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 has opioid misuse previously
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