Closing the Loop: Towards Smart Integrated Medical Systems & Assistive Technologies

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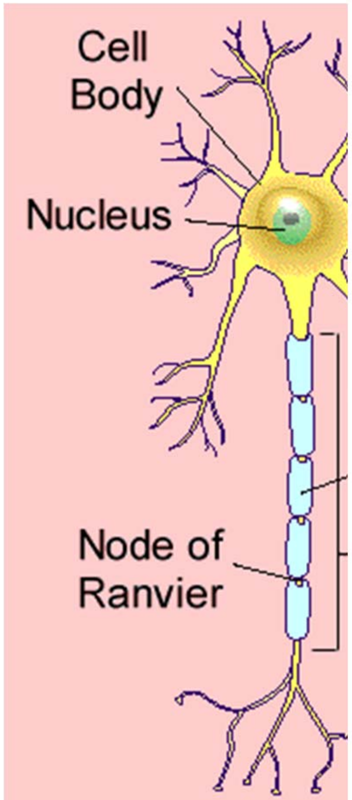
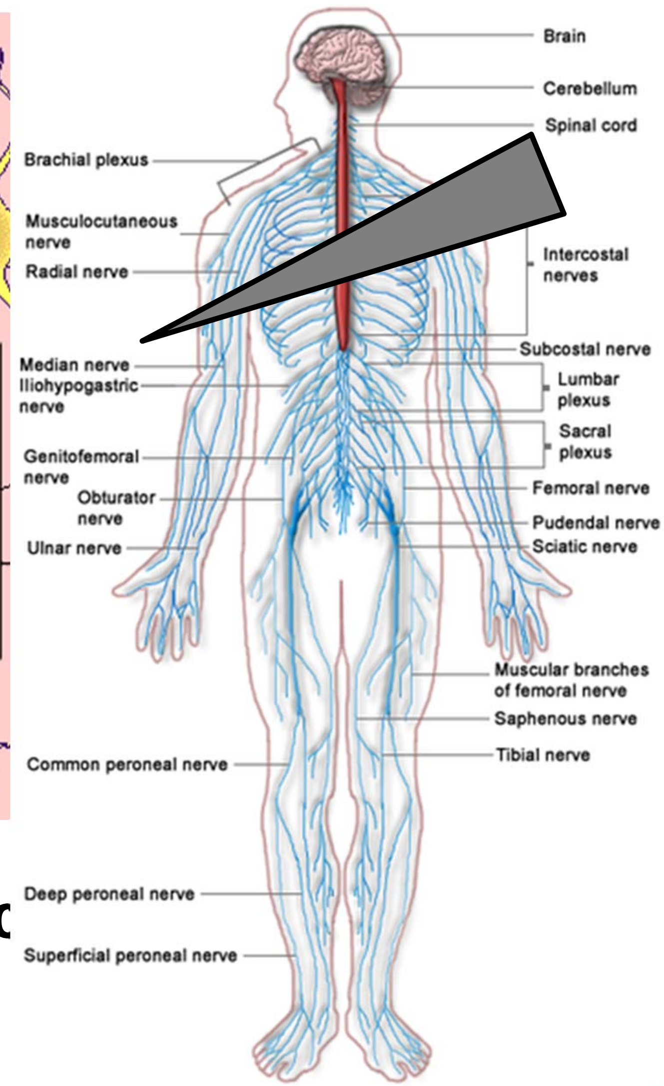
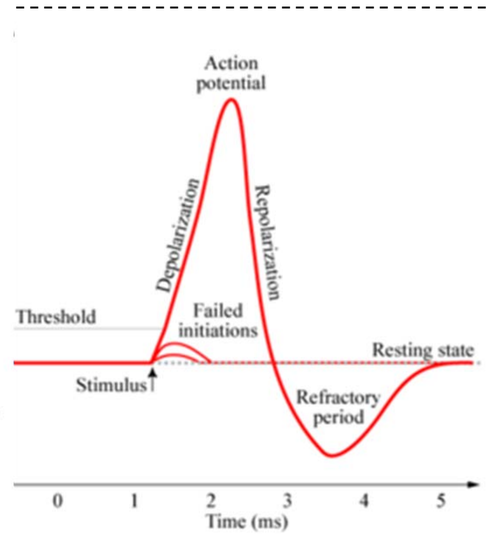
Outline

- Integrated Solution for Pain Management
  - Recording from Spinal Cord
  - Recording from Thalamus
  - Recording from Somatosensory
- Integrated Solution for Relieving Gastroparesis
  - Gastric Electrical Activity
- Integrated Assistive Technology for Speech Impairment
  - Tongue Tracking System
- Integrated Solution for Medication Adherence
  - Smart Connected AT/WD
- Conclusion

Basic Neuroscience



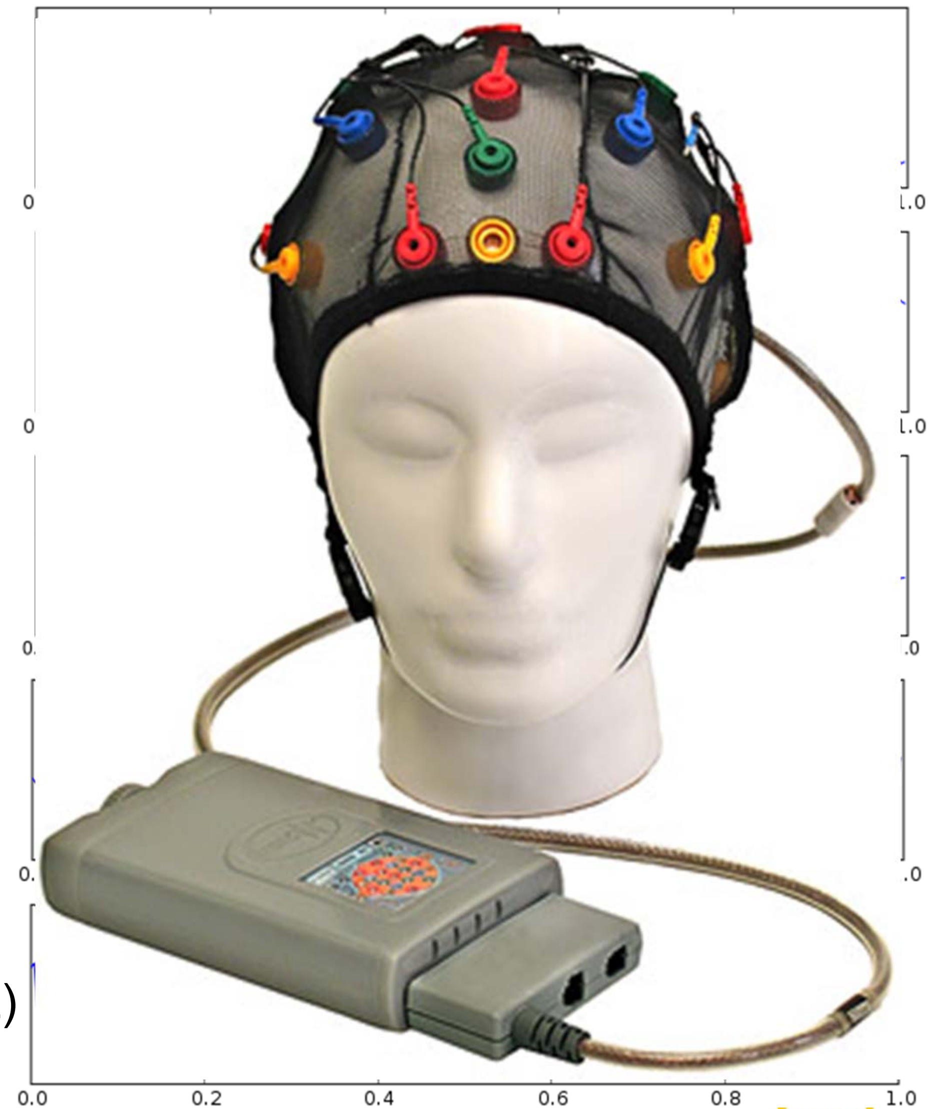




Extrac ording

http://en.wikibooks.org/wiki/Human_Physiology/The_Nervous_System

Background on EEG/ECoG



Delta (up to 4 Hz)	Sleeping
Theta (4 - <8 Hz)	Drowsy
Alpha (8 - <13 Hz)	Relaxed
Beta (13 - <30 Hz)	Alert
Gamma (30 - 100 Hz)	Complicated Sensory Proc.

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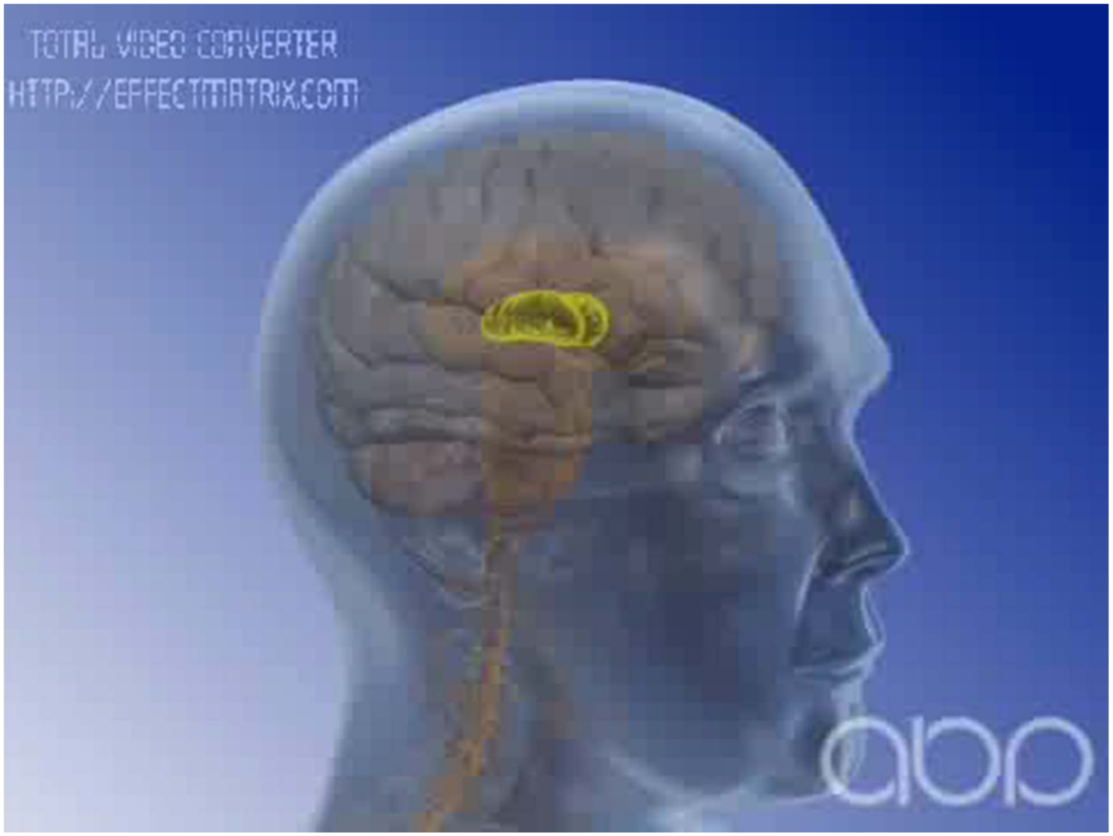
Brain Machine Interface (BMI)

- A **bra**[redacted]tion betwee[redacted]

- BMIs[redacted]ng human [redacted]

Neurostimulation: Deep Brain Stimulation



http://www.youtube.com/watch?v=izKL1mVXF7c&feature=related

DBS mechanism

Problems of Current Neurostimulators

- Tuning (trial and error)
- Feedback from nervous system
- The battery life

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Closed-loop Integrated Solution

Develop an integrated system, to acquire information about the state of nervous system, and stimulate the brain when necessary in order to normalize the state.

http://pcnews.ro/wp-content/uploads/2008/02/_dbs-depression-side300.jpg

http://s3819378.files.wordpress.com/2009/05/matthepg

Treating Neural Disorders: Neurostimulation

Chronic Pain

Gastroparesis
GERD

Epilepsy
Depression

Respiratory Support

http://pcnews.ro/wp-content/uploads/2008/02/_dbs-depression-side300.jpg

Parkinson's
Dystonia

Incontinence
Sexual Dysfunction

Alzheimer's
Huntington's

Obesity
TBI

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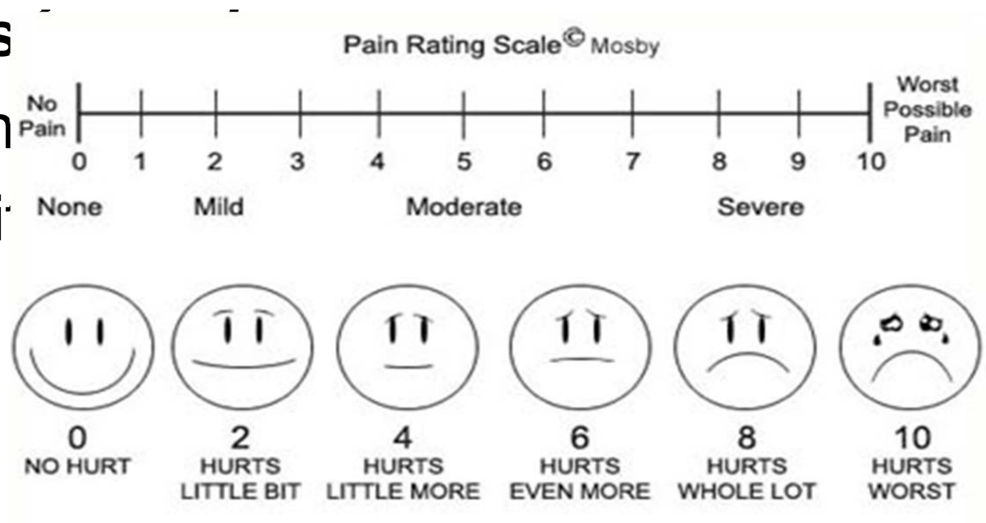
Chronic Pain

- **Statistics**
  - 40 million medical visits annually
  - $100 billion costs annually

- **Little has**
  - Treatin
  - Quanti



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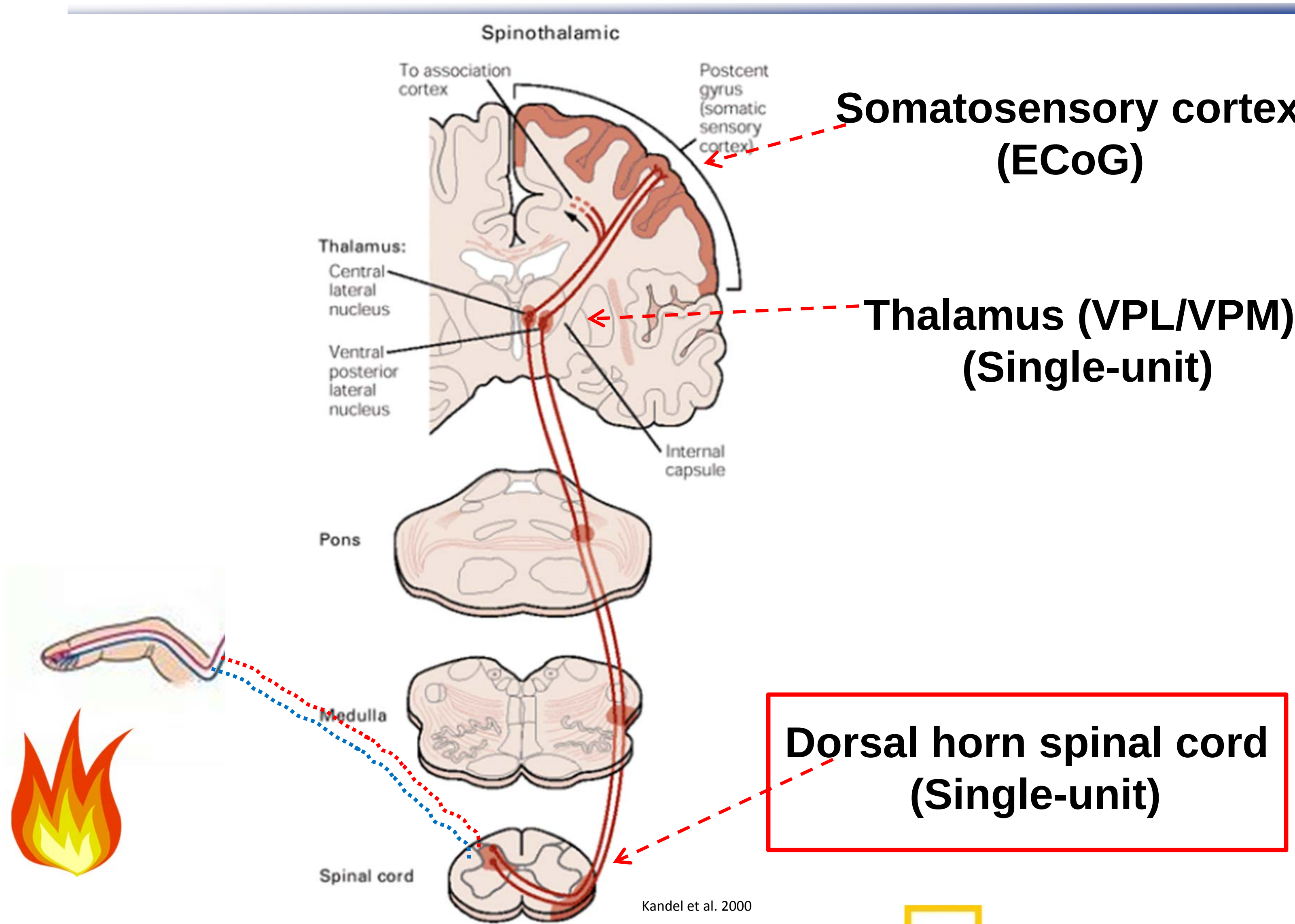
Pain Pathways (Spinothalamic)



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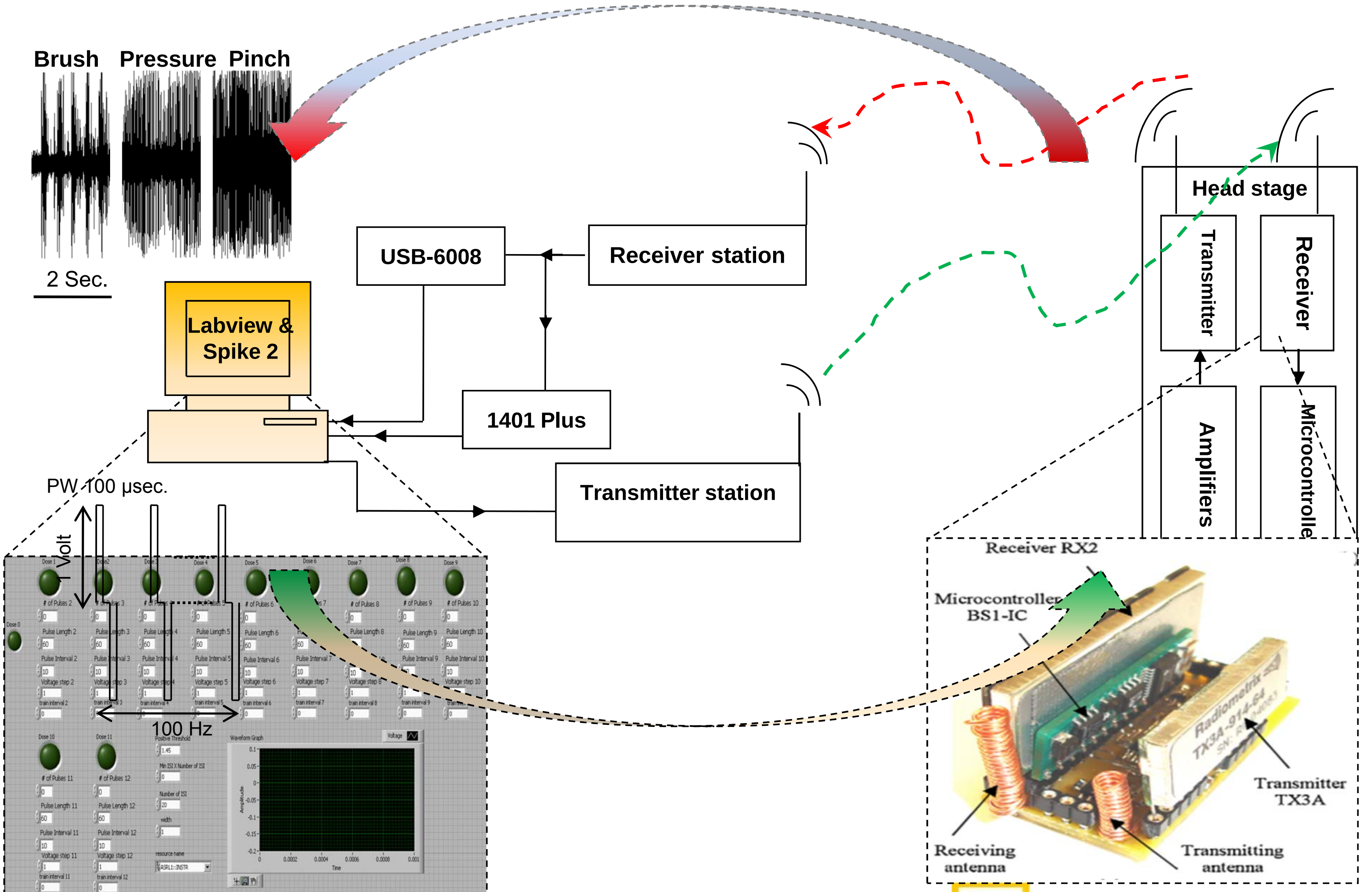
Extracellular Recording from SC Stimulating PAG



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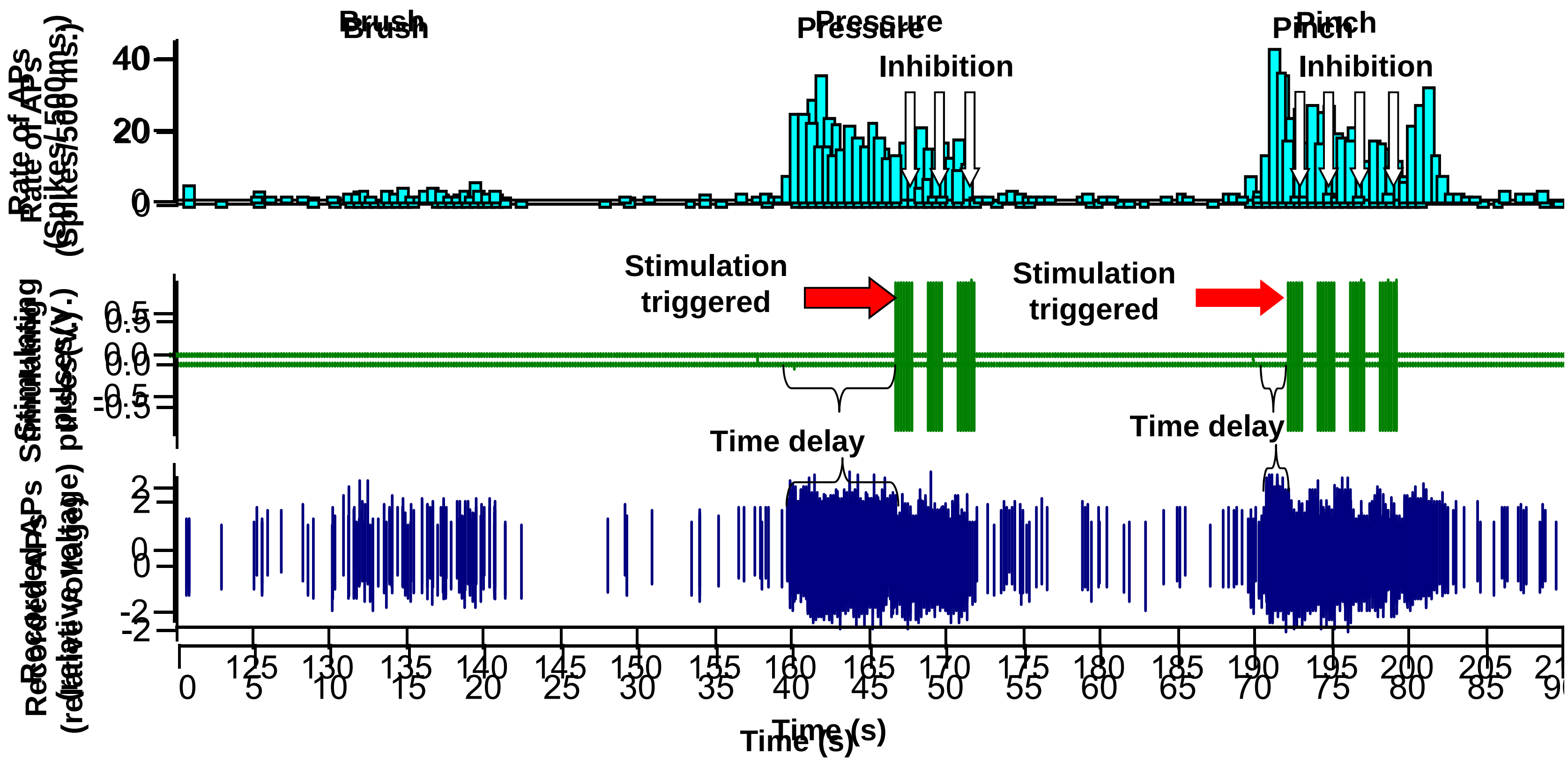
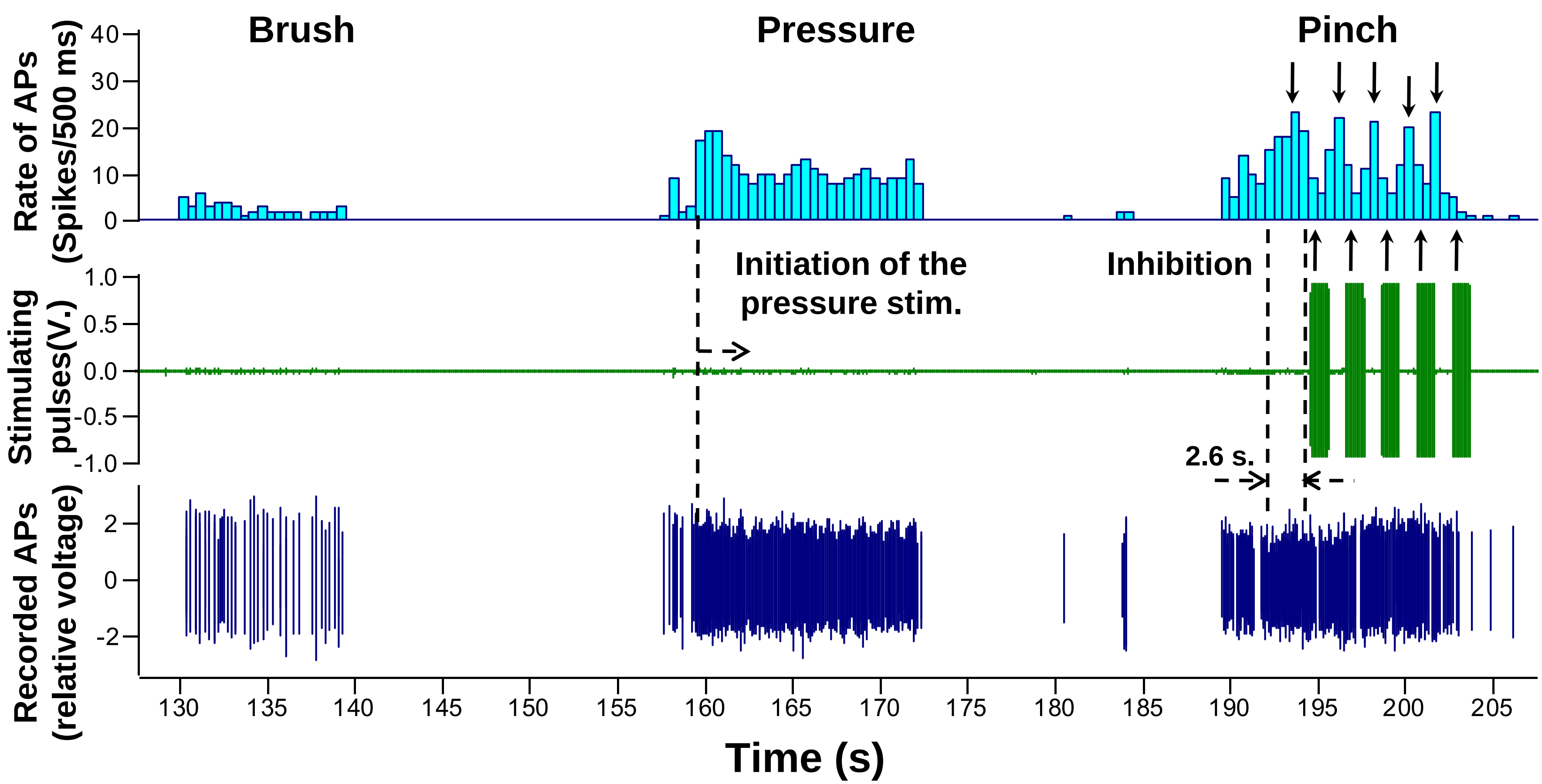
Real-time Experiments



Real-time Experiments



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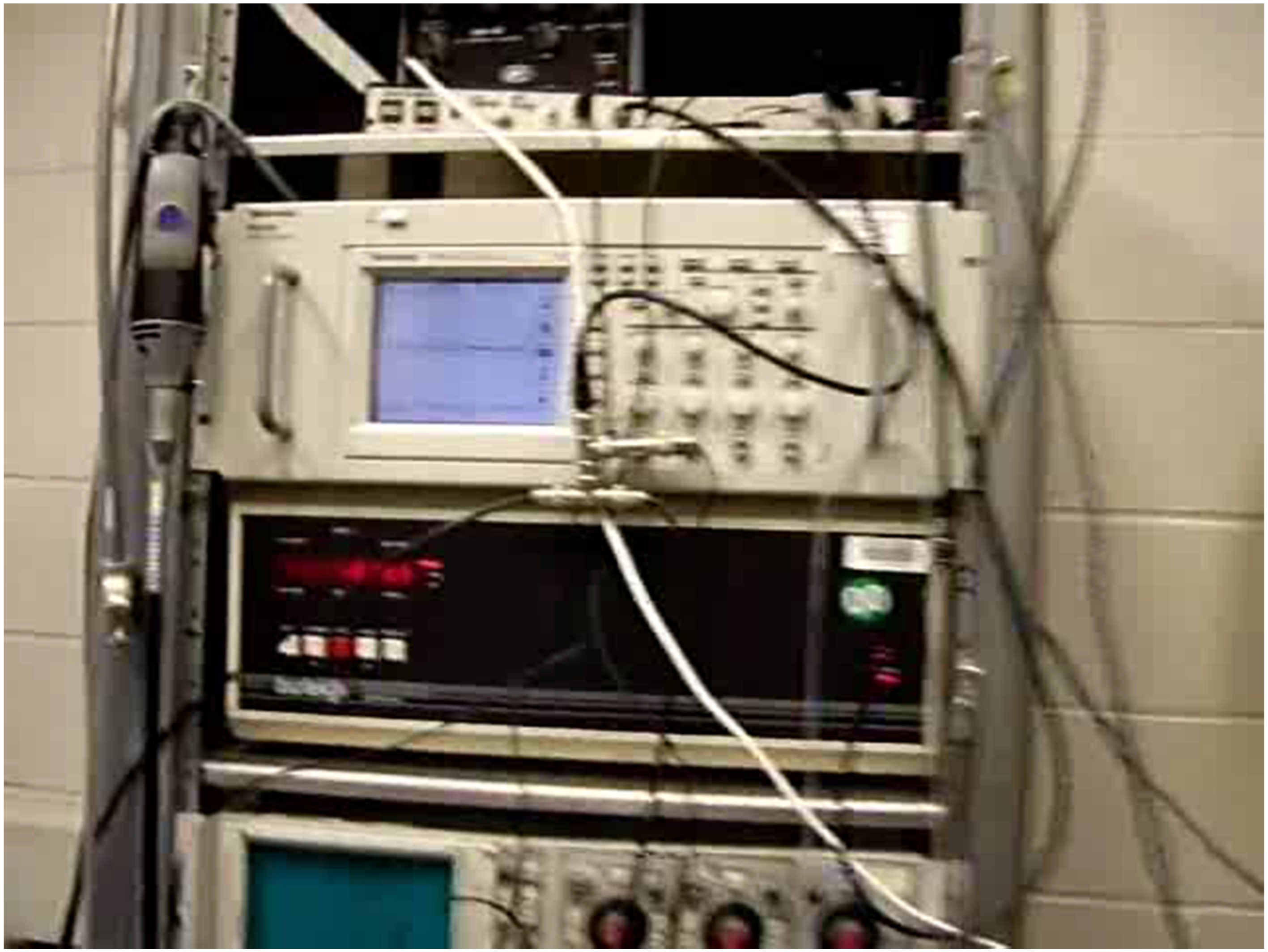
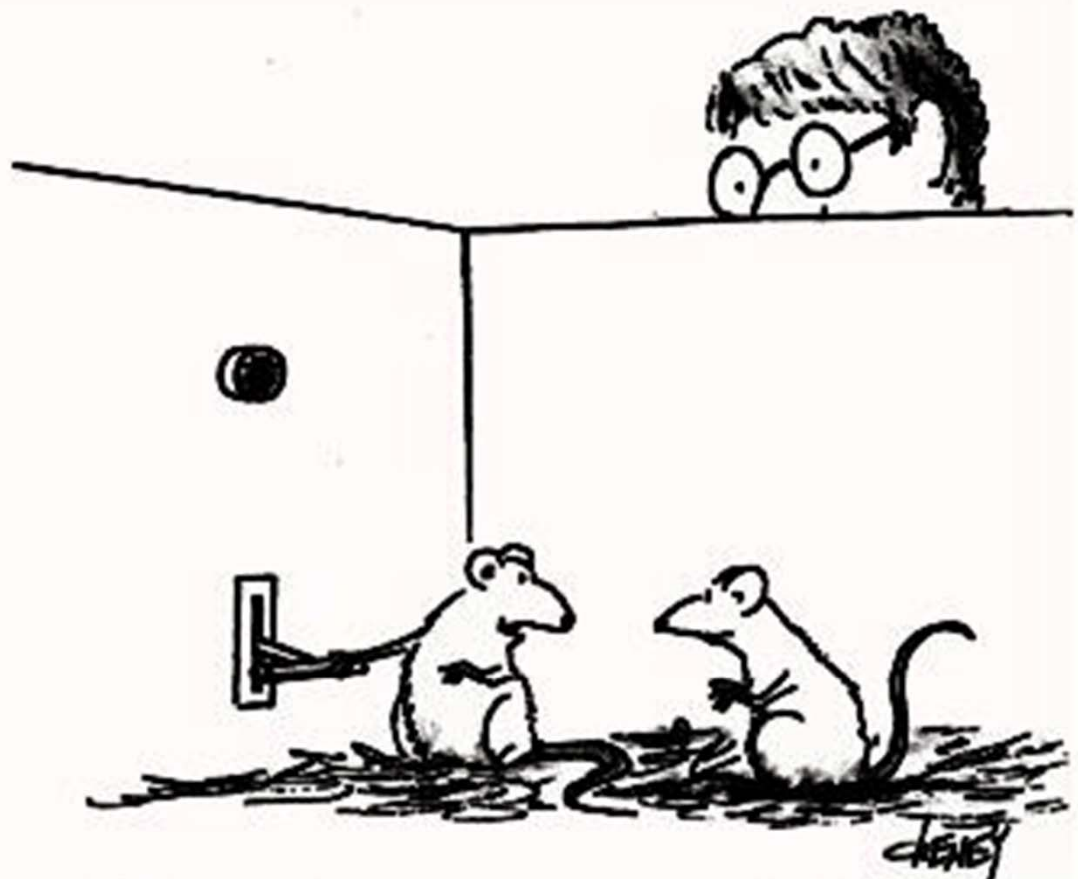
Experiment Video



Importance of Statistical Results



It is rater interesting phenomenon. Every time I press this lever, that post-graduate student breathes a sigh of relief.

http://www.cyc-net.org/humour/070801laugh.html

Performance of the System

Mean number of stimulation triggered ± SEM		
brush	pressure	pinch
0	1.85 ± 0.23	3.62 ± 0.16

System found pinch stimulus twice as painful as pressure (n=29).

Mean time delay in ± SEM		
brush	pressure	pinch
--	4.46 ± 0.49 (s)	0.91 ± 0.16 (s)

System detected pinch stimulus five times faster than pressure (n=29).

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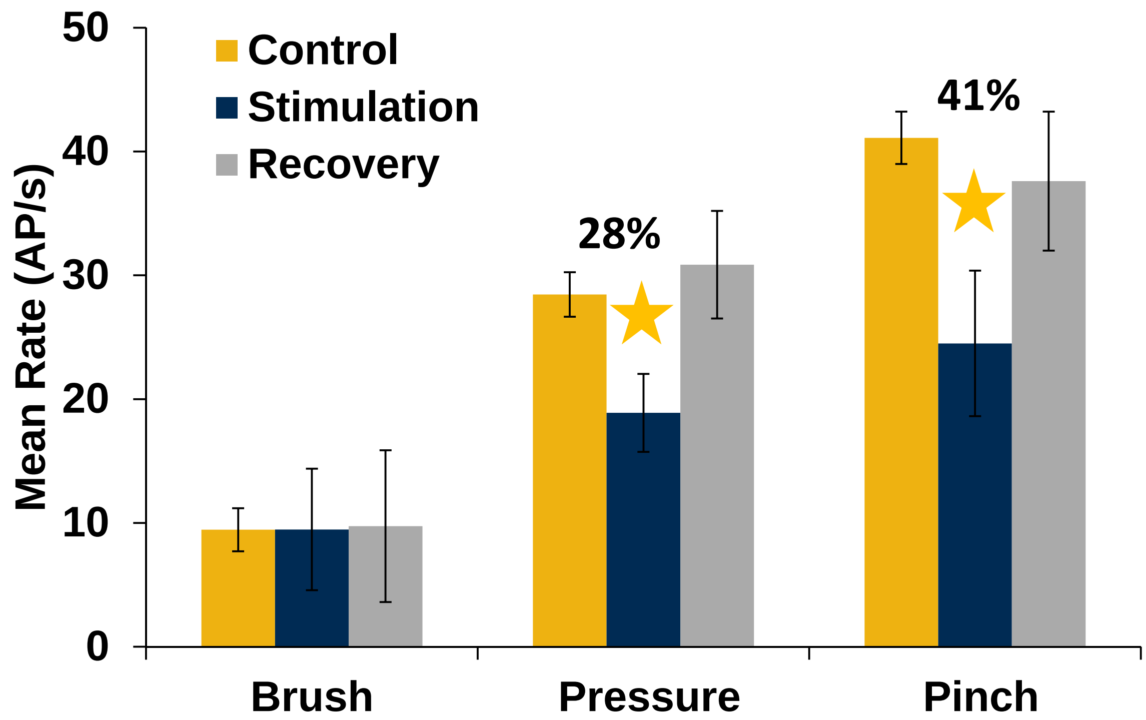
Statistical Results



The mean rate of Action potentials (APs)/sec. ± SEM (standard error of mean), n=29 (number of recorded neurons)

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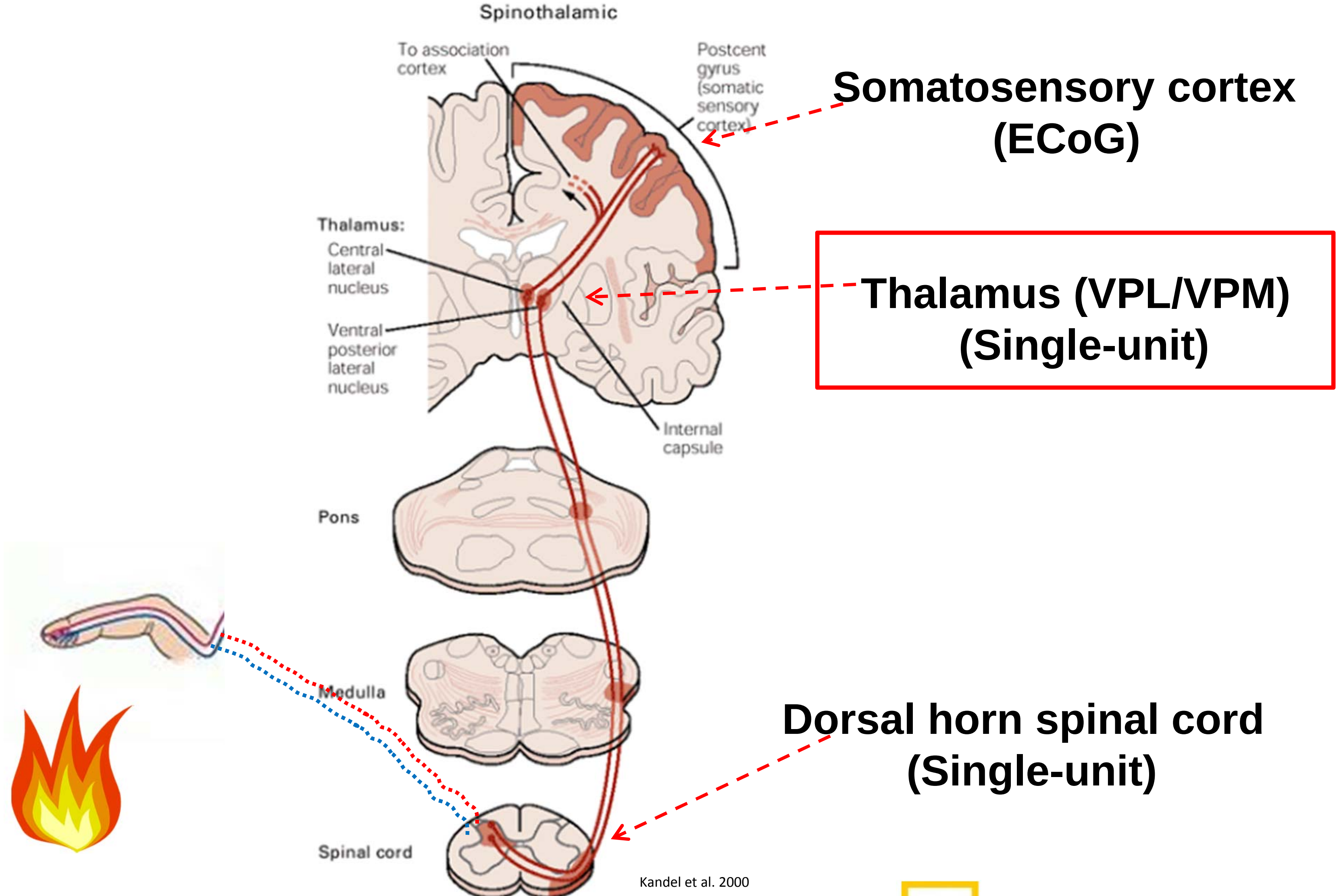
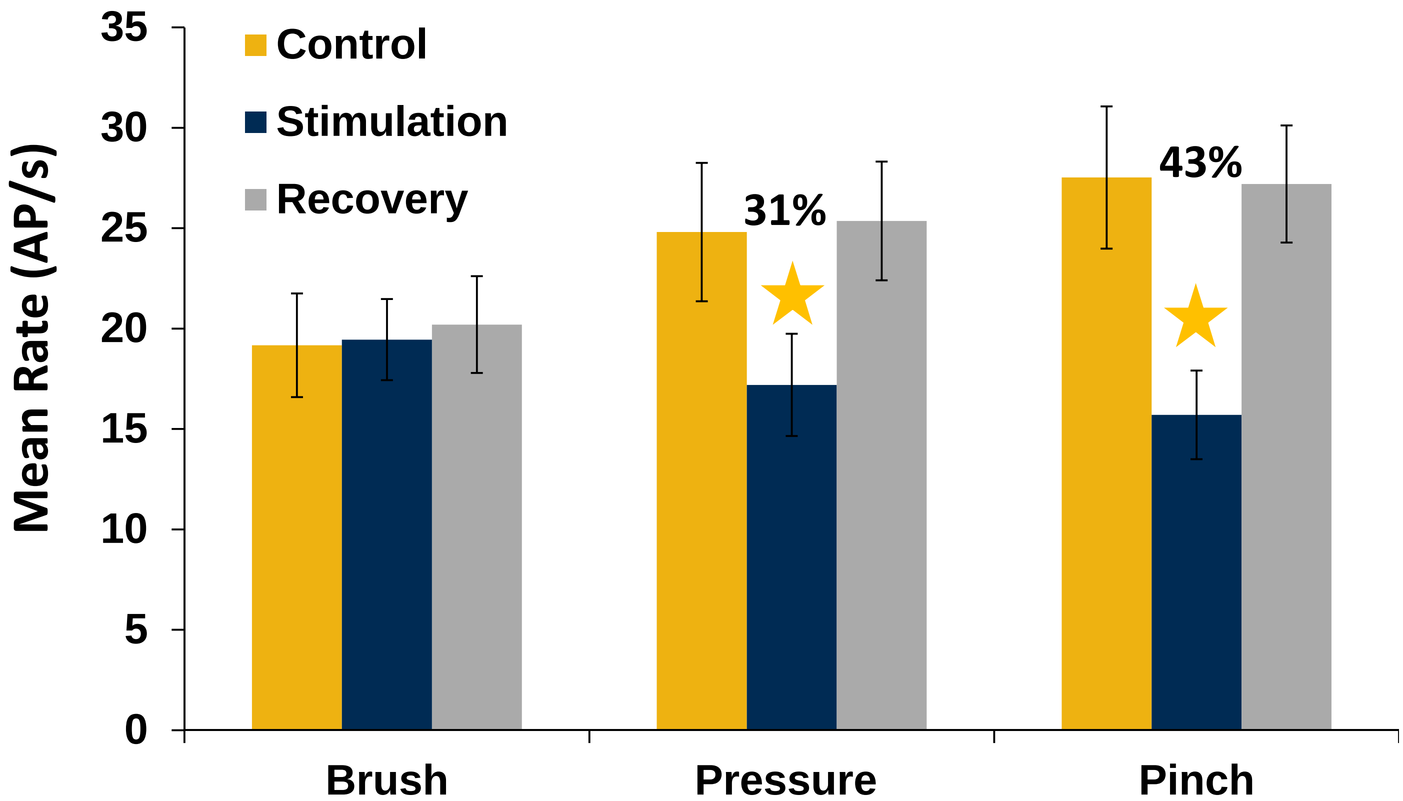
Pain Pathways (Spinothalamic)



Statistical Results



The mean rate of Action potentials (APs)/s. ± SEM (standard error of mean), n=40 (number of recorded neurons)

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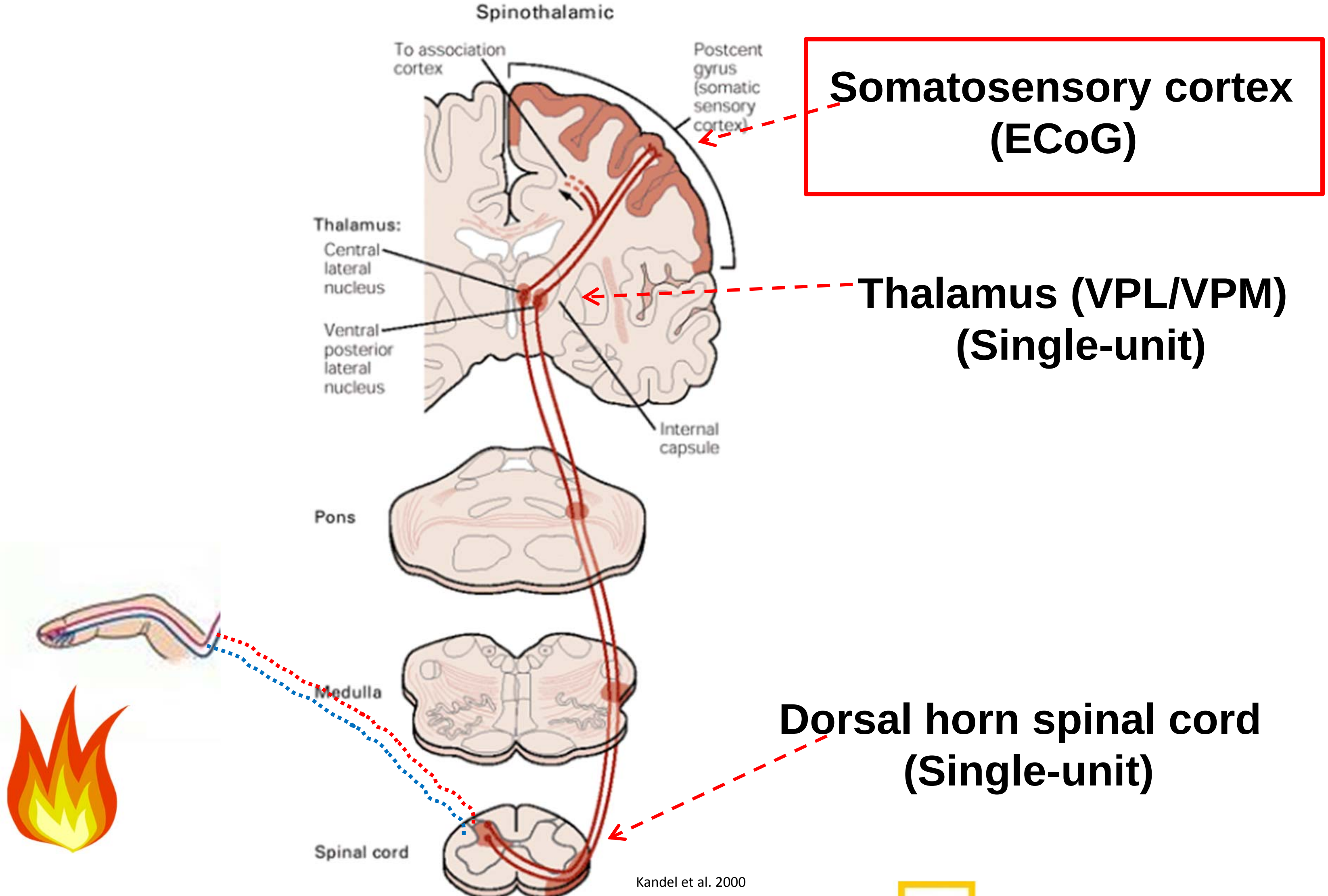
Problems and Issues with Single-Unit APs

- **Long-term recording of single-unit action potential has not been demonstrated in clinical practice.**

- **Adds extra surgical procedures to the implantation of DBS.**

Pain Pathways (Spinothalamic)



Hardware Characteristics to Acquire EEG/ECoG

(1) **Size and weight**

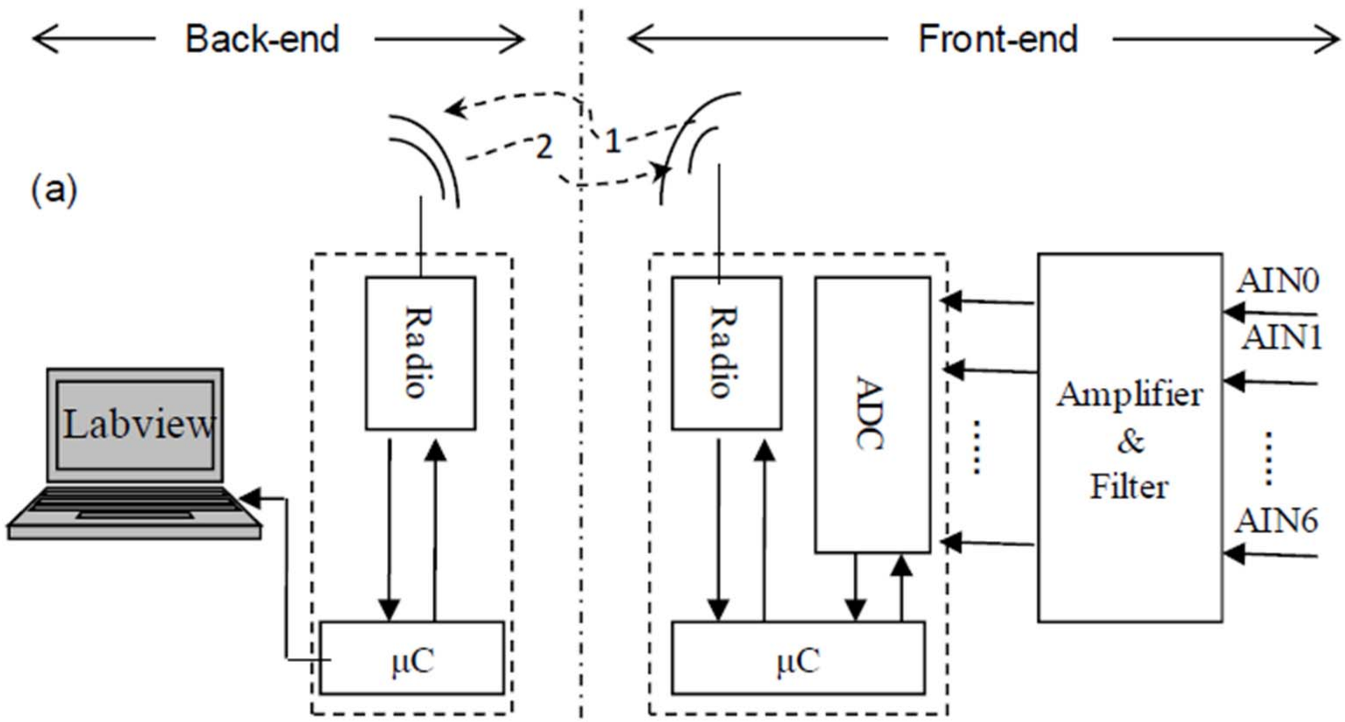
(2) **Wireless transmission**

(3) **Multichannel recording**

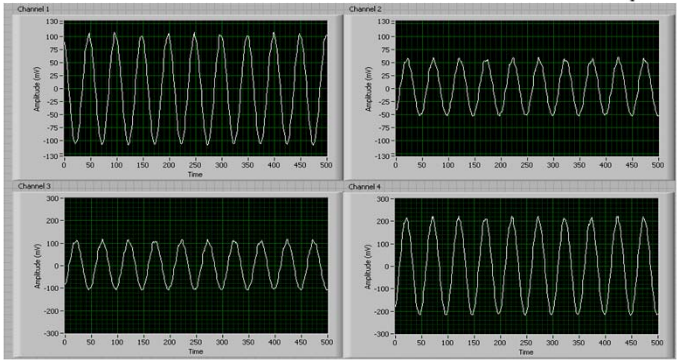
(4) **Energy consumption**

(5) **Cost efficient**

Multichannel Wireless System to Acquire EEG/ECoG



(b)



(c)

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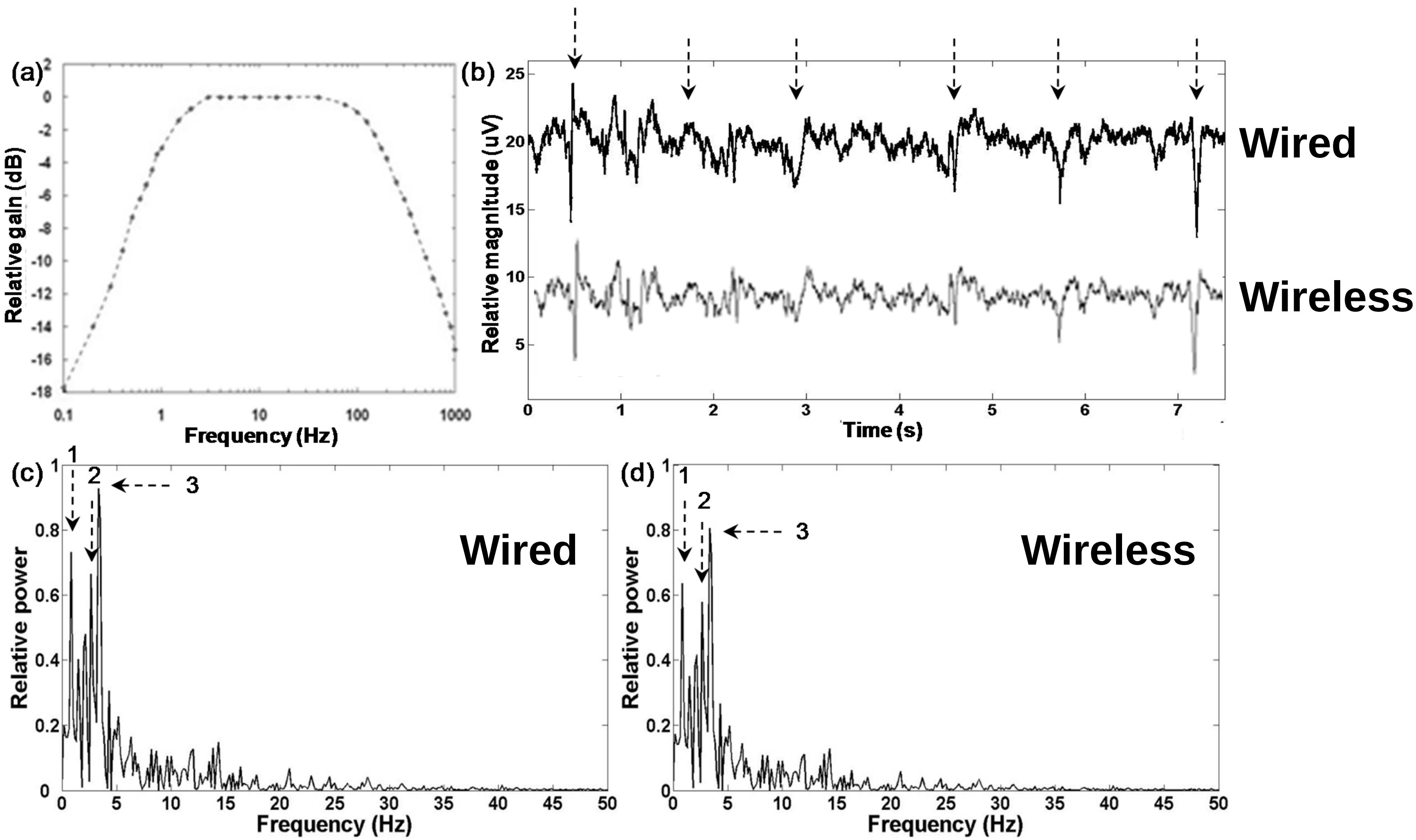
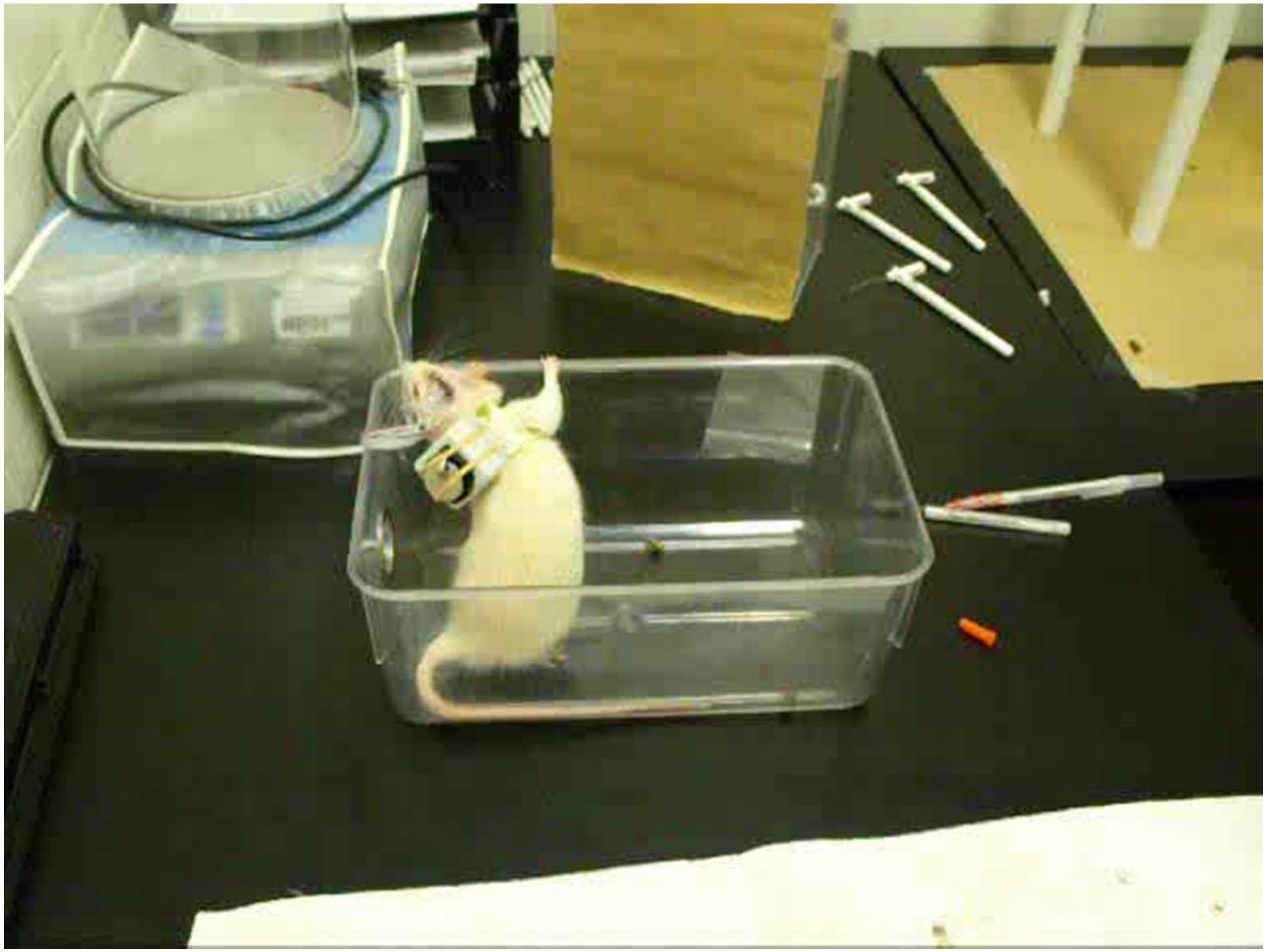
Comparing Wired and Wireless Systems



Video of a Rat with the ECoG Front-end

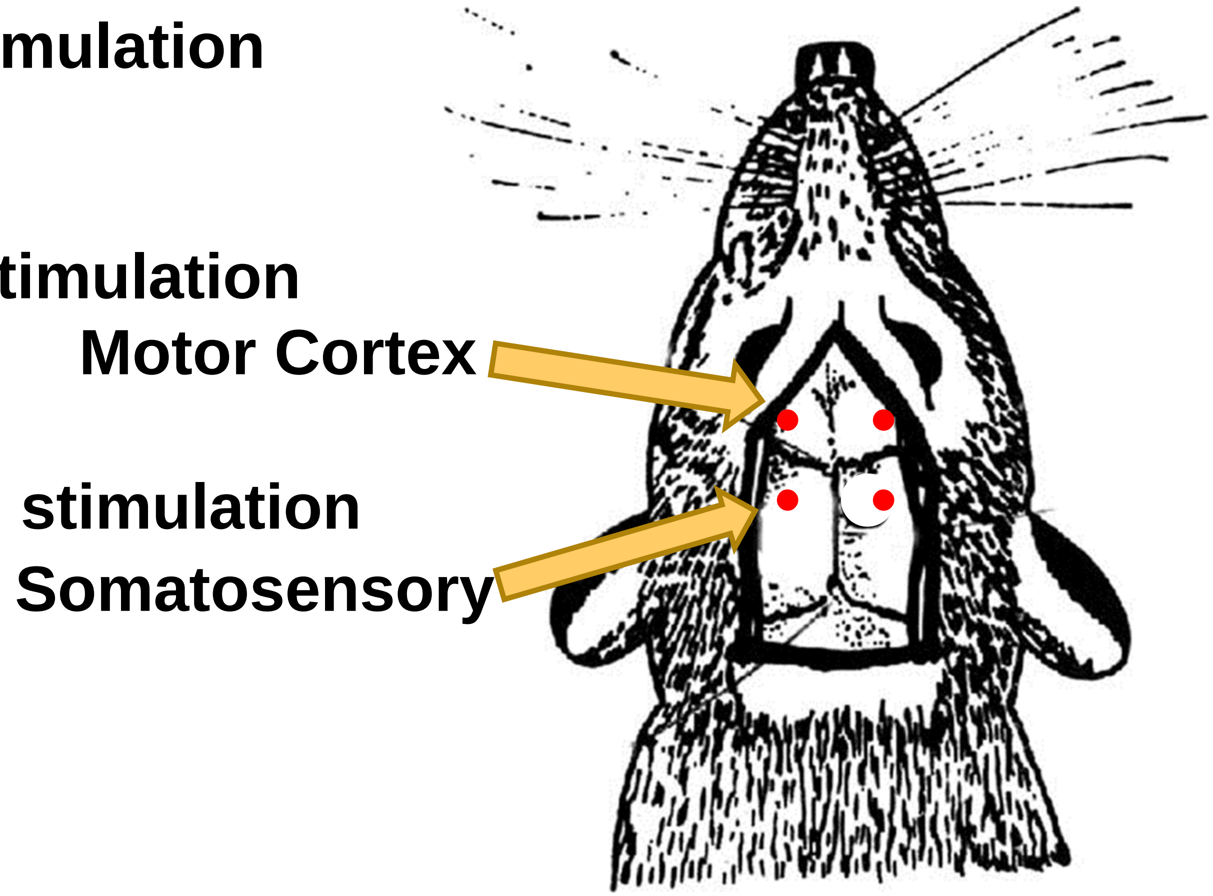


Experimental Procedures

1. Thermal stimulation

2. Chemical stimulation

3. Mechanical stimulation



Ling et al. 2004

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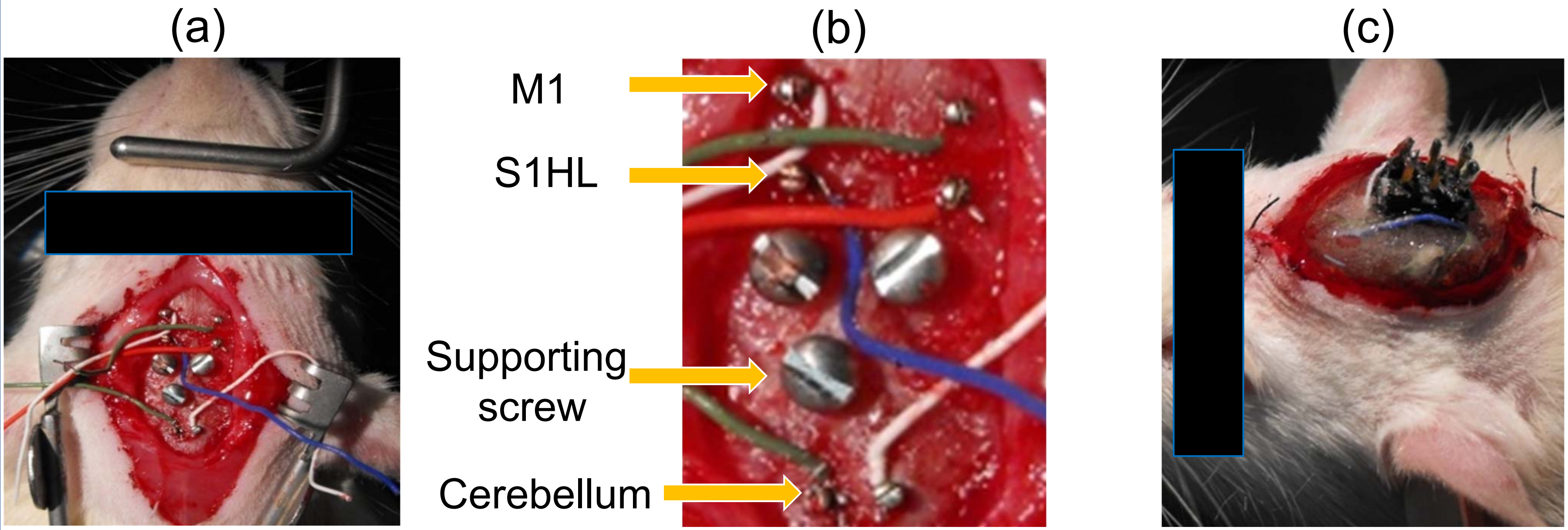
Implantation Methodology



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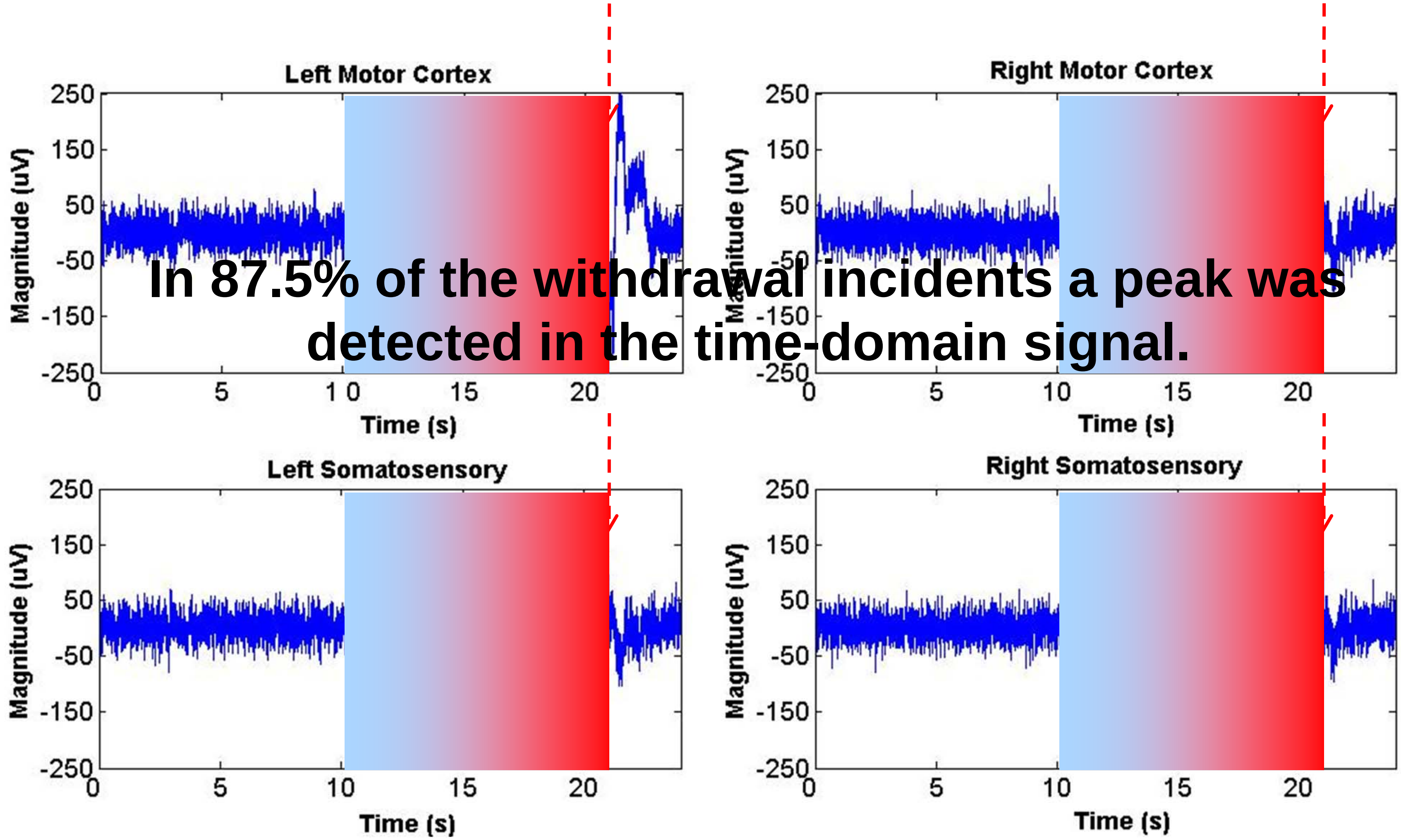
Thermal Stimulation in Right Paw



In 87.5% of the withdrawal incidents a peak was detected in the time-domain signal.

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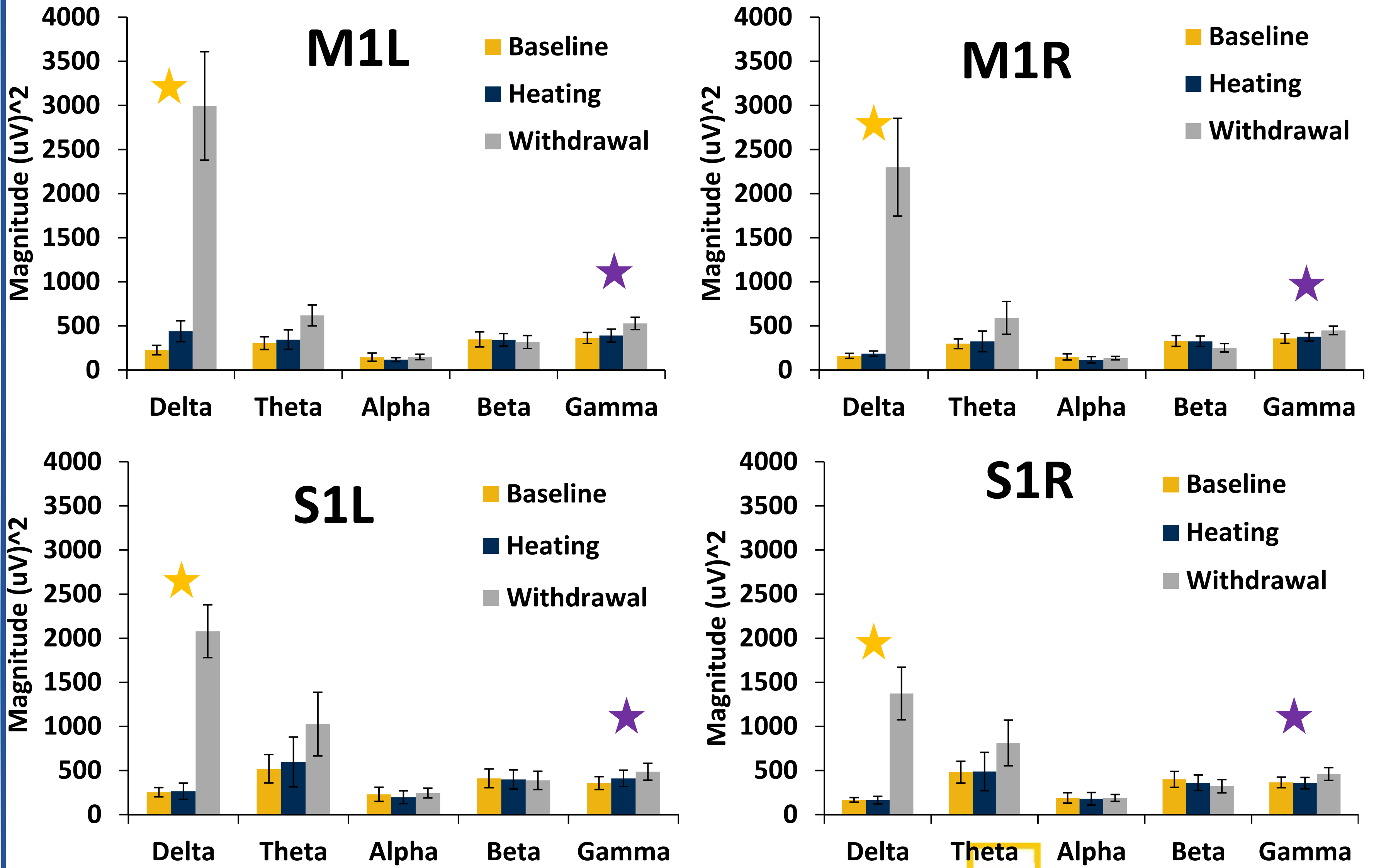
Power Spectrum in Various Frequency Bands for Thermal Stimulation to Right Paw



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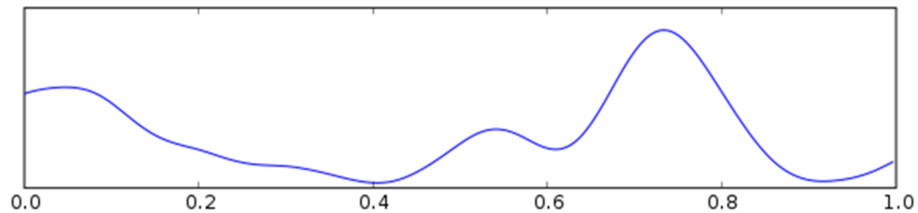
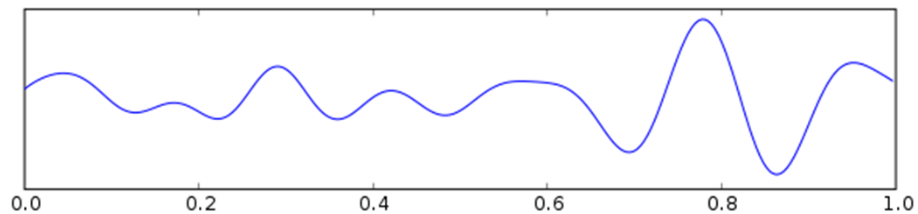
Background on EEG/ECoG

Delta (up to 4 Hz)



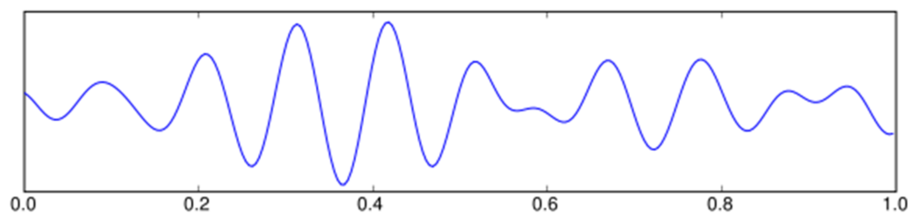
Sleeping

Theta (4 - <8 Hz)



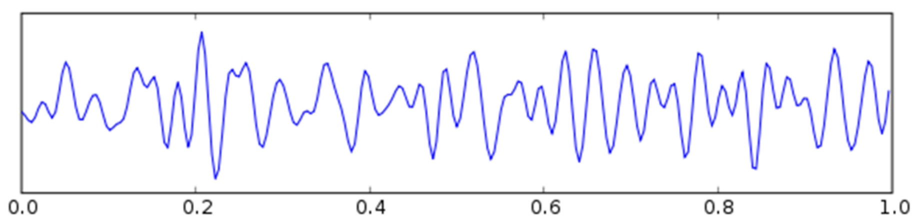
Drowsy

Alpha (8 - <13 Hz)



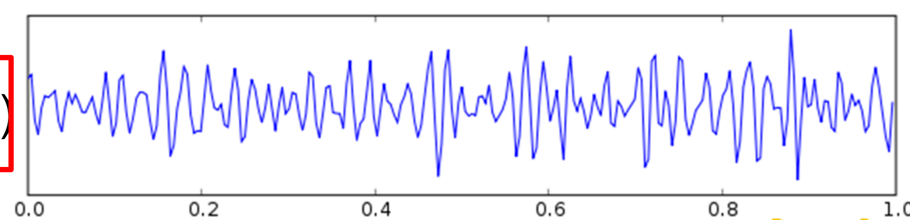
Relaxed

Beta (13 - <30 Hz)



Alert

Gamma (30 - 100 Hz)



Complicated Sensory Processing

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Treating Neural Disorders: Neurostimulation

Chronic Pain

Gastroparesis
GERD

Epilepsy
Depression

Respiratory Support

Parkinson's Dystonia

http://pcnews.ro/wp-content/uploads/2008/02/_dbs-depression-side300.jpg

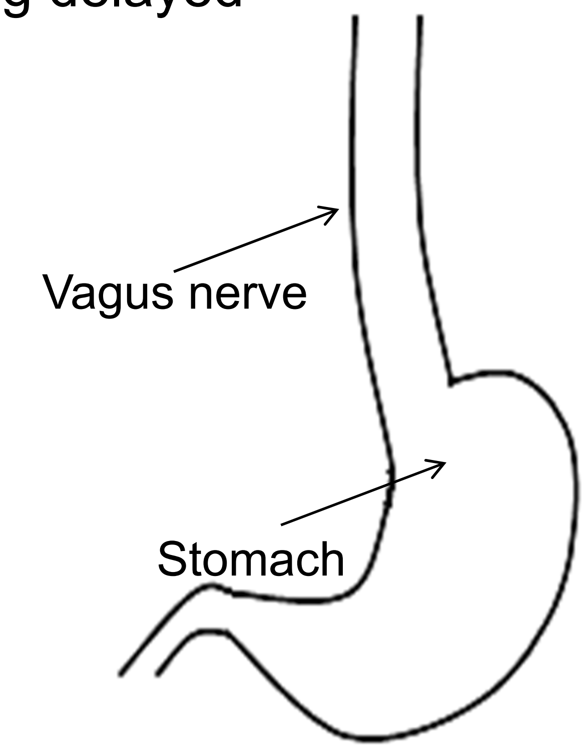
Incontinence
Sexual Dysfunction

Alzheimer's
Huntington's

Obesity
TBI

Gastroparesis

- Vagus nerve is damaged / Gastric emptying delayed
- Stomach does not move



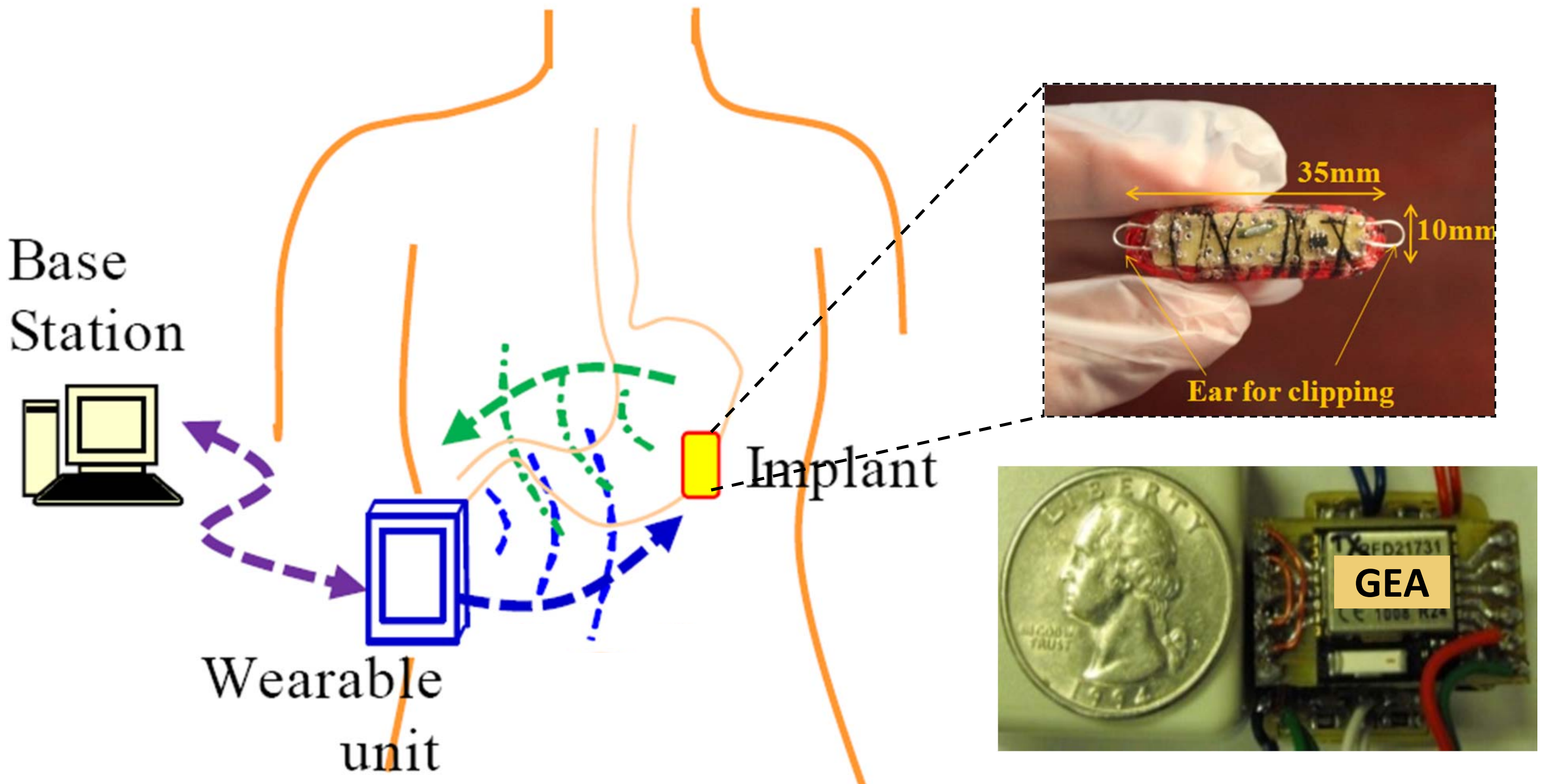
Symptoms

- Nausea
- Vomiting
- High / low blood glucose levels

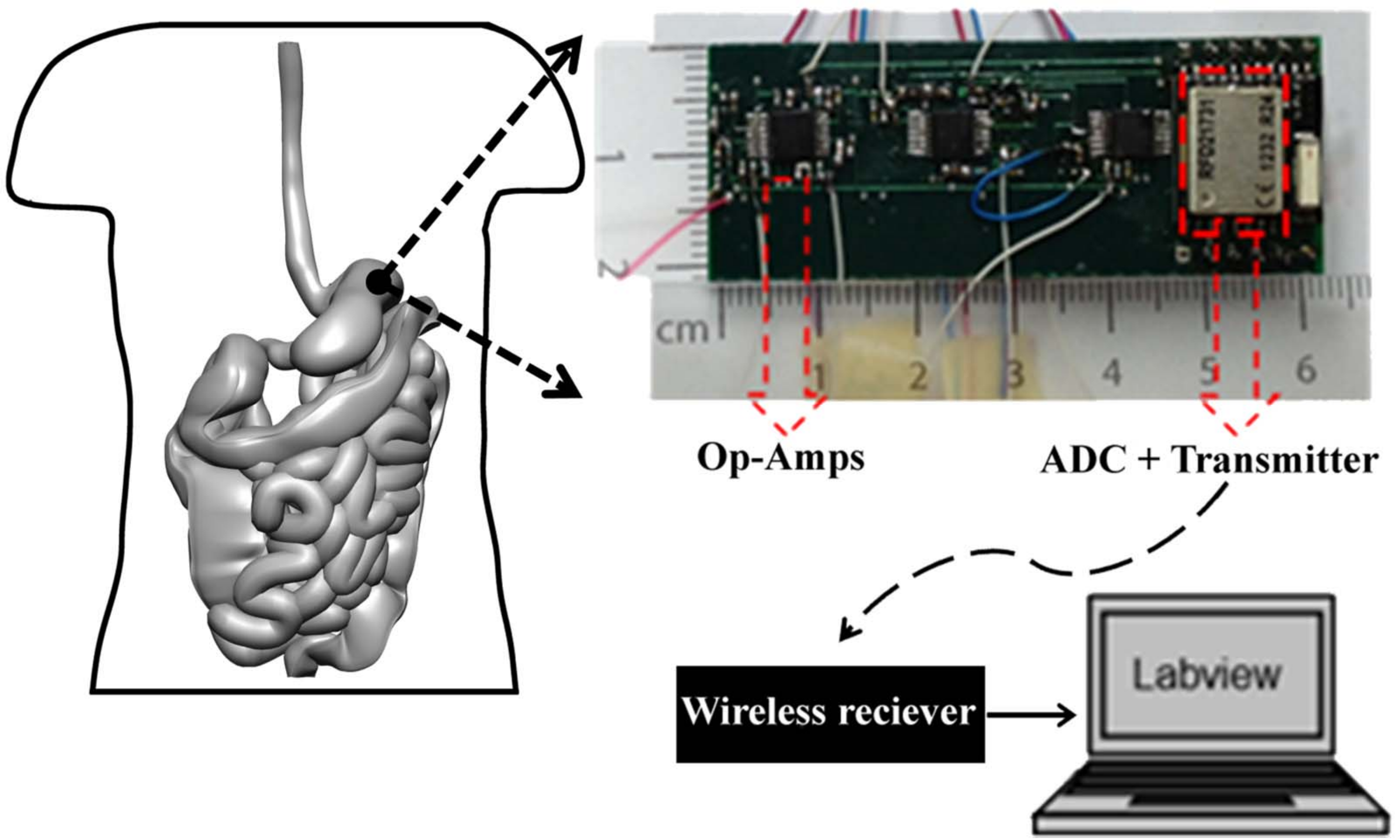
Statistics

- 40-50% of diabetic population suffers from Gastroparesis
- 25 million people in the US suffering from Diabetes in 2010

Integrated Solution for Relieving Gastroparesis

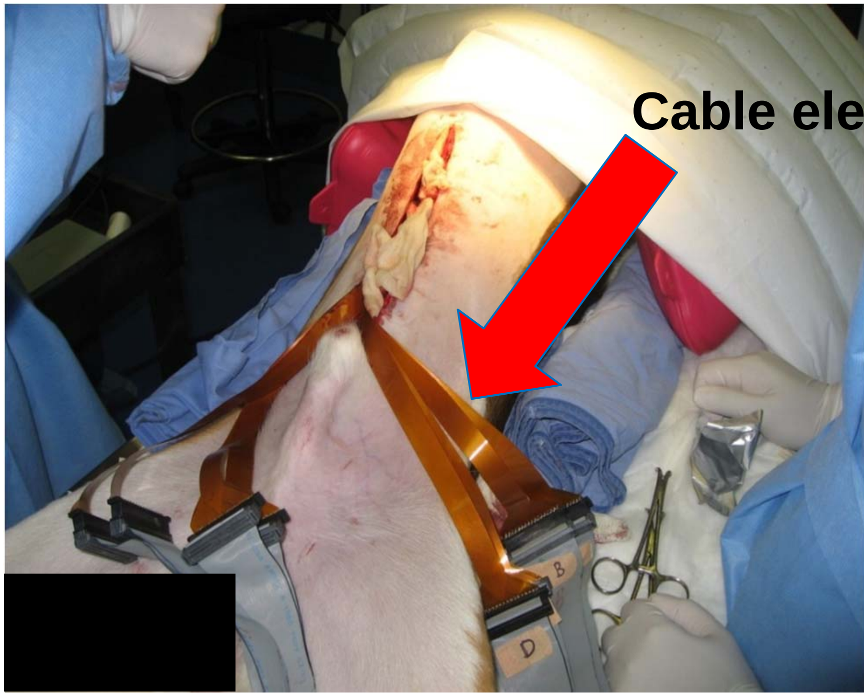


Acquiring Gastric Electrical Activity (GEA)

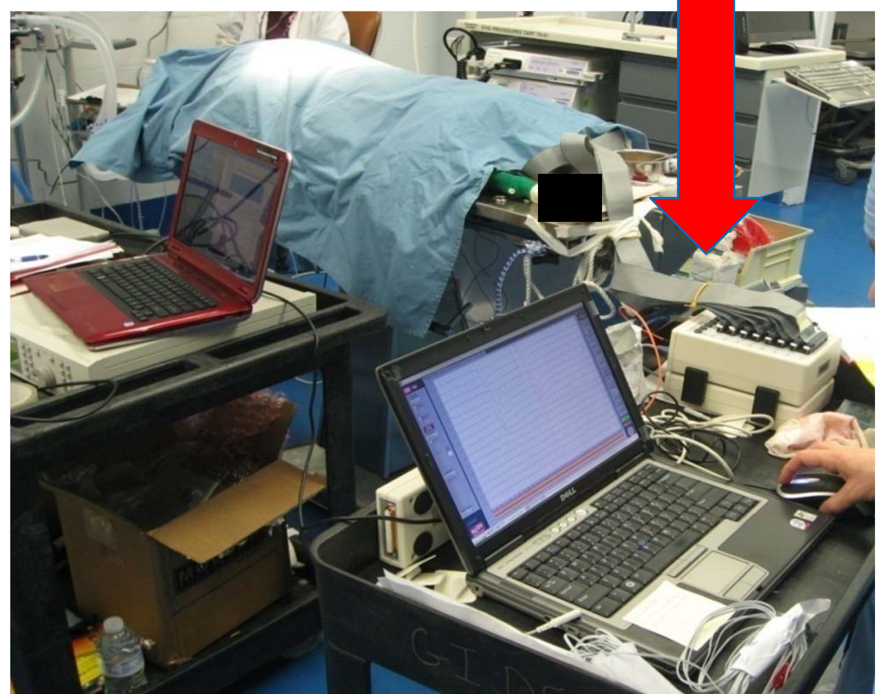


In-vivo Experiment for Recording GEA

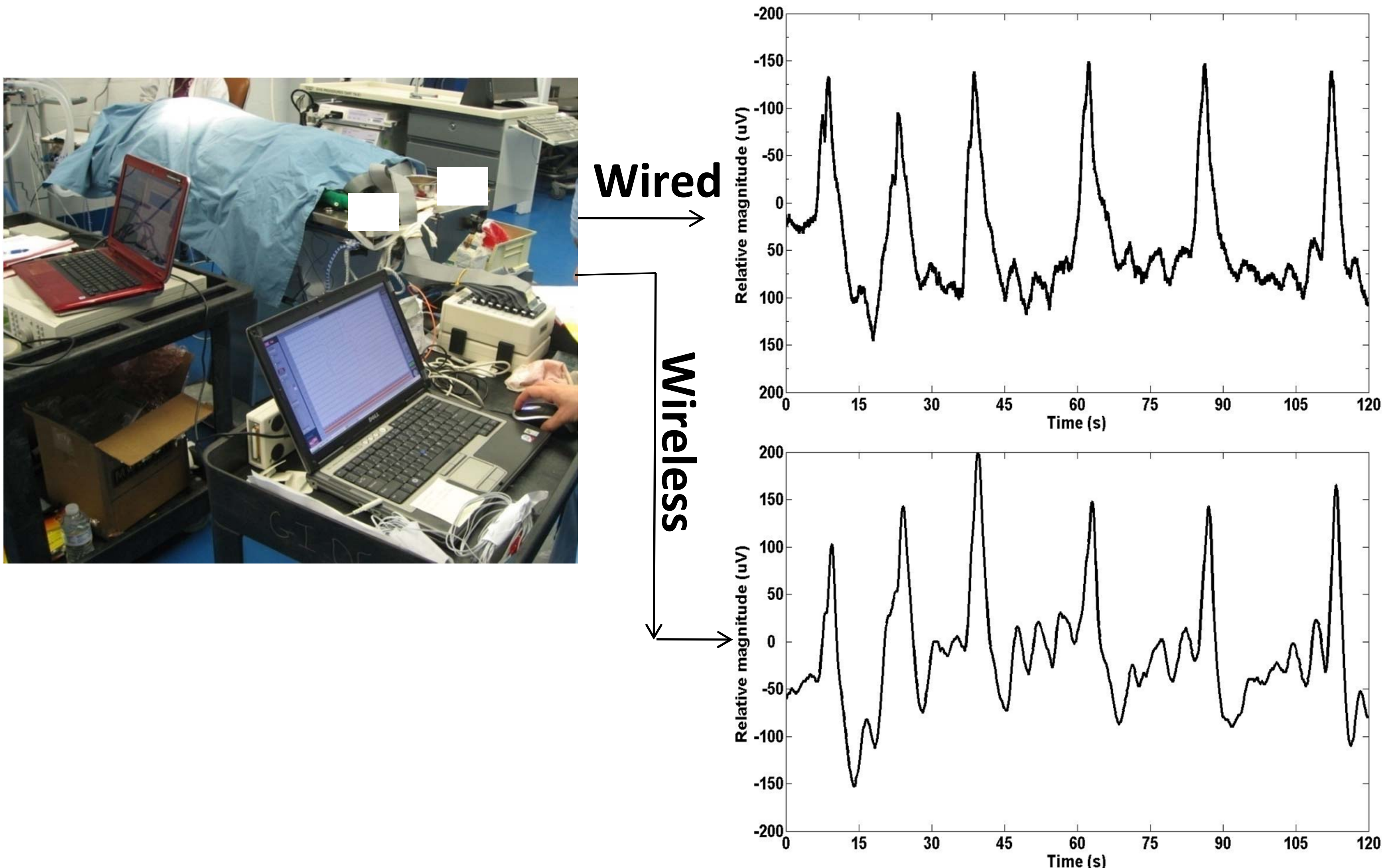
Cable electrodes



Recording system



Results for GEA



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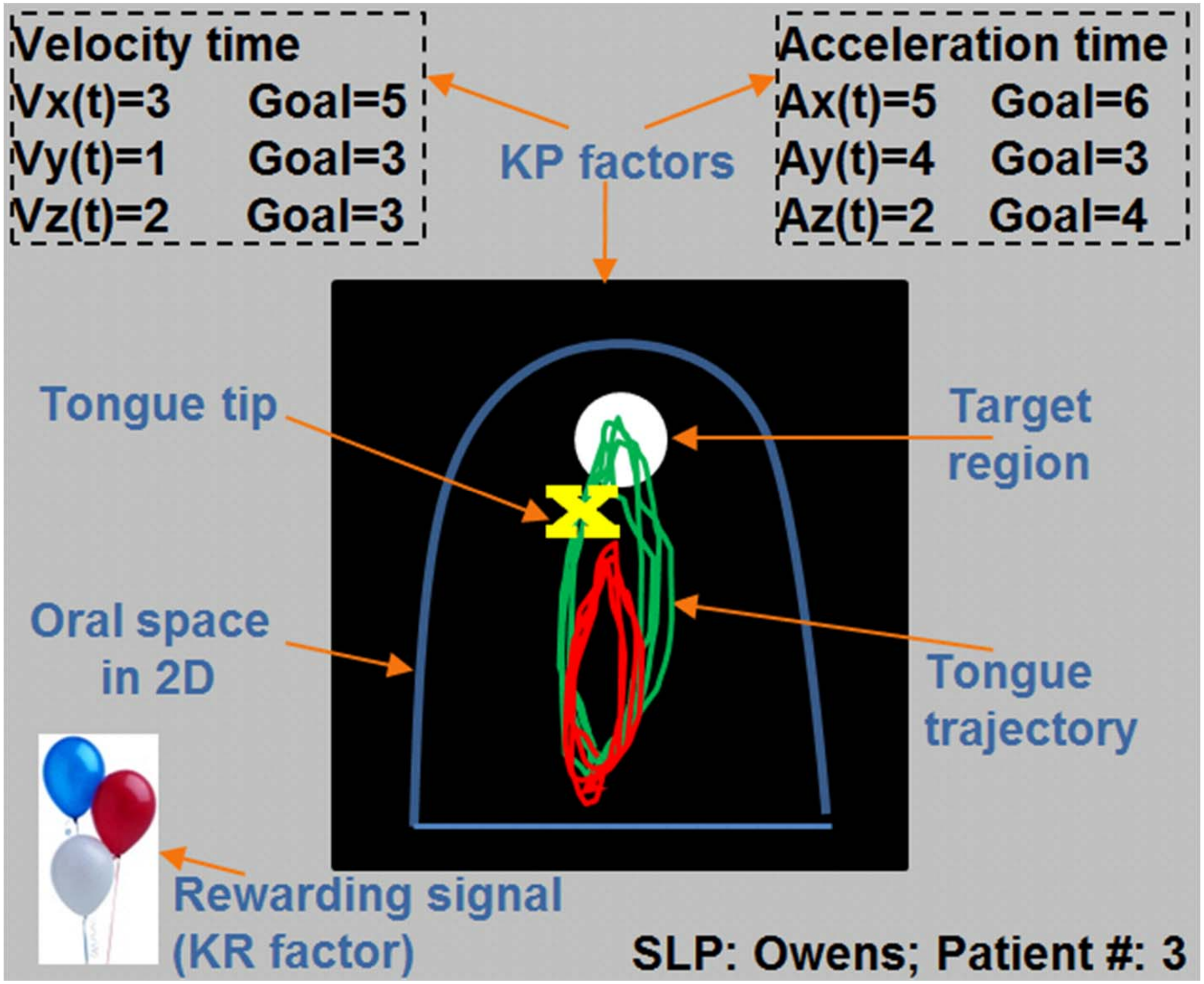
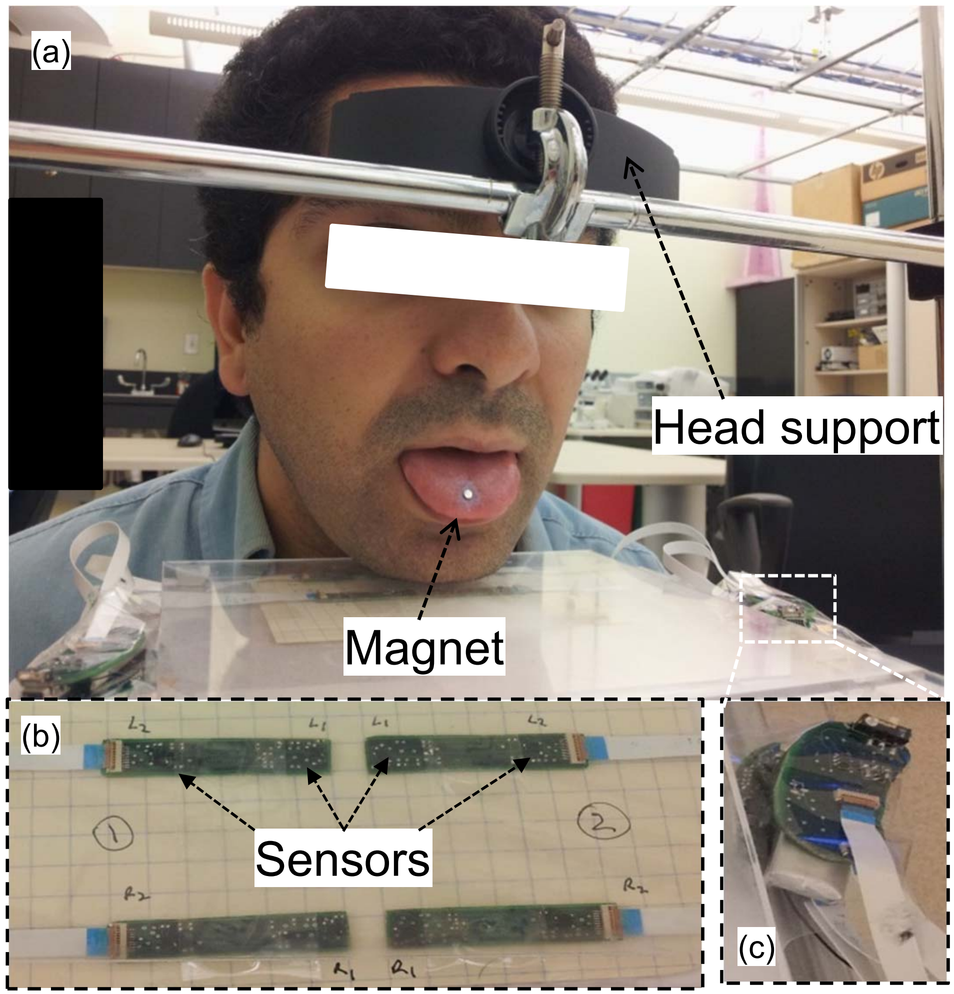
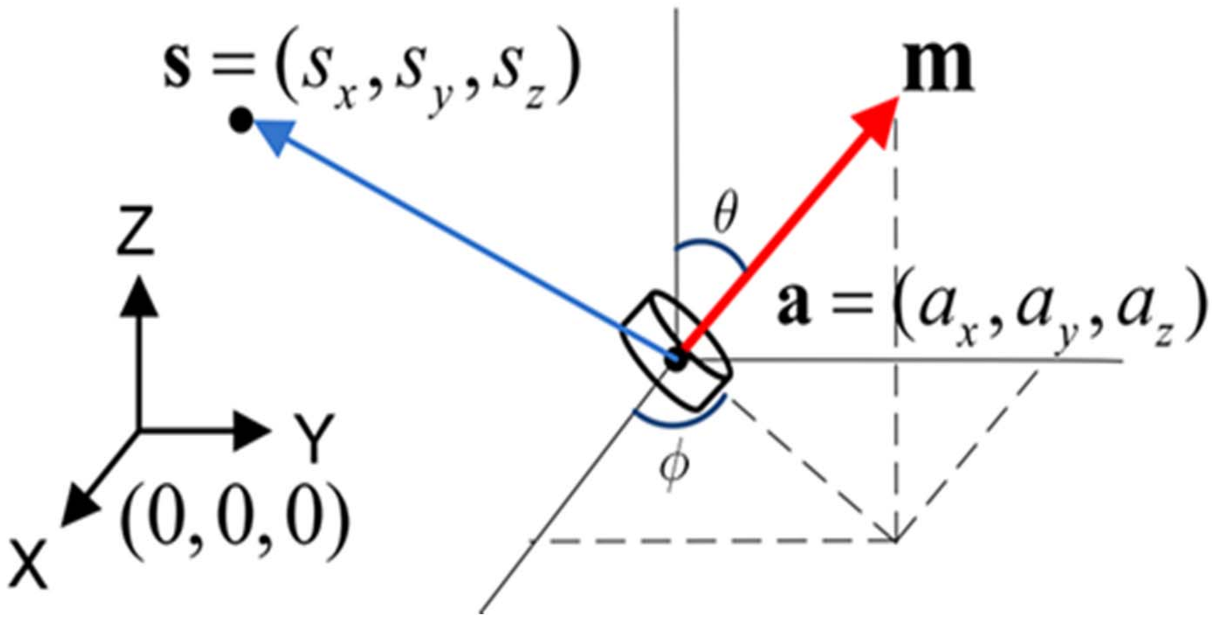
Visual Biofeedback for Speech Impairment



Tongue Tracking Systems (TTS)

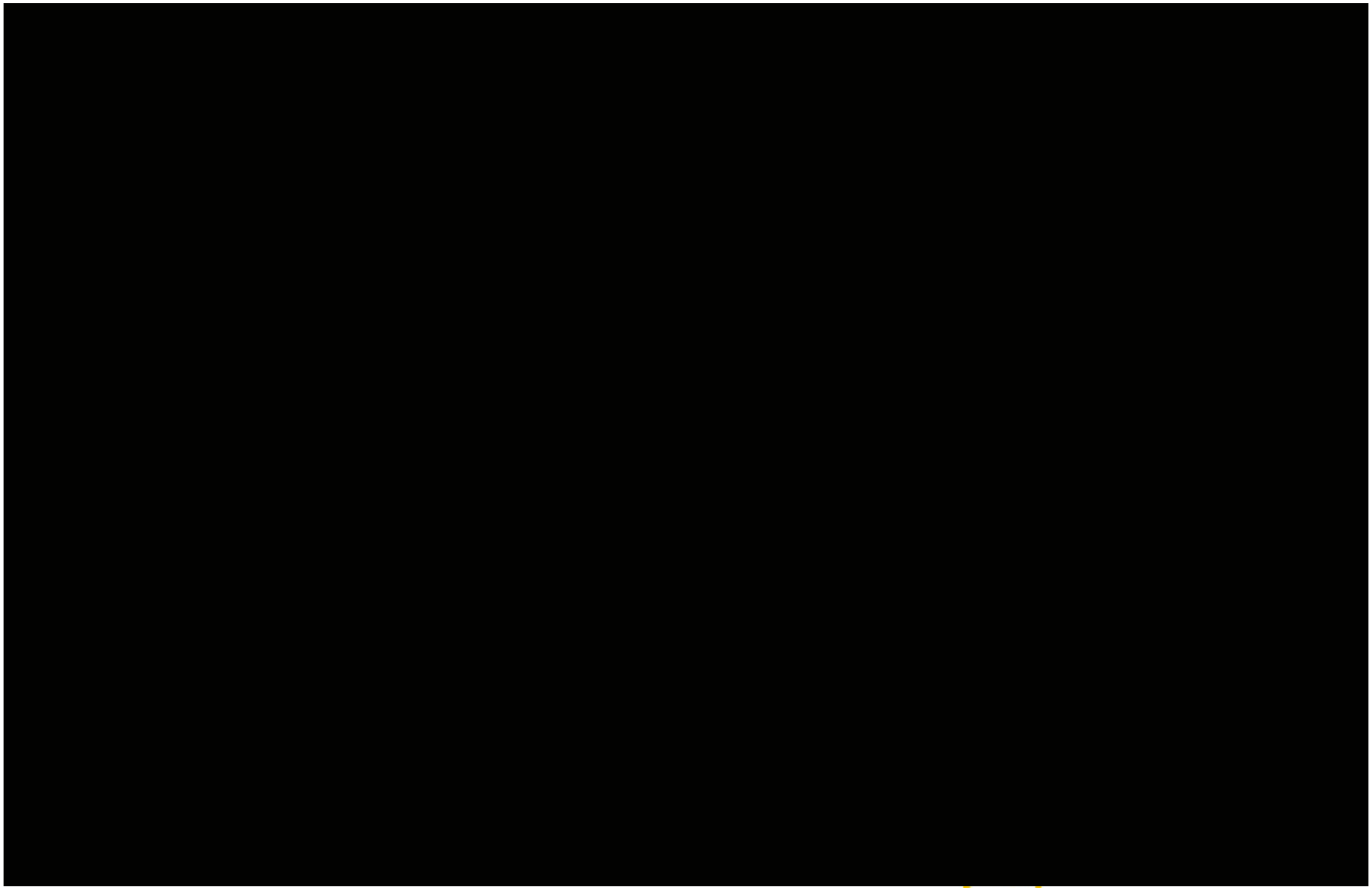


Mathematical Model for A Magnetic Dipole

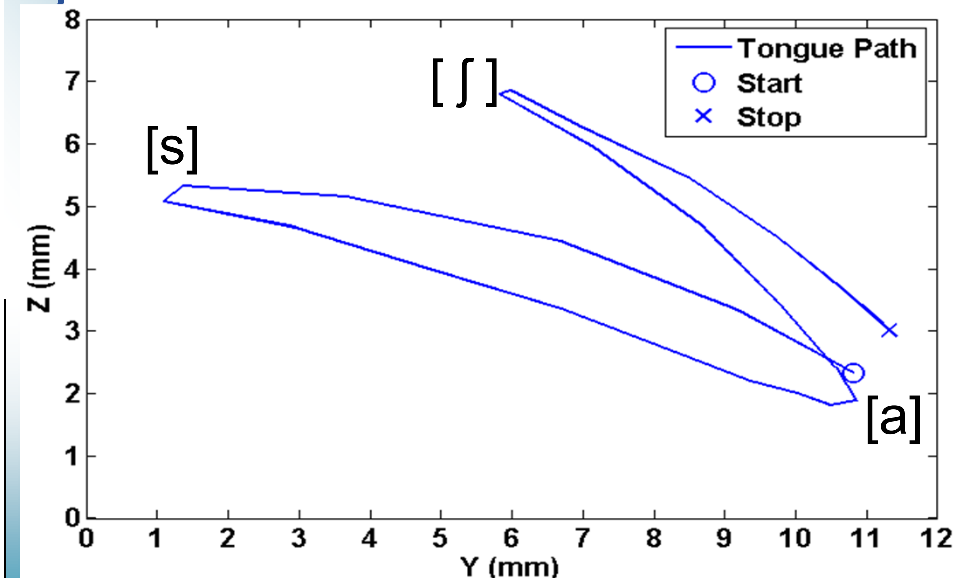


$$B(s,a,m) = \frac{\mu_o}{4\pi} \frac{3[m \cdot (s-a)](s-a) - \|s-a\|^2 m}{\|s-a\|^5},$$

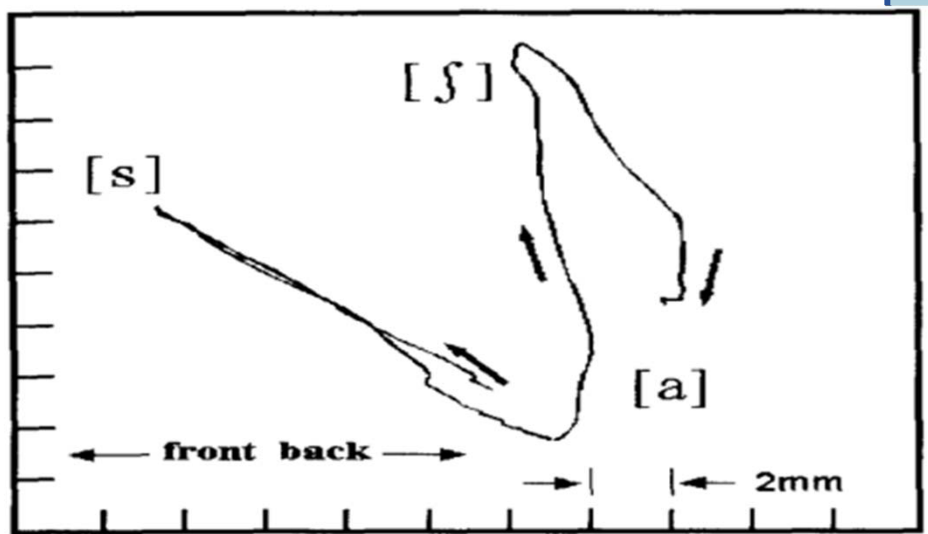
Tongue Tracking Systems (TTS)



Human Subject Experimental Results



Recorded by our TTS System



Recorded by Carstens (Katz et al.)

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Conclusion

Integrated Closed-loop systems are the game-changers of future wearable / implantable medical systems and assistive technologies since they can improve the quality of human life more efficiently, help patients live independently, and significantly reduce clinical costs.

Acknowledgements

- Drs. Balagani, Delgosha, Abramson, Krishnamachary, NYIT
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- National Science Foundation/ National Institute of Health
- Texas Instrument

IMS Lab Members

Questions?

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