

# Painometry: Wearable and Objective Quantification System for Acute Postoperative Pain

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# Motivation

The United States has faced an opioid epidemic.

- 40,000 lives lost annually
- 50 million surgeries, 70% opioid prescriptions
- 25% misuse, 10% addiction, 5% heroin
- 80% heroin users started by misusing prescription meds.

## Utah Opioid Misuse: By the Numbers

By the Numbers:

### Prescription Opioid Misuse in Utah

Between 2000-15, there was a **400%** increase in drug overdose deaths in **Utah**.

 **117,000**  
Utahns misused pain relievers in the past year



**80%**  
of heroin users started by misusing prescription meds.



There were **466** opioid-related overdose deaths in **Utah** in 2016.



An estimated **3.2 million** people in the U.S. (aged 12 or older) reported past month misuse of pain relievers.



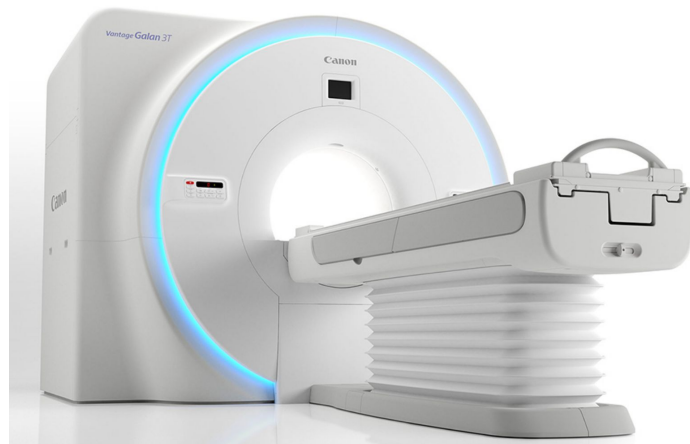
Each day, over **174 people** die as a result of a drug overdose in the United States.

\*Sources include: Prescription Drug Overdoses, Utah Department of Health's Violence & Injury Prevention Program; Utah Opioid Summary, National Institute on Drug Abuse; National Survey on Drug Use and Health, SAMHSA; Center for Disease Control and Prevention; 2015 and 2016, JAMA; CDC; Heroin use and misuse in the United States among commercial users of prescription pain relievers - United States, 2002-2014 and 2009-2012; Drug Abuse; Depend, 2013-2015; 12-95-102, 2017; National Survey on Drug Use and Health, September 2016; Centers for Disease Control and Prevention; Increases in Drug and Opioid-Involved Overdose Deaths - United States, 2010-2016.

# Motivation

Current pain management methods:

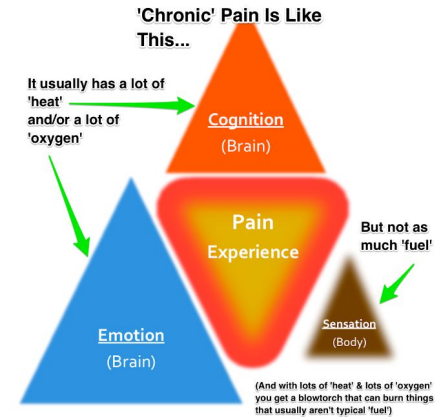
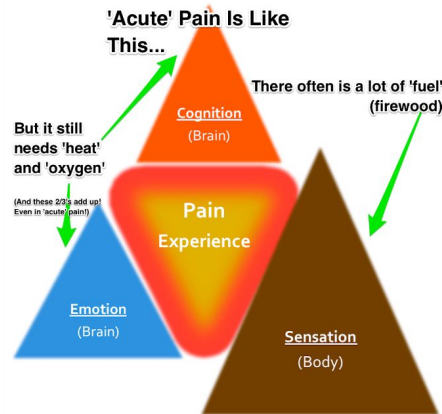
- fMRI
- Invasive nervous sensor
- Self-reporting
  - Subject to cognitive load and emotion
  - Bias from suggestion
  - Limit in availability



# Background information

## Some physiology about pain and opioid misuse

- Balance is the key
- Acute vs chronic pain
- Overdose vs underdose



# Problem Formulation

## Goal of the project

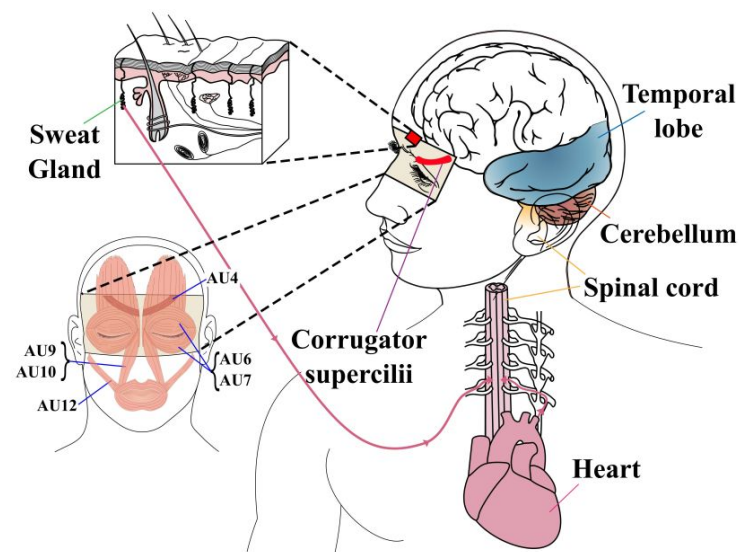
- Wearable
- No human involvement
- Quantifiable and objective
- Non-invasive



# Problem Formulation

What we rely on

- ANS(autonomous nervous system)
- hypothalamus and limbic brain
- Facial expression(44 AUs)
- EEG, GSR, SIP, PPG



# System Development

- Sensitive / high resolution muscle activity sensing
- Reliable / Safe System
- Highly Accurate / Lightweight

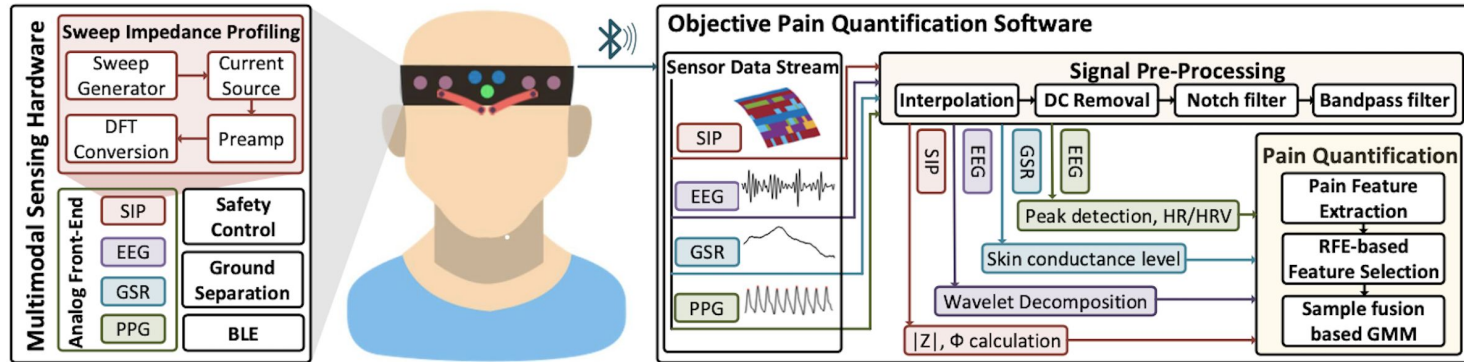
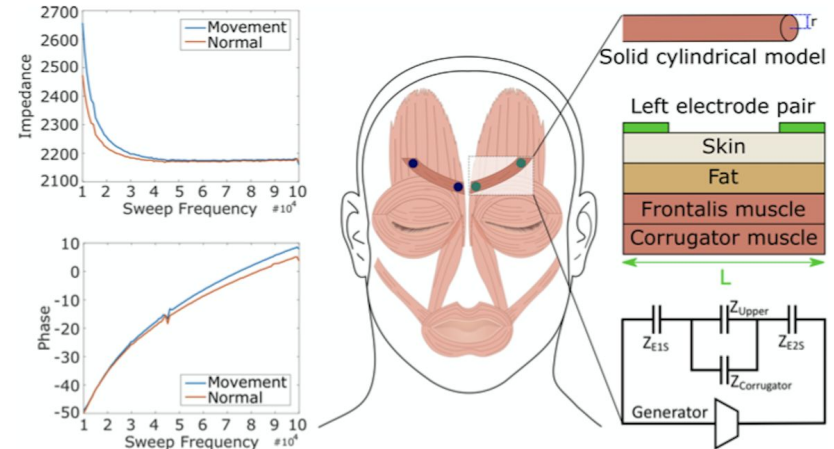


Figure 3: Painometry System Overview. Sensing data collected with multimodal sensing hardware (Left) and streamed via Bluetooth to software on host device (Right) that process data stream, extract pain features, and quantify pain level.

# Sensitive / High Resolution

- Traditionally, EMG used
- Crosstalk noise, nearby muscle activity
- Use SIP, measures impedance



**Figure 4: SIP sensors over corrugator supercilii and the corresponding circuit.**

# Reliable and Safe

- Many sensors, very small hardware
- Crosstalk interference
- Active sensors (GSR, SIP)



**Figure 7: Sensor placements in various Painometry form-factors.**

# Highly Accurate & Lightweight

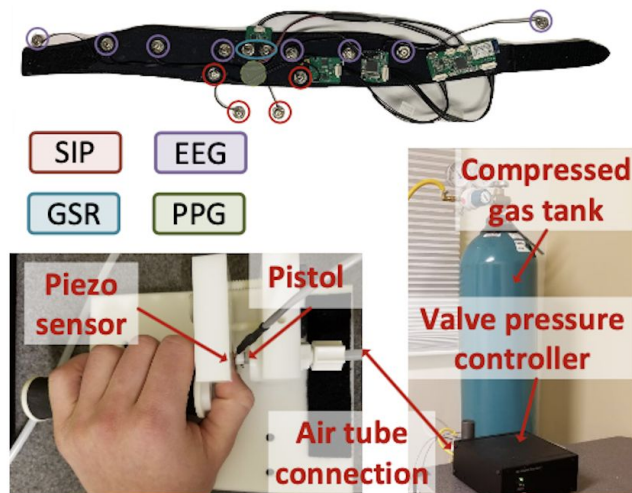
- Pain is subjective
- No universal set / existing quantifiable pain
- Recursive feature elimination to learn

# Evaluation

- Reliability / safety of experimental protocol
- Performance of pain quantification pipeline
- User experience

# Evaluation: Experimental Protocol

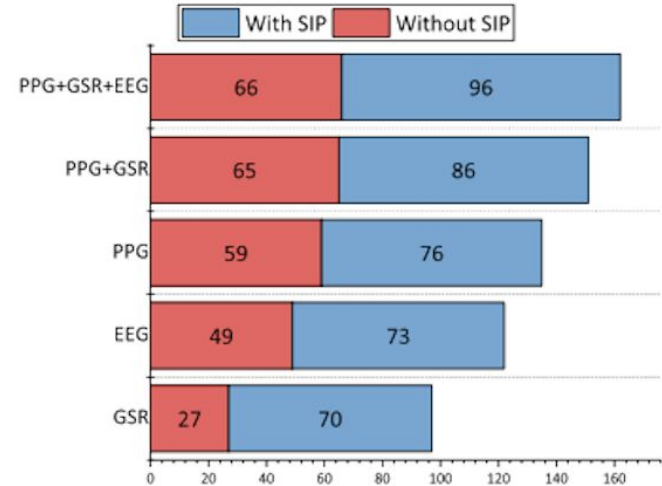
- Goals:
  - Distinguishable pain levels
  - Avoid short term pain tolerance
  - Safety of experiment
- Pressure Pain Device
  - Pressure, thermal, cold pain
  - Compressed air, piston
  - Clear and distinct pain
  - 3 levels given, pseudorandom order



**Figure 9: Painometry headband form-factor and pain-inducing experiment setup**

# Evaluation: Performance

- Accuracy, precision, recall
- Each sensor in isolation
- Leave one out cross validation
  - 22/23 to train, 23rd test
- SIP has a high impact --->
- Power considerations
  - 292.1 mW active
  - 56.8 mW idle
  - 500 - mAh : 5.6 hours active state



**Figure 13: Impact of sensor combinations**

# Evaluation: User Experience

- Difficult to quantify pain
- Willingness to wear ~ 15-30 min

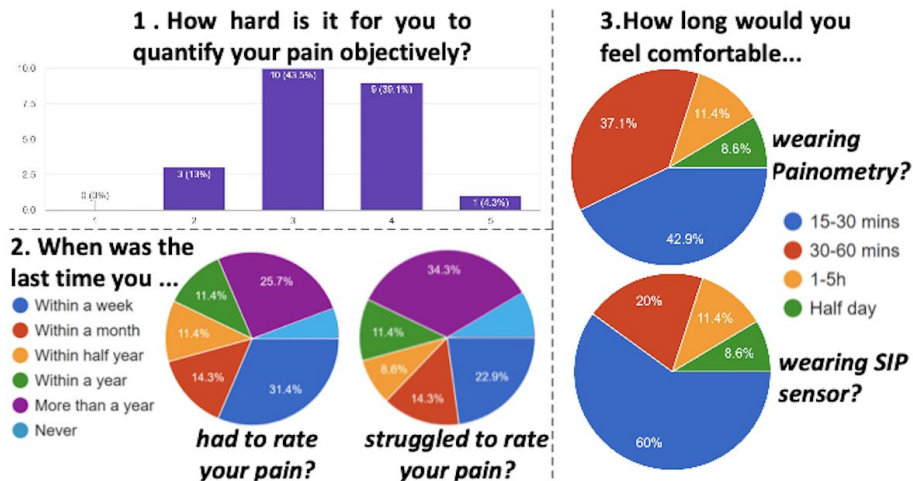


Figure 19: User study results

# Your Insight

- Problem very well defined
- Is objective pain a good measurement?
- Users' willingness to wear a device

# Your Insight

Probably not easy to commercialize

- Inefficient market with negative social externality
- Might be difficult to find pusher