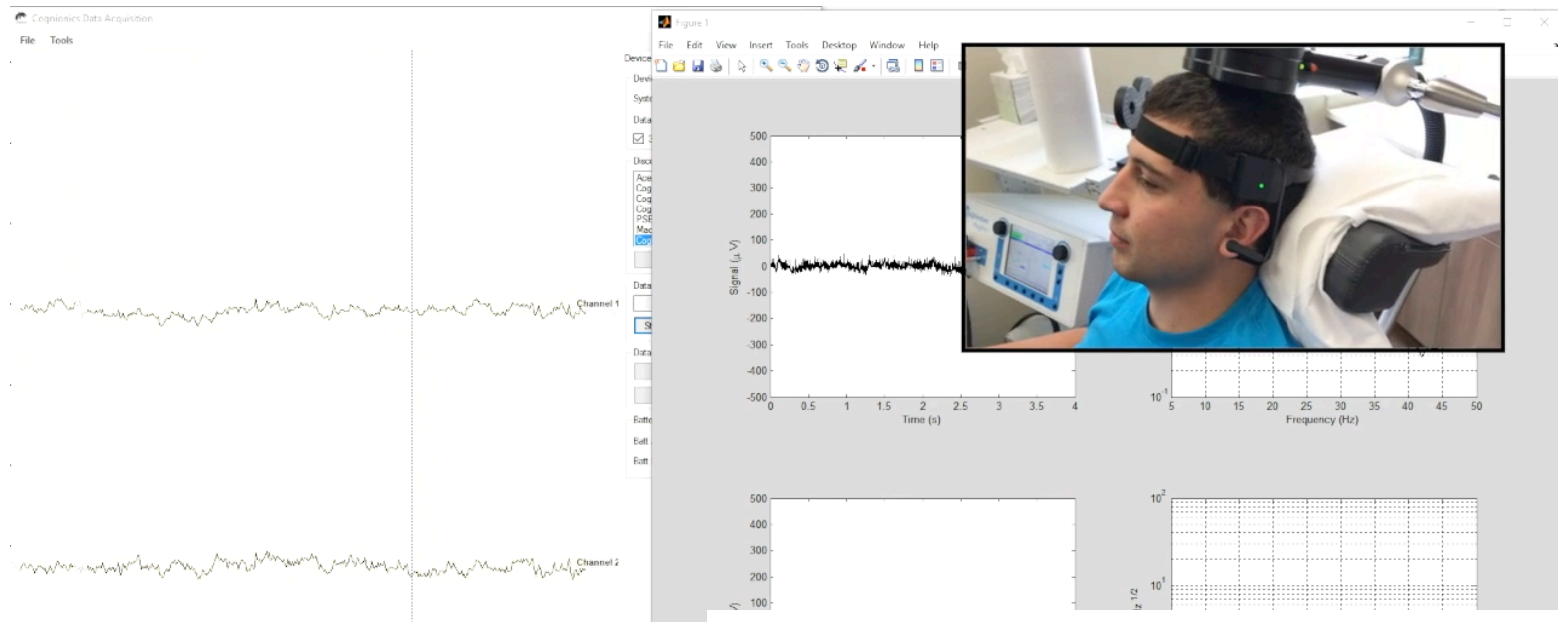
Real-world Neuroimaging



BCI



Clinical



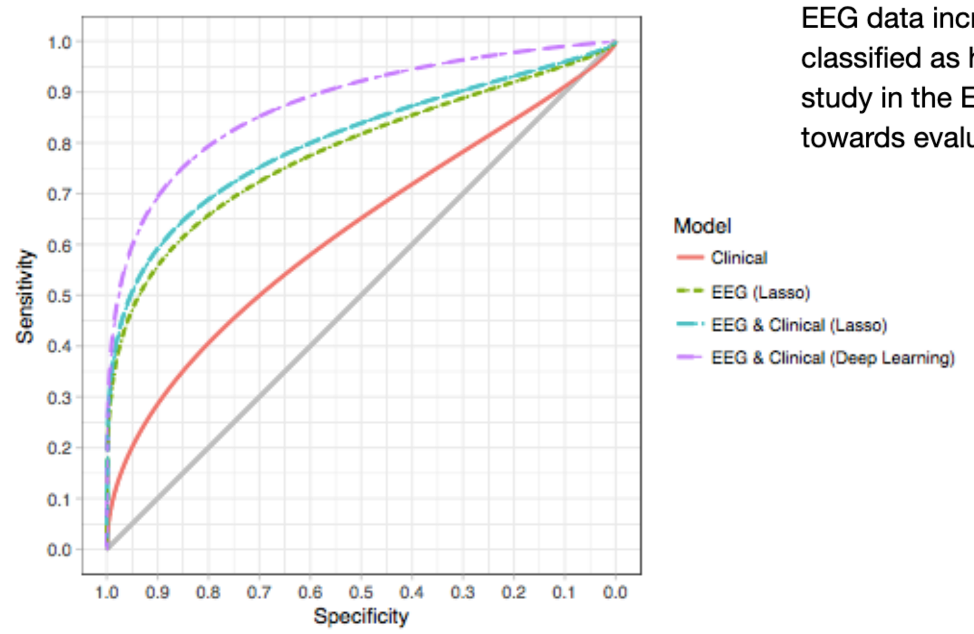
Abstract TP314: EEG Has High Precision for Diagnosing Stroke Hours After Onset

Fareshte Erani, Nadezhda Zolotova, Benjamin Vanderschelden, Jennifer C Wu, Anirudh Wodeyar, Hagop Sarian, Bharath Chakravarthy, Wirachin Hoonpongsimanont, Wengui Yu, ... Show all Authors

Originally published 30 Jan 2019 | https://doi.org/10.1161/str.50.suppl_1.TP314 | Stroke. ;50:ATP314

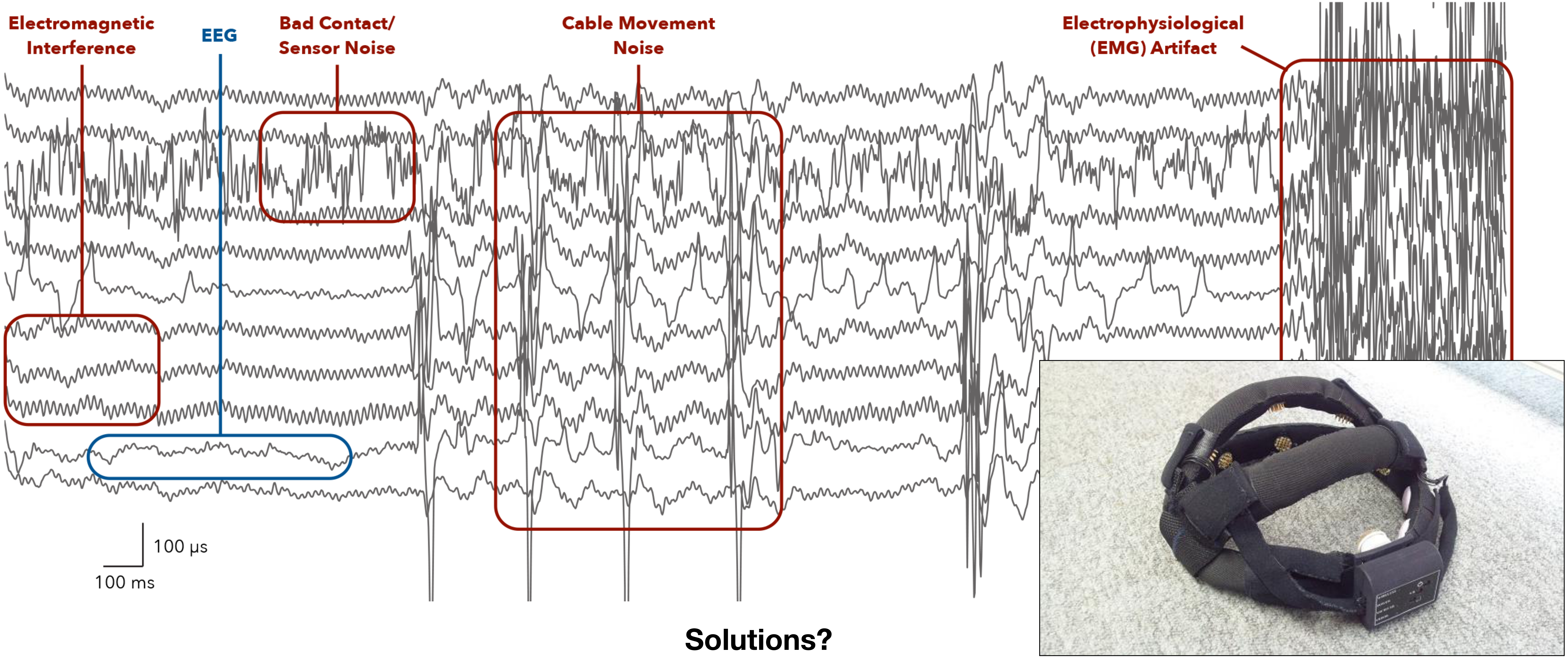
Abstract

Background: Improvements are needed in prehospital diagnosis of stroke. The electroencephalogram (EEG) changes immediately after brain ischemia, and advances in EEG technology enable rapid acquisition in the acute care setting. We hypothesized that EEG data increase the accuracy with which patients are correctly classified as having acute stroke or not, and so performed a study in the Emergency Department (ED) as an initial step towards evaluating prehospital utility of EEG.



Challenges in 'Out of Laboratory' Environments

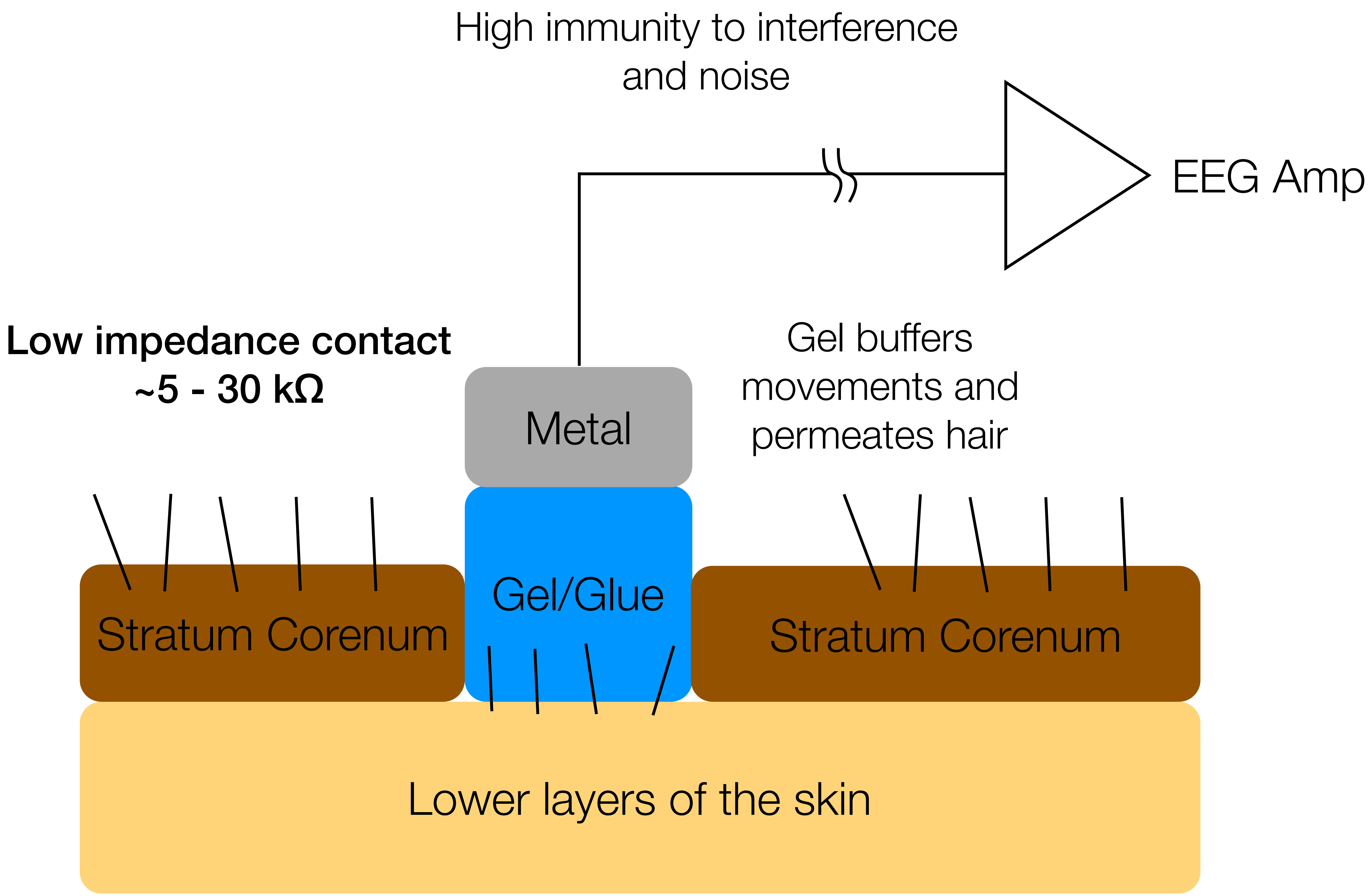
Noise and artifacts are a major issues with EEG recordings



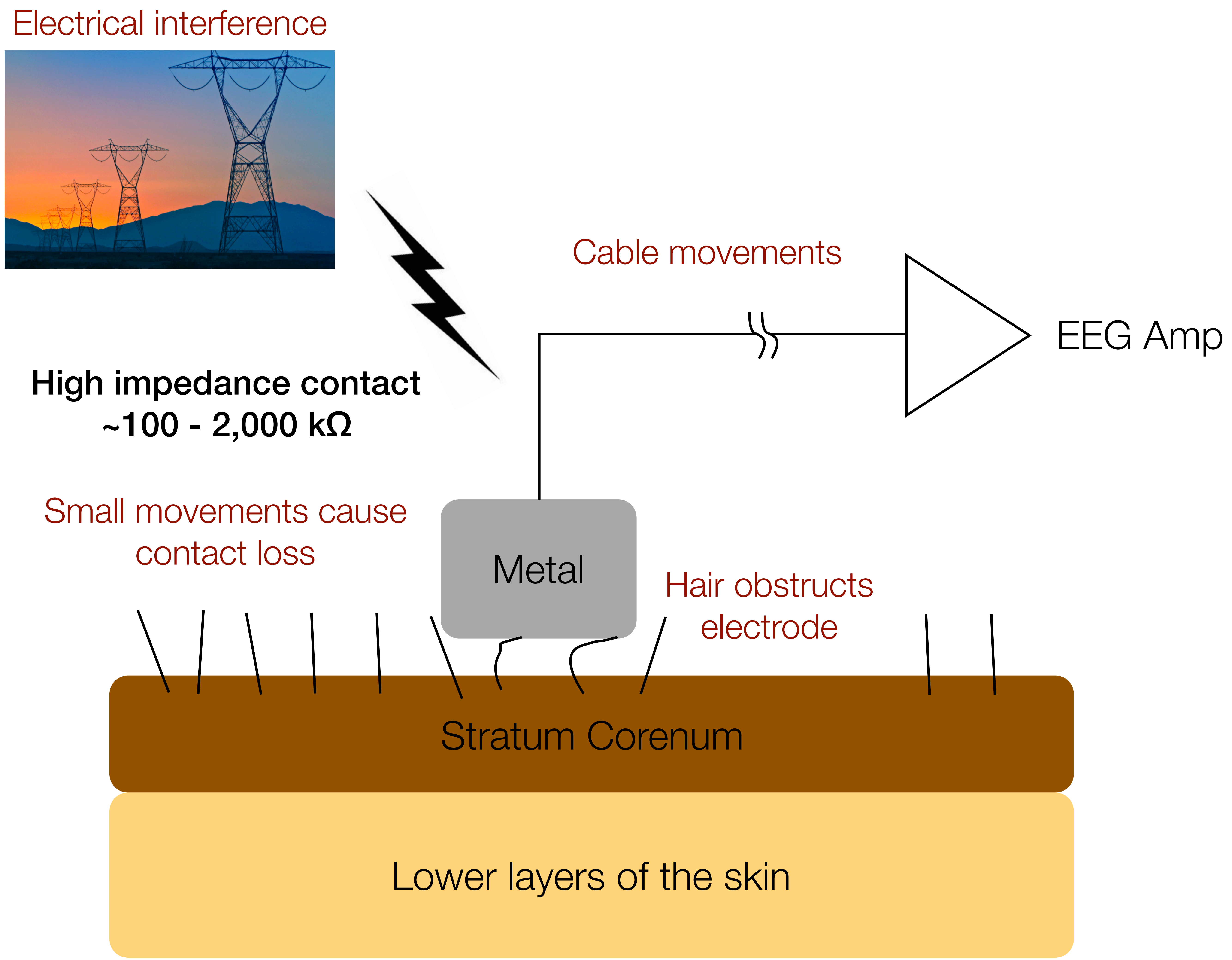
Solutions?

Wet EEG Electrodes

Standard gel electrode



Dry EEG Electrodes



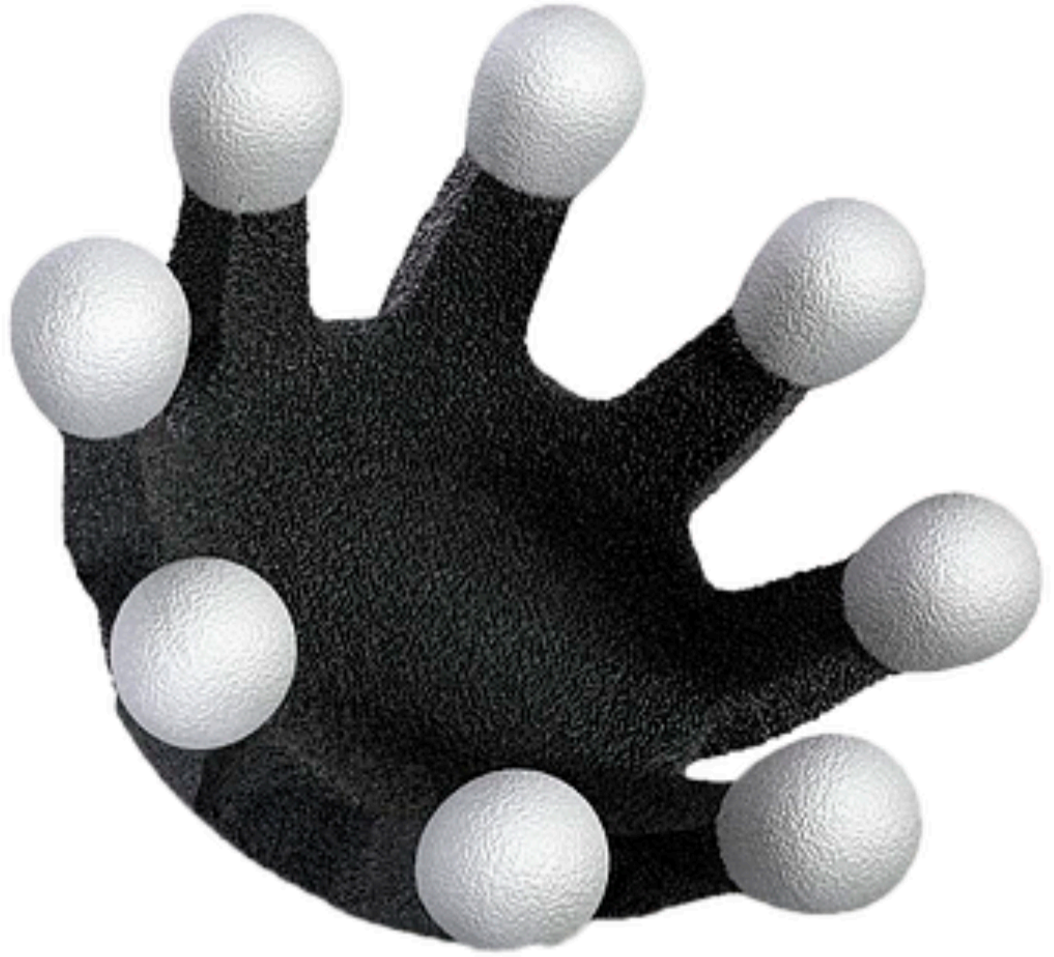
Dry electrodes:

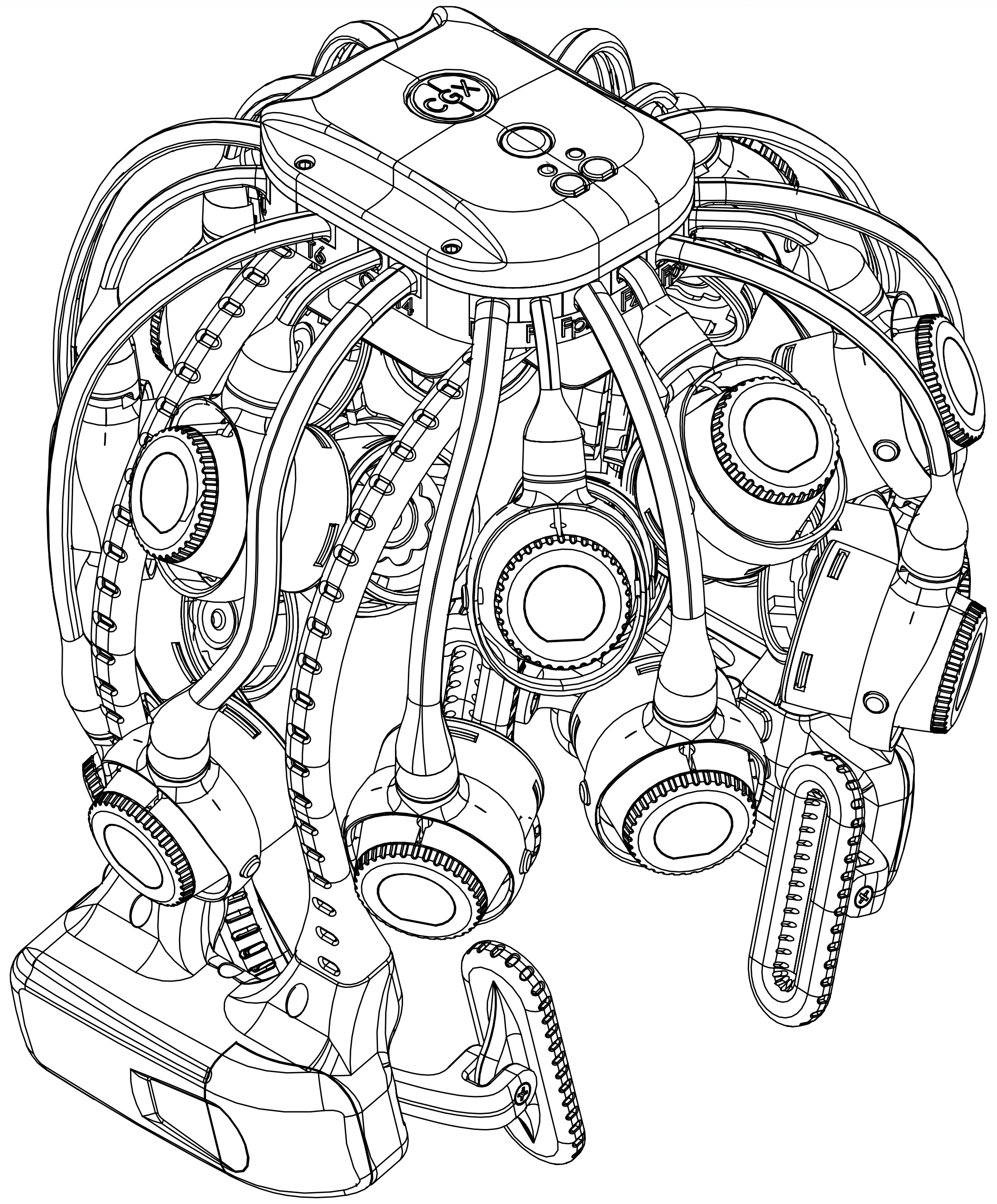
- No gel to lower skin impedance
- No gel to go through hair
- No adhesive to affix electrode
- No skin abrasion to improve contact
- Orders of magnitude higher impedance

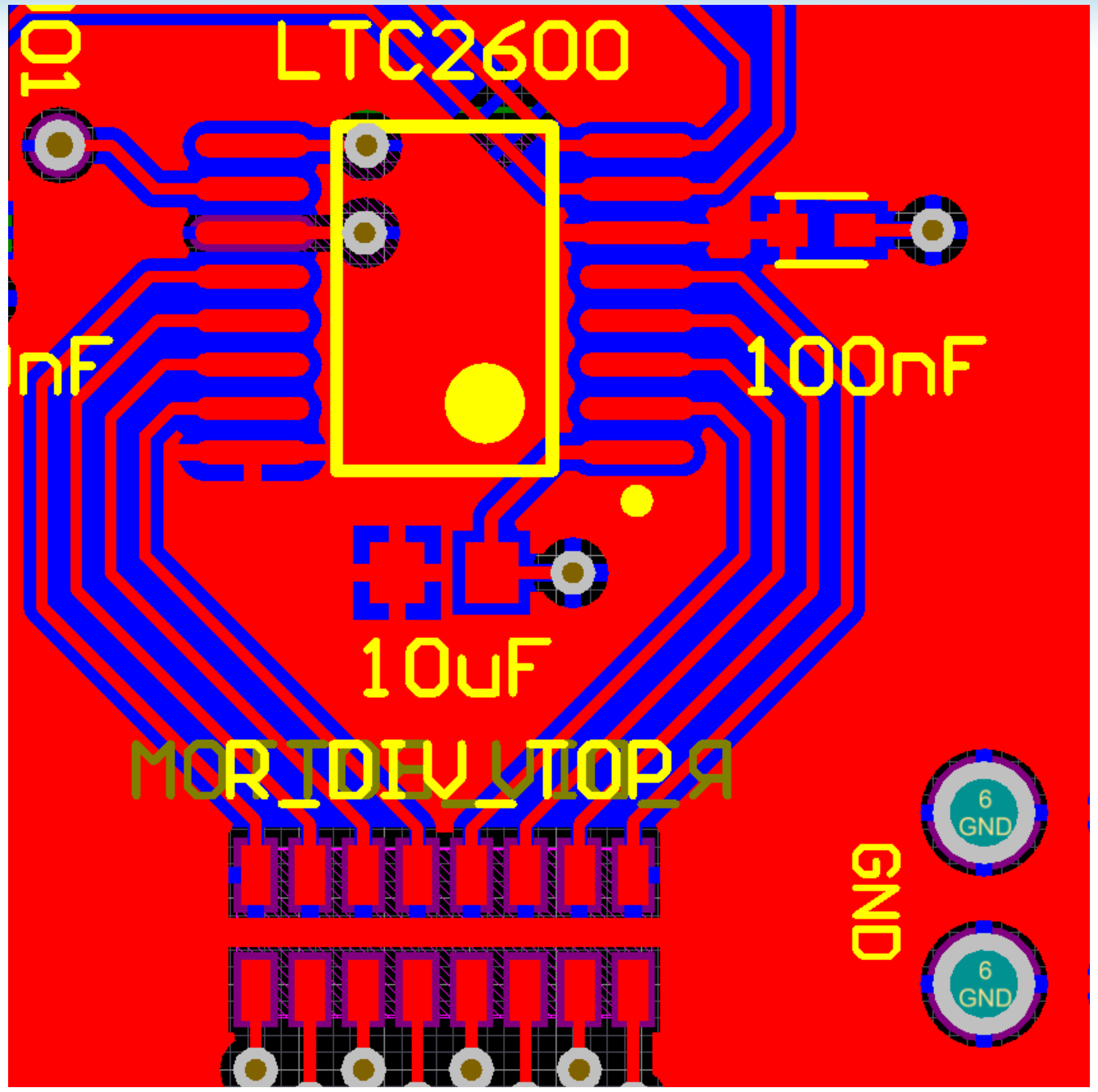
High susceptibility to noise:

- Movement
- Electrical
- Electrochemical

Key Components of a Dry System







Sensors

- Go through hair
- Electrochemical compatibility
- Remain comfortable
- Durable/long-life

Mechanics

- Conform to head shapes
- Control sensor pressure
- Remain comfortable
- Stable and motion resistant

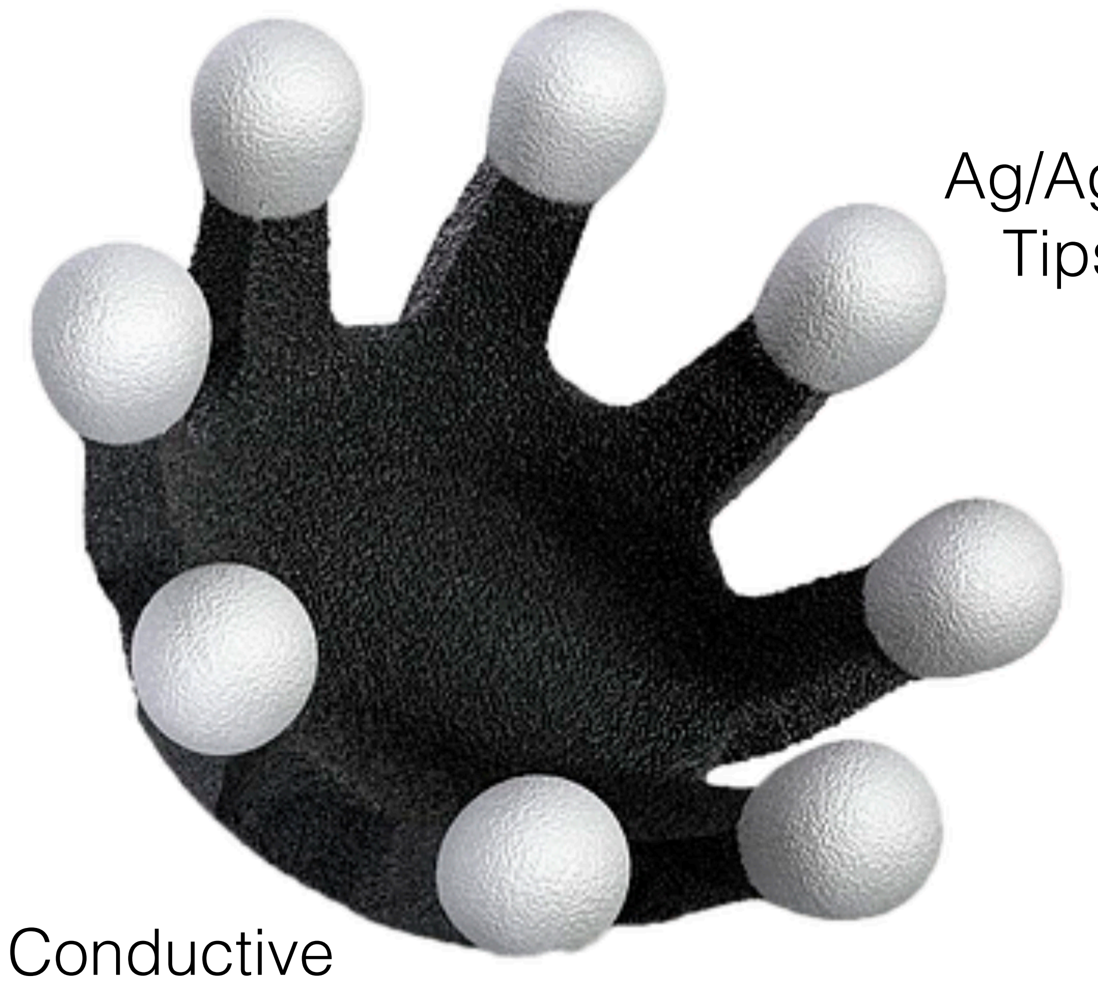
Electronics

- Low-power
- Minimize size
- Reject electrical noise
- May be the easy part :-)

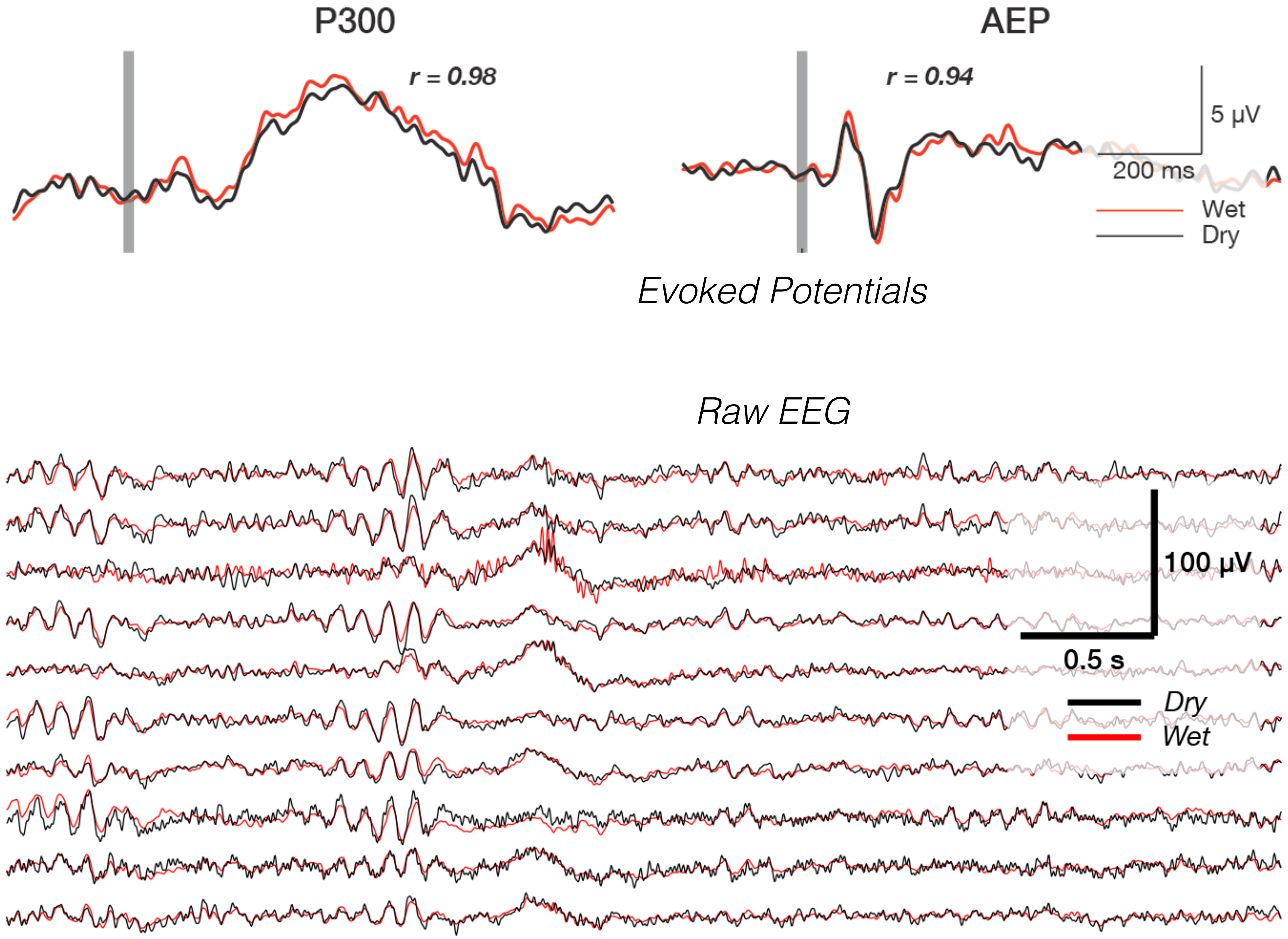
Sensor Design

Goal: Slide through hair to contact scalp with minimal discomfort

First Generation:
Gold plated pins



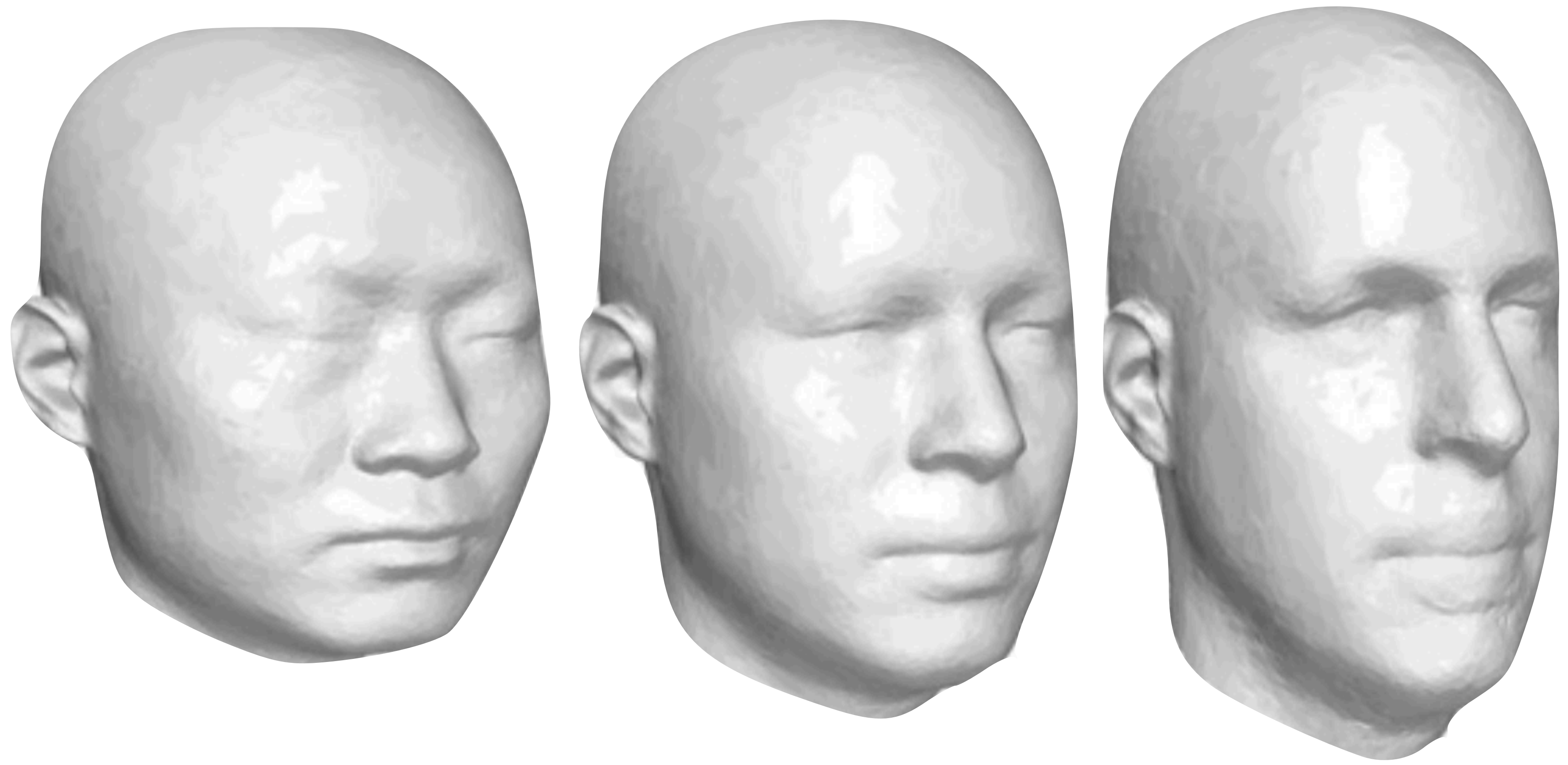
Second Generation:
Conductive Plastic/Polymer



Headset Design: The Most Difficult Challenge

Huge variation in head shape across: age, sex and race

Chinese ⟷ Caucasian



Ball et al. "A comparison between Chinese and Caucasian head shapes." Applied Ergonomics 2010. Fig. 5

Goal: single headset that conforms ~51cm - 62cm across head size and hair density variations

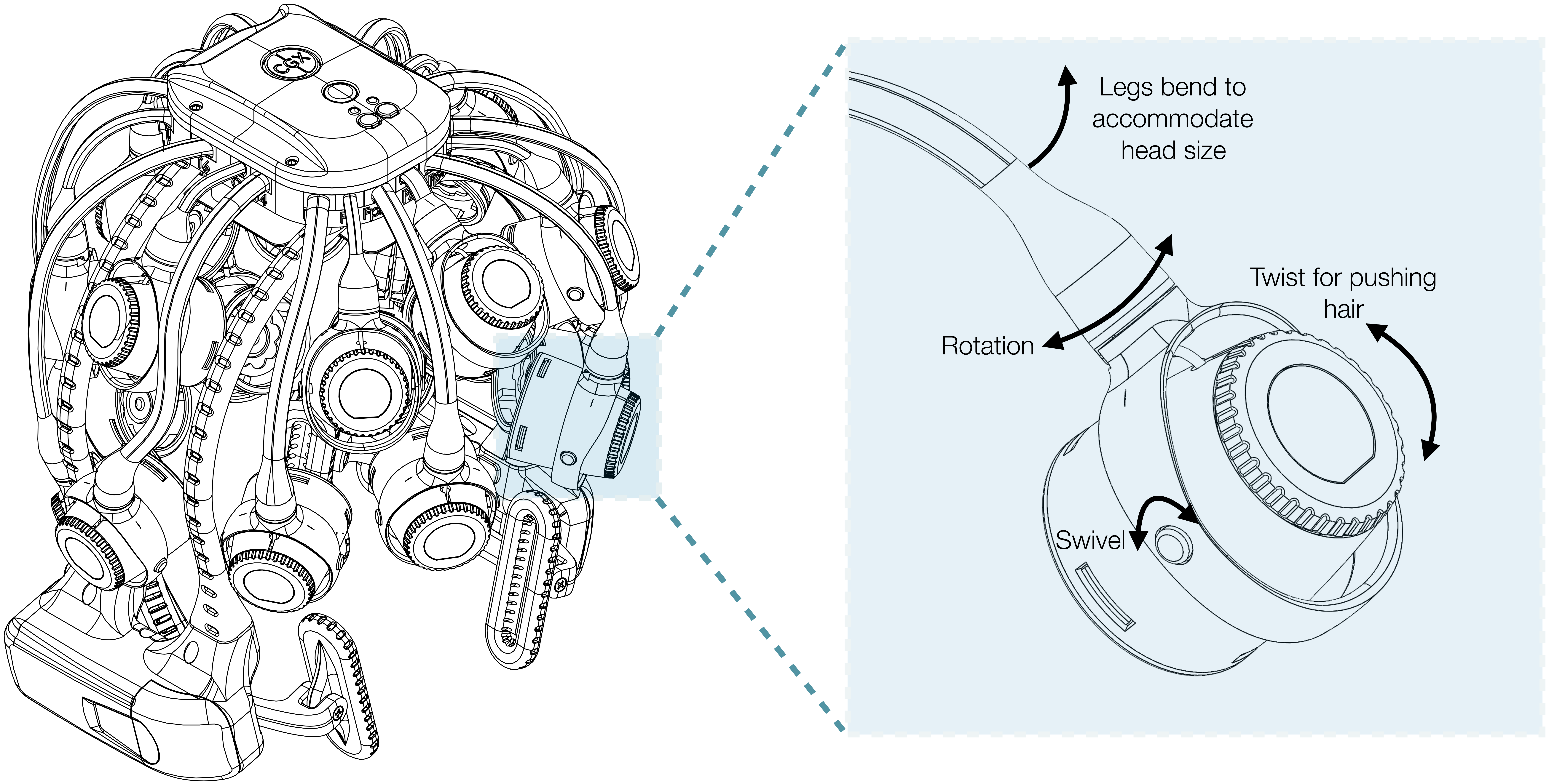
2013

2015

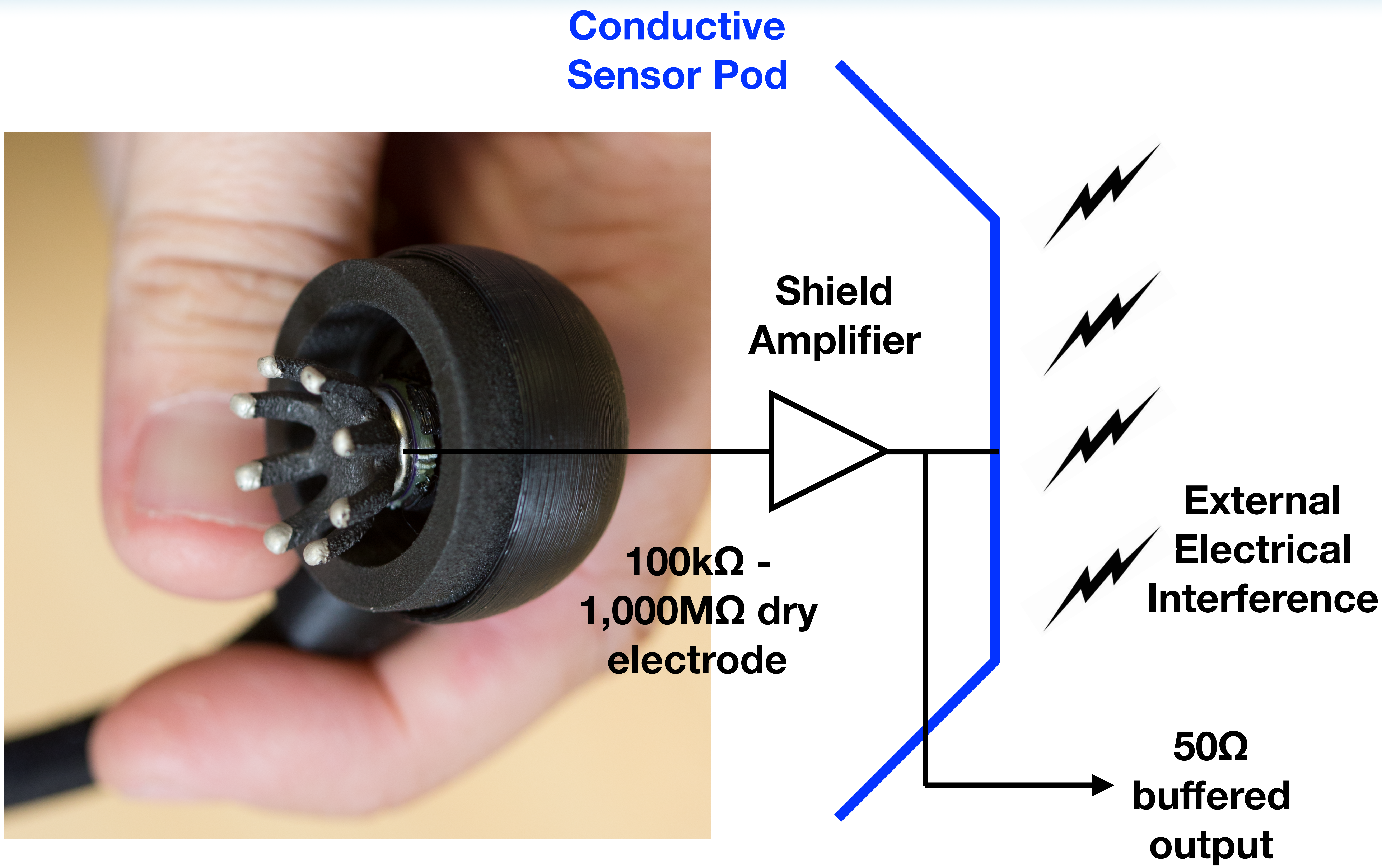
2017

2019

Headset Mechanics: “Zero” Adjustment Design



Electrical Design: Active Electrode Pods



The environment is full of electrical noise

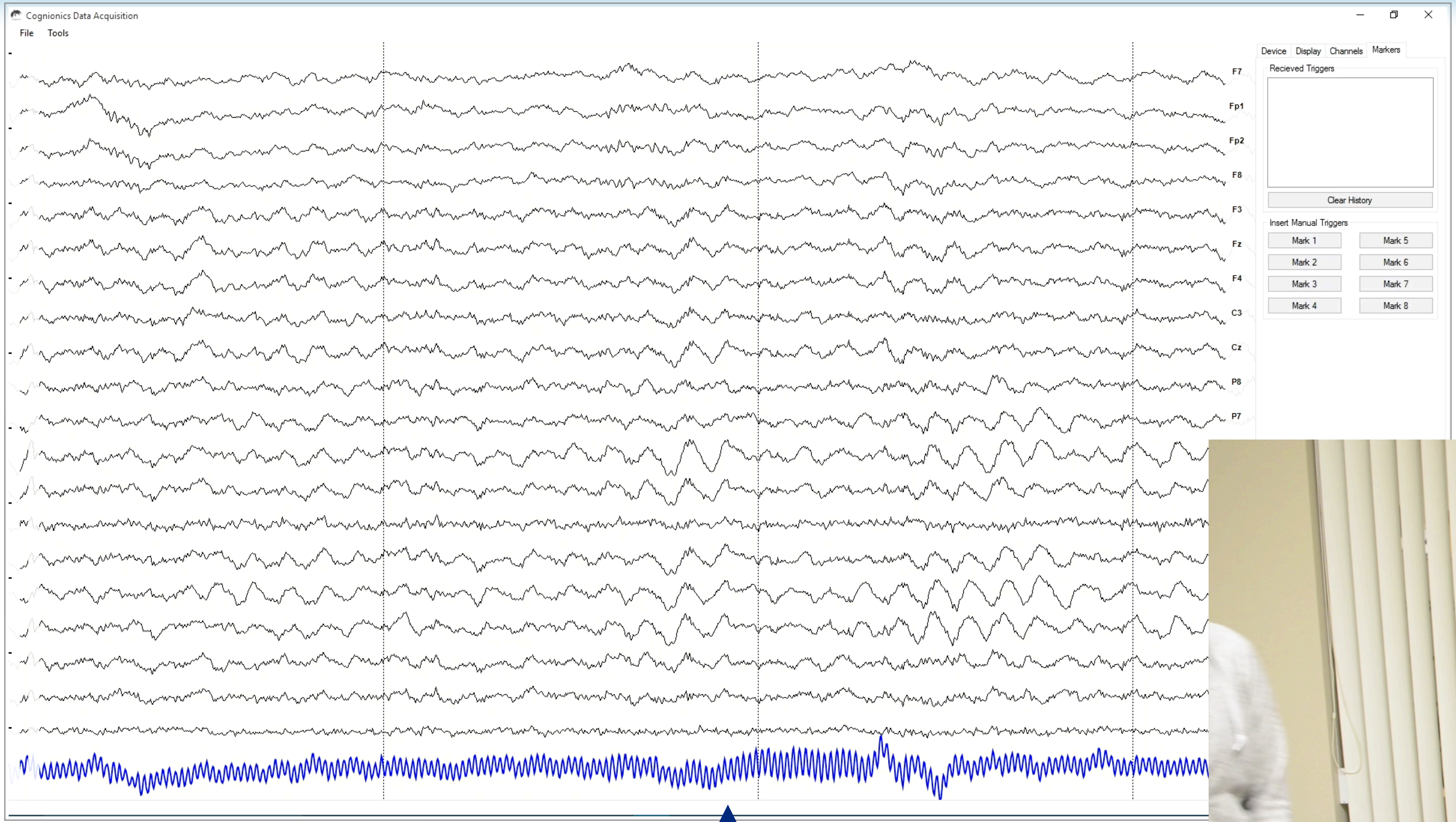
- Electronic equipment
- Power lines
- Other people

Without adequate shielding, an electrode may pick up the several orders of magnitude larger external interference rather than the microvolt EEG.

Notch filtering can only remove rhythmic power line noise and at the cost of signal distortion. They only mask, not solve, the problem.

Cognionics headsets use active shielding to **block out external noise before they reach the EEG sensor.**

Electrical Artifact Resilience Demonstration



EEG Acquisition Settings

Device: Cognionics Quick-20

Resolution: 24-bits

Sampling Rate: 1000 samples/sec

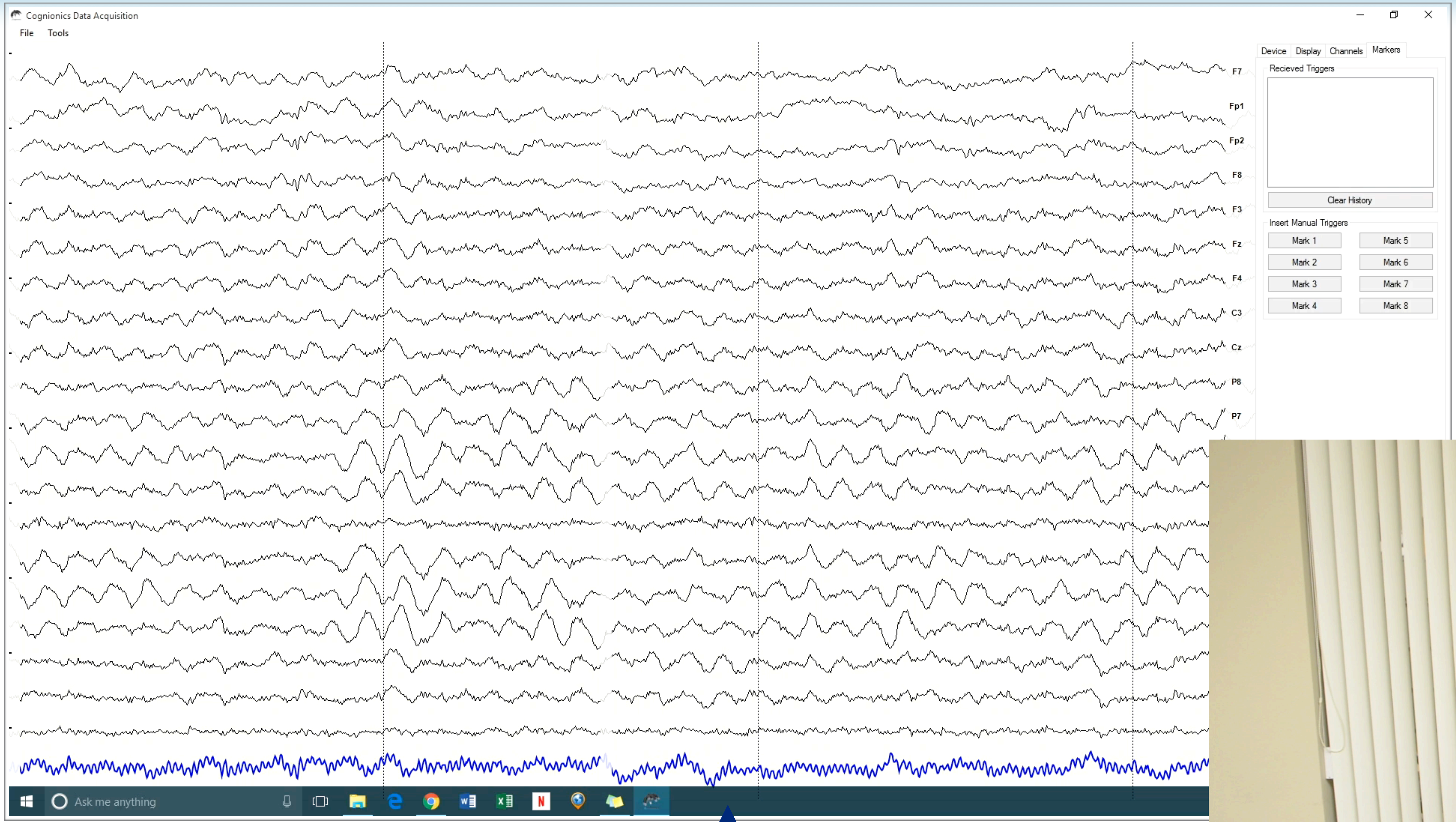
Display: Raw 0.5-100 Hz

Notch: None

Mode: High-speed Wireless

Active Ground Output

Rejecting External Electric Fields



EEG Acquisition Settings

Device: Cognionics Quick-20

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Display: Raw 0.5-100 Hz

Notch: None

Mode: High-speed Wireless

Active Ground Output

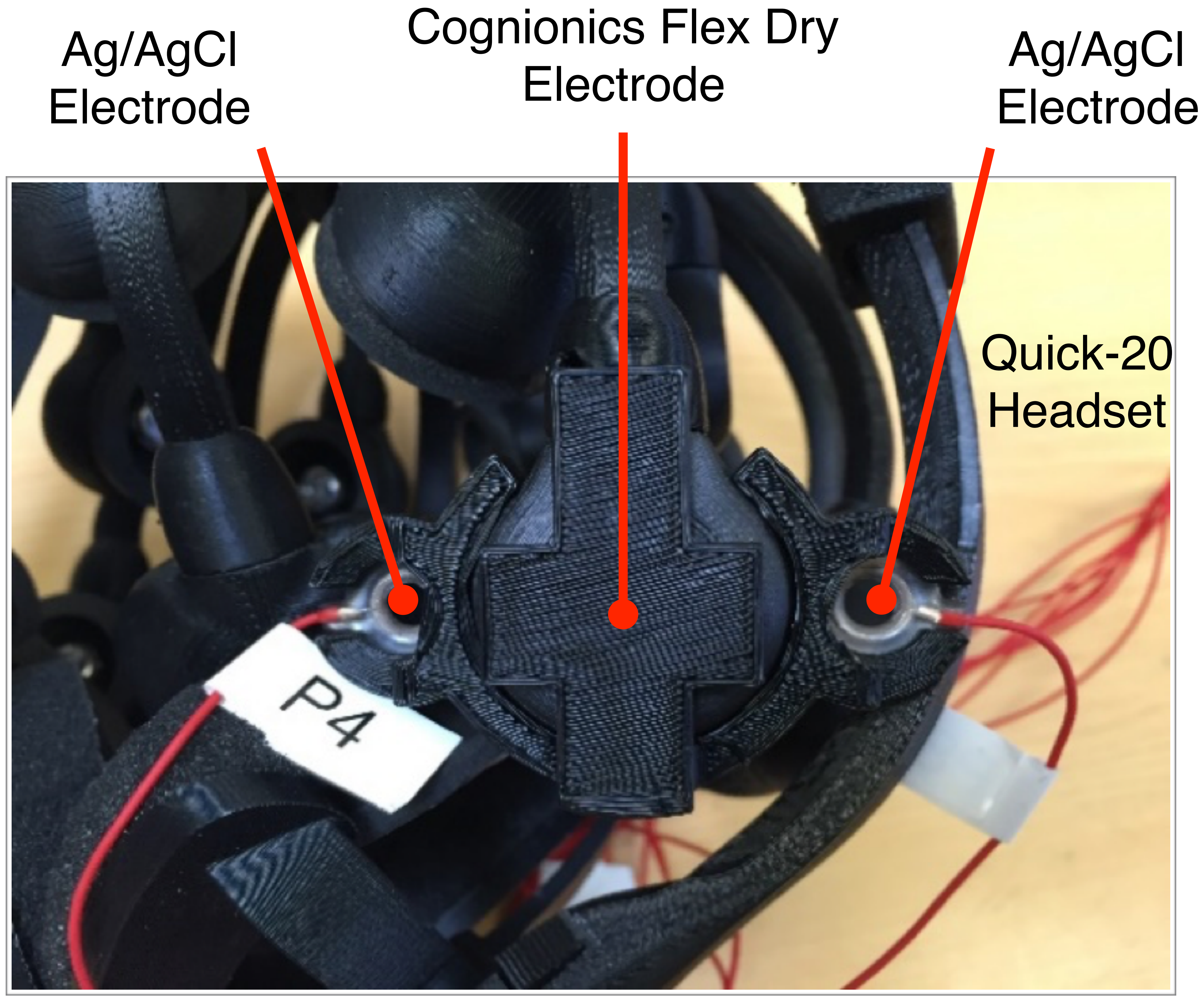
Signal Quality Test: Wet vs. Dry

Signal quality testing for dry systems is difficult:

- Bench tests do not simulate effect of skin and hair
- Data sheet specs do not necessarily reflect performance
- High subject-to-subject and environmental variability

Test protocol:

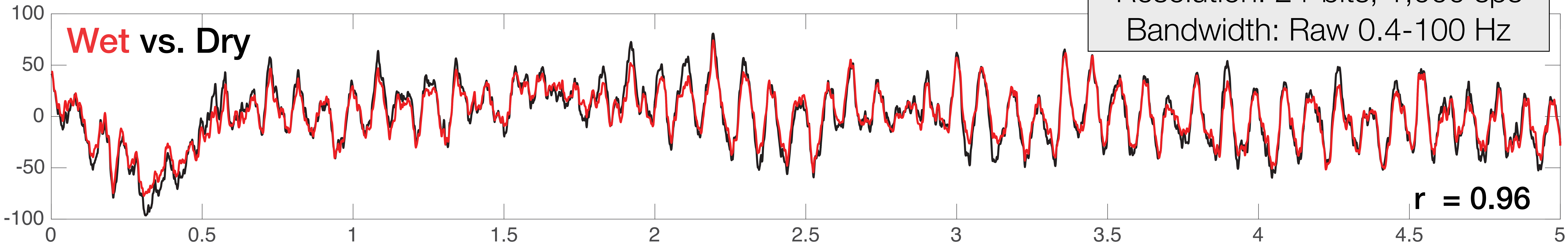
- Test on multiple subjects to capture real-world effects while minimizing effects of experimental variability
- Record simultaneous signals from dry electrode with “gold standard” wet electrodes
- Current protocol examines 10 second raw EEG and evoked potential (50 odd trials, 150 normal trials)
- Repeat experiment by swapping dry electrode under test with wet for control data
- Open ended problem, suggestions welcome :)

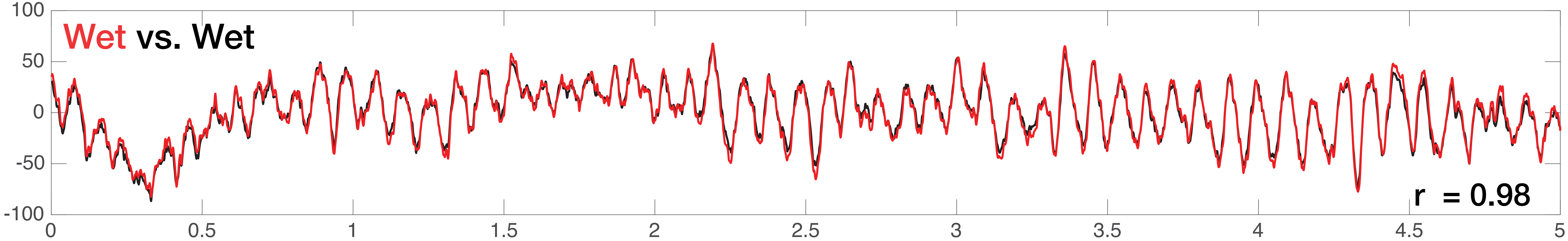


Compare dry versus average of two wet electrodes to minimize effect of spatial displacement

Signal Quality Test: EEG Results

EEG Acquisition Settings
Device: Cognionics Quick-20
Resolution: 24-bits, 1,000 sps
Bandwidth: Raw 0.4-100 Hz



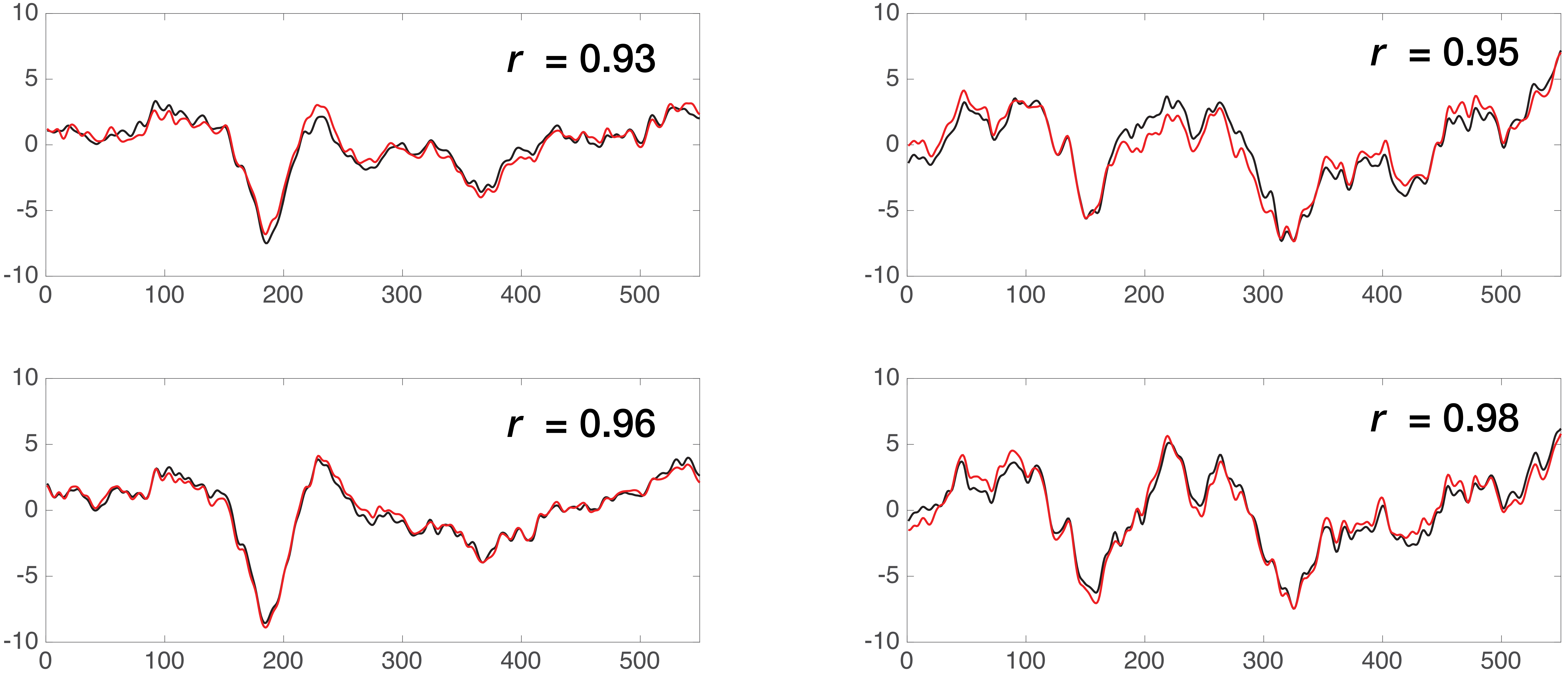


Signal Quality Test: ERP Results

Normal Tone (150 trials) | Odd Tone (50 trials)

Wet vs. Dry

Wet vs. Wet



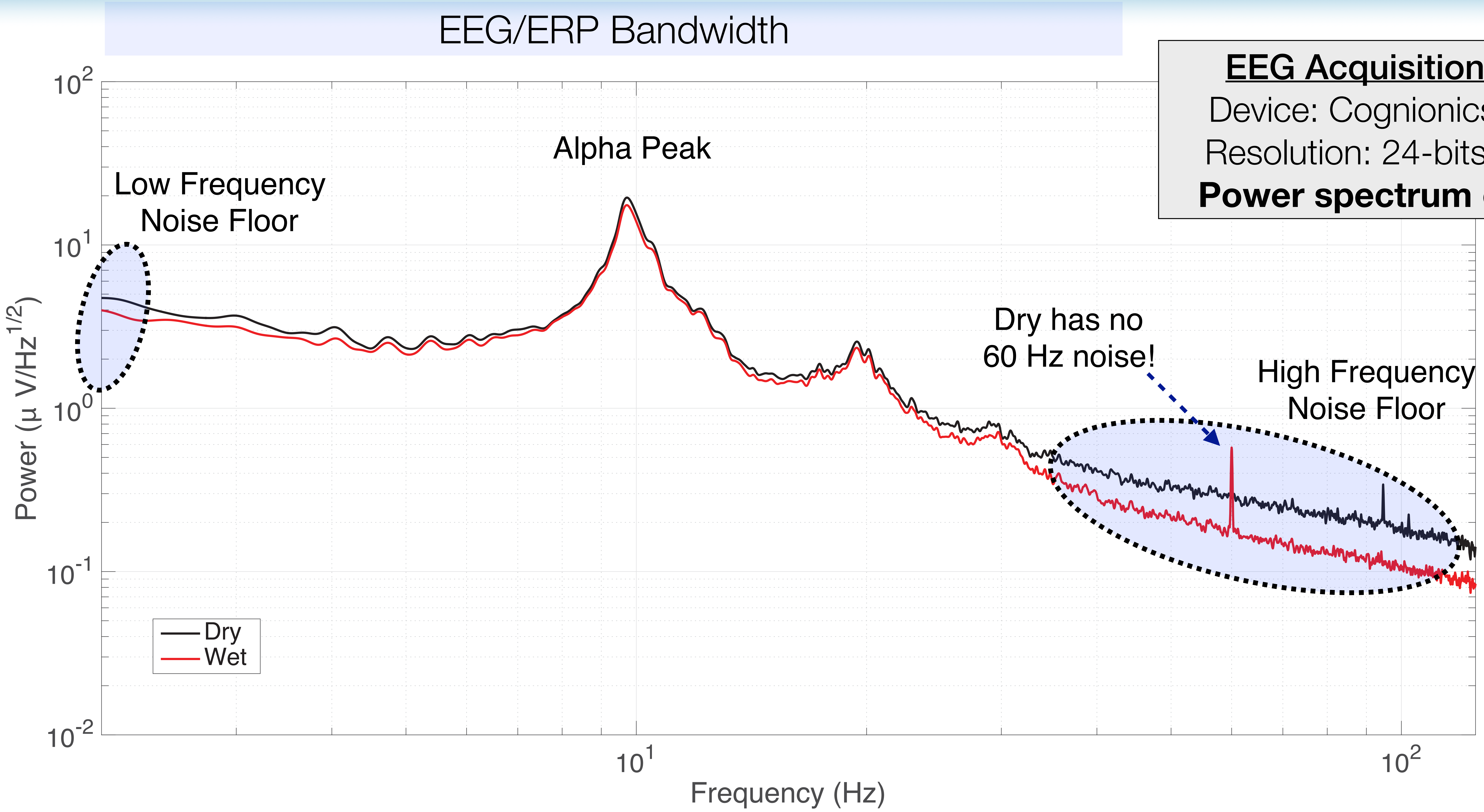
CGX

Signal Quality Test: Correlation

Table I - Wet/Dry and Wet/Wet Correlation Results

	Raw EEG		AEP Normal		AEP Oddball	
	r - Dry	*r* - Wet	*r* - Dry	*r* - Wet	*r* - Dry	*r* - Wet
S1	0.9	0.95	0.99	0.99	0.98	0.99
S2	0.96	0.98	0.93	0.96	0.95	0.98
S3	0.95	0.97	0.97	0.99	0.96	0.98
S4	0.97	0.99	0.97	0.98	0.94	0.99
S5	0.93	0.98	0.93	0.98	0.95	0.97
S6	0.97	0.99	0.97	0.98	0.94	0.97
Mean	**0.95**	**0.98**	**0.96**	**0.98**	**0.95**	**0.98**

Differences between Wet and Dry



EEG Acquisition Settings

Device: Cognionics Quick-20

Resolution: 24-bits, 1000 sps

Power spectrum over 5 min