



Is Thought the Future of Wearable Input?

Jim McKeeth

Embarcadero Technologies

jim.mckeeth@embrcadero.com

Computer-brain interface is a mainstay of science fiction, and devices are available today to use our brainwaves as a computer input. But is it practical? How far away is it? Will "Big Brother" read our thoughts and hack our brains?

In this class, we will dive into the future of thought as input for wearable devices with real-world examples and code. Demonstrations will be shown using the Emotiv EPOC headset, a revolutionary high resolution, neuro-signal acquisition and processing wireless neuroheadset that uses a set of sensors to tune into electric signals produced by the brain to detect thoughts, feelings and expressions.

You will see the EEG neuroheadset and computer interface with examples of interfacing with desktop, mobile and wearable apps. We will dive into the roots of the technology, showing code and examples along with big pictures of the technology. You will walk away with an understanding of how this still evolving and largely unknown technology really works, how it can be used, as well as longer-term implications.

Code used in the session will be made freely available and different tools and languages will be used in the demonstrations. There are no real specific prerequisites, but this isn't an introductory course.

About Jim McKeeth

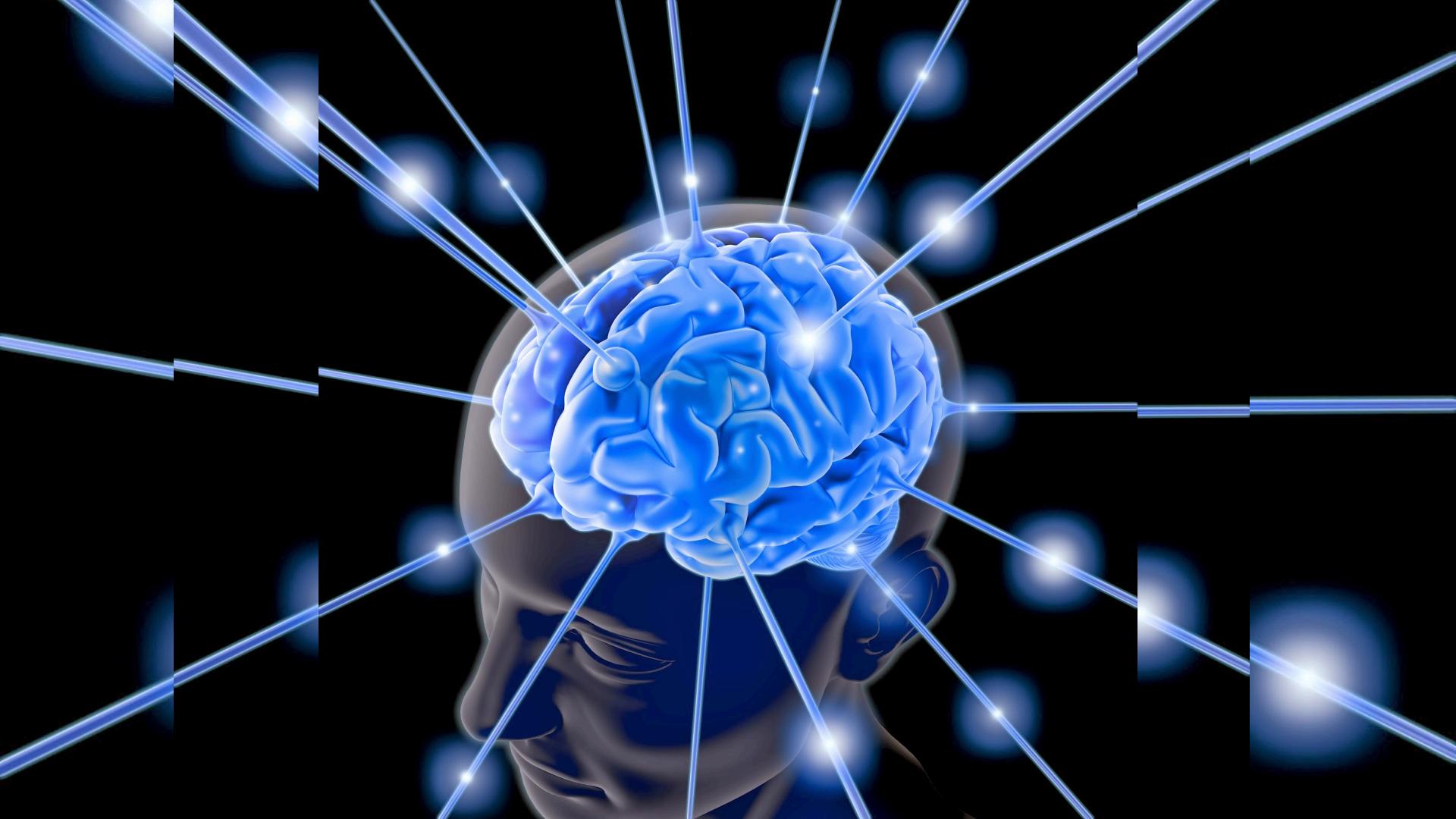
- Lead World Wide Developer Evangelist
- Host of [Podcast at Delphi.org](#)
- Longtime developer
 - Delphi, Java, C#, JavaScript, Objective-C, etc.
- Invented and patented swipe to unlock in 2000
 - US Patent # 8352745 & 6766456, etc.
- Improvisational performer with ComedySportz Boise
- *I am not a neuroscientist, but I find this all fascinating!*

About Embarcadero Technologies

- Provide software tools for developers, DBAs, and architects
- Over 3 million users worldwide
- Founded 1993, headquartered in San Francisco
- Over 500 employees
- Global presence with offices in 29 countries
- Over 90 of the Fortune 100 rely on Embarcadero products
- Products include:
 - Delphi, InterBase, DB PowerStudio, DBArtisan, ER/Studio

About Delphi

- Integrated Development Environment
- Native compiler for Win32, Win64, OS X, iOS & Android
- Multi-platform visual designer
- Framework for rapid prototyping and accelerated development
- Architecture allowing shared code across platforms
- Advanced language features like ARC, Generics, etc.



The Brain Computer Interface in
SCIENCE-FICTION

Monitor What you See



Record and Playback Senses & Experiences



The “Hat” from *Brainstorm* - 1983

Brain Computer Interface



Complete Reality Replacement



Brain-Computer Interface

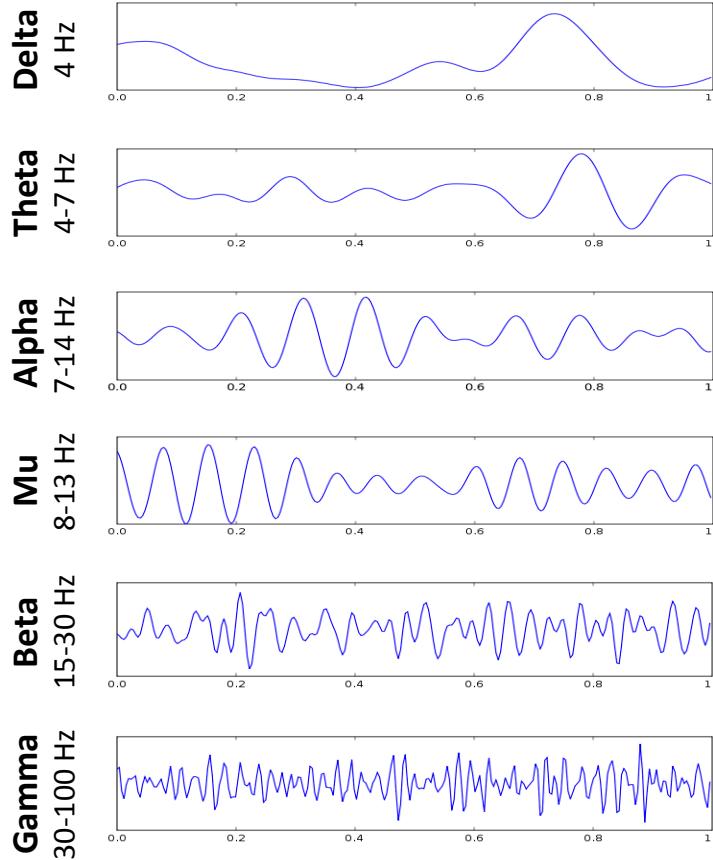
SCIENCE OF READING THE BRAIN

Vocabulary and Roots

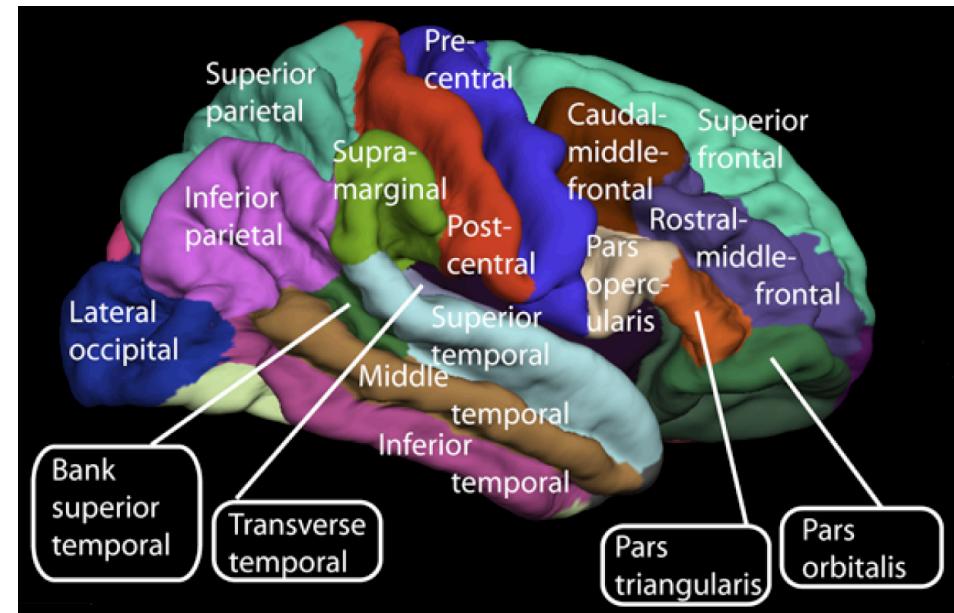
- Encephalon = *Latin*. The brain.
- -graphy (sufix) = *Greek*. One who draws or writes.
- Encephalography = Drawing (or picture) of the brain
- Poly- (prefix) = *Greek*. Many
- Tomos = *Greek*. Cut into parts or sections.
- Neuro- (prefix) = *Greek*. Relating to nerves or nervous system
- Hemo- (prefix) = *Greek*. Pertaining to blood.
- Dynamics = *Greek*. Active; in motion

Understanding the Brain

Neural Oscillation



Hemodynamics (Blood flow)



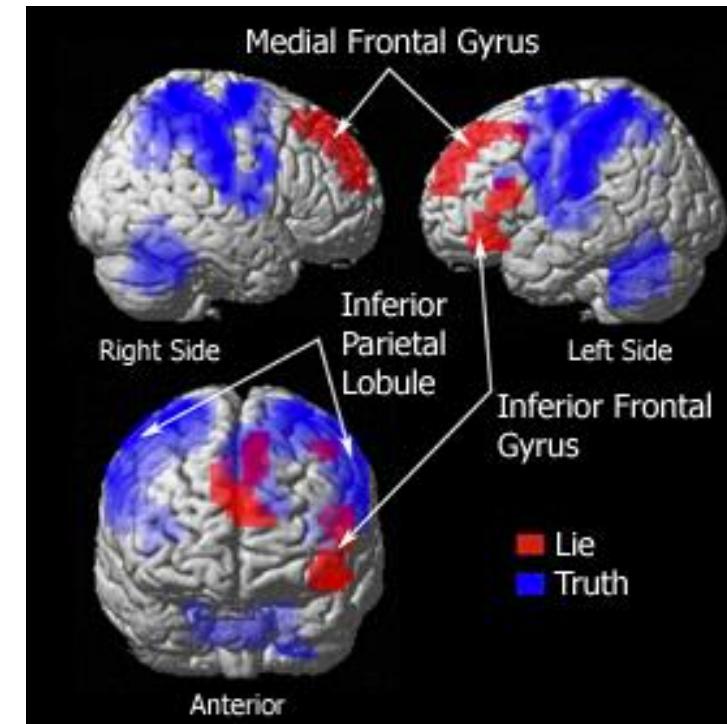
Polygraph (aka Lie Detector)

- Measures blood pressure, pulse, respiration, skin conductivity, etc.
- Looks for changes during questioning.
- Requires specialized training by operator.
- *Validity challenged.*



Magnetic Resonance Imaging (MRI)

- Uses oscillating magnetic fields at different resonant frequencies.
- Function MRI uses software to analyze images.
- Shows activity (blood flow) in different parts of the brain.
- Combined with brain mapping can reveal thought information.



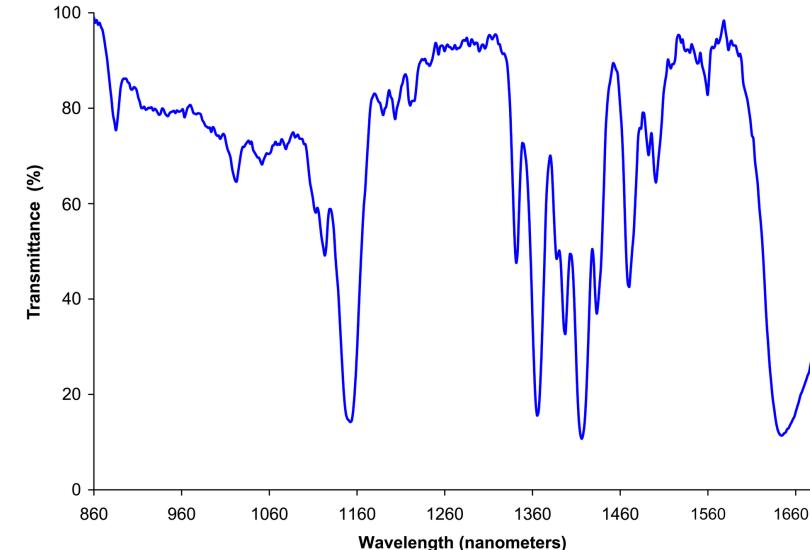
MRI Downsides



- Large
- Noisy
- Strong magnetic fields
- Slow process
- Very expensive

Near-Infrared Spectroscopy (NIRS)

- Spectroscopic use of near-infrared (700-900nm) light through the skull and detecting degree remerging light is attenuated.
- Detects blood oxygenation levels in different areas of the brain.
- More portable than fMRI but only scans cortical tissue.



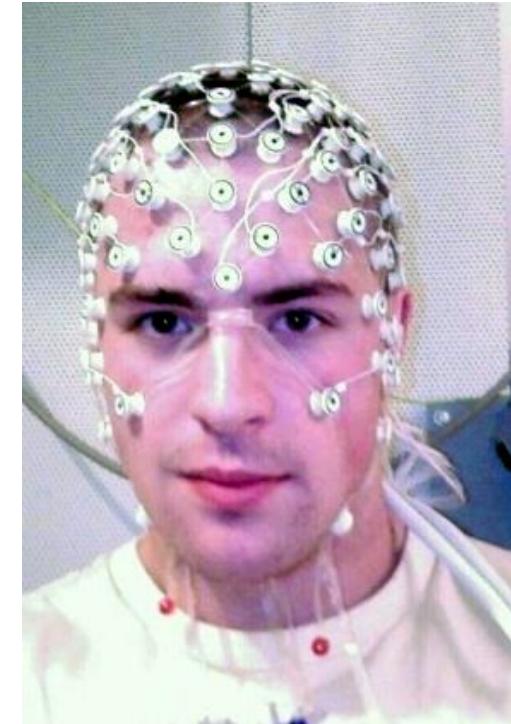
CT / CAT Scan (Computed Tomography X-ray)

- Faster & cheaper than an MRI
- Uses ionizing X-ray radiation
- Lower detail images
- Sometimes combined with *Positron Emission Tomography (PET)* scans which use **gamma radiation**.



Electroencephalography (EEG)

- Measures electrical activity along the scalp.
- Detects voltage fluctuations resulting from ionic current flows within neurons of brain.
- Millisecond-range resolution (faster than CT or MRI)

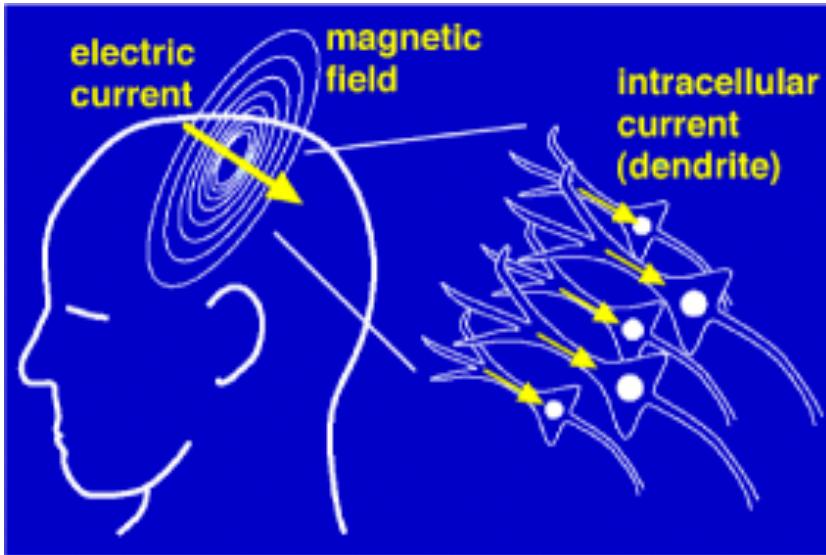


Electroencephalography

- Series of electrodes placed next to scalp.
- Difference in voltage is measured between each electrode and the reference.



Magnetoencephalography (MEG)

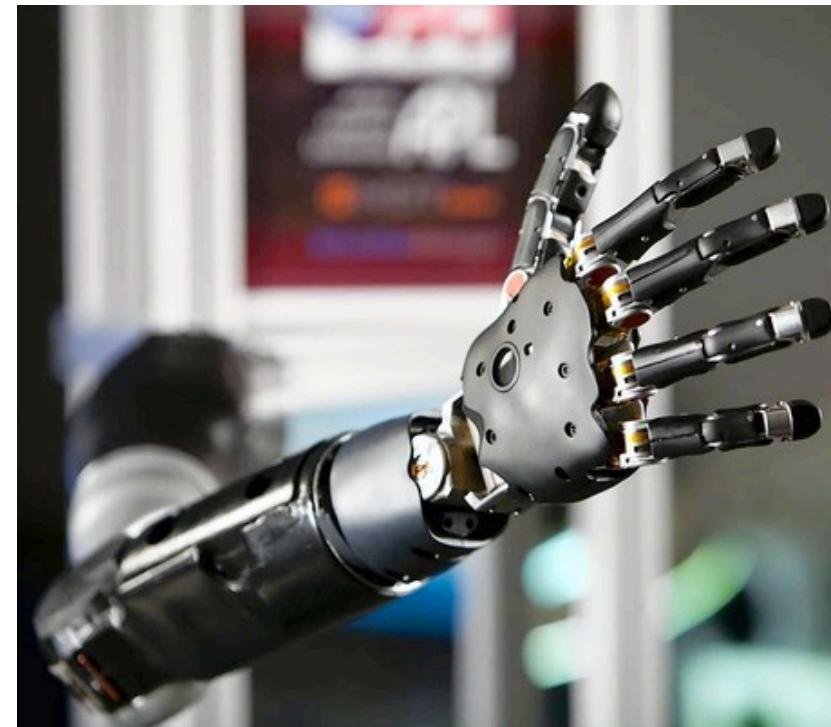


Uses Arrays of SQUIDs (superconducting quantum interference devices)



DARPA's Brain Controlled Prosthetic Arm

- Part of DARPA's Innovation Pathway
- Uses microchip implanted in brain
- 27 different fine grained controls to arm, hand and fingers



Identifying Your Thoughts

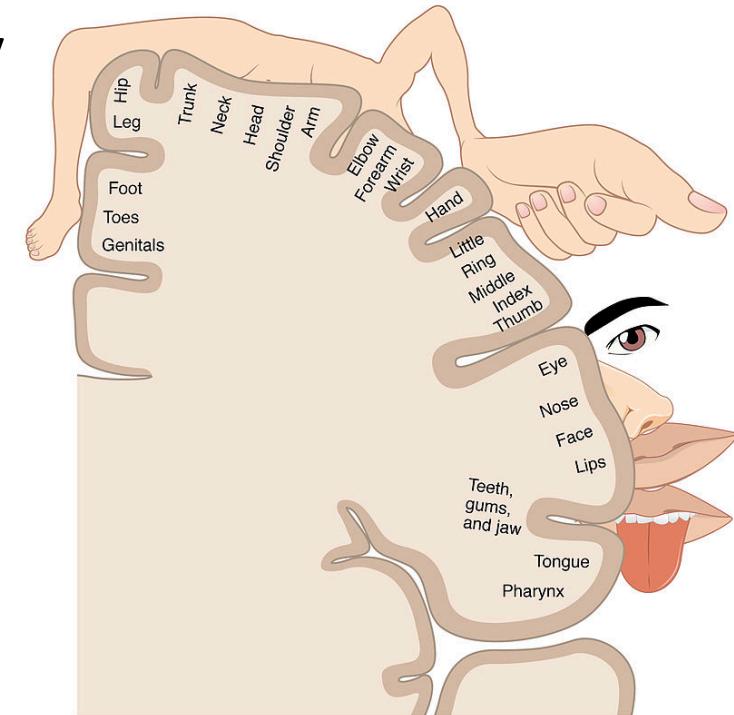
- 2008 – Brain researchers predicted subject intentions up to 10 seconds before subject expressed them.
- 2009 – Psychologists used fMRI to recognize which of 10 objects subject was thinking.
- 2010 – IBM filed patent US 20100049076 on process of facial recognition from human brain.
- 2012 – UC Berkeley paper on reconstructing sound from neural processing of electrical signals from brain.

Brain-Computer Interface

DIRECT BRAIN INPUT

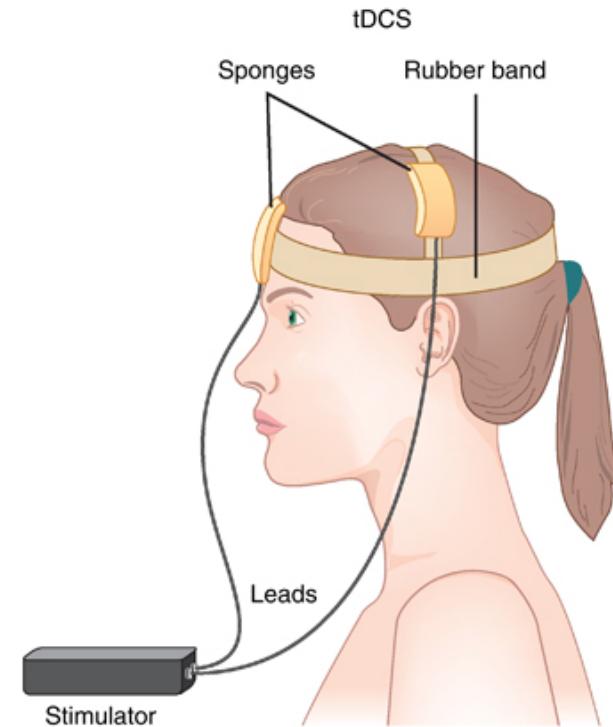
Cortical Stimulation Mapping (CSM)

- Application of electrodes directly to portions of the brain & mapping the results
 - Motor Mapping - movement
 - Language Mapping – speaking, reading & understanding
 - Somatosensory Mapping – sensory perception
- Used to target brain surgery



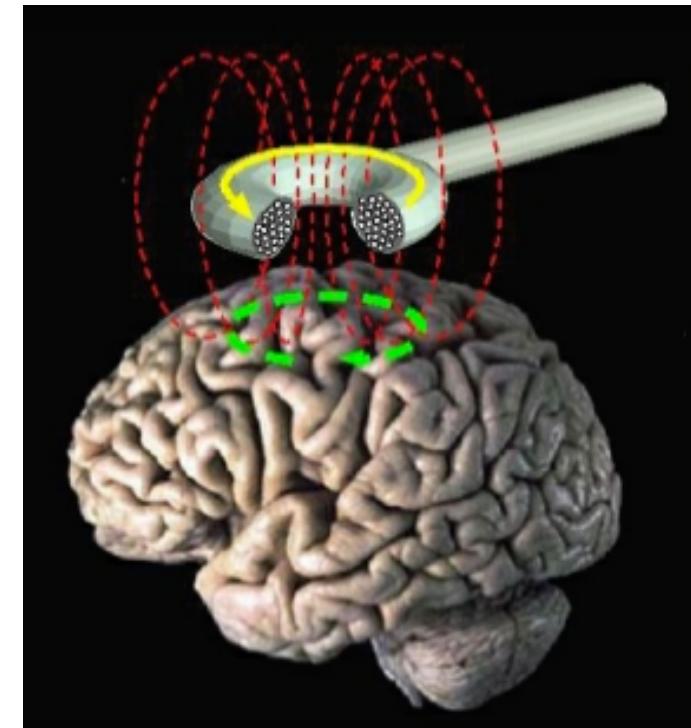
Transcranial Direct-Current Stimulation (tDCS)

- Constant, low current delivered via small electrodes
- Results:
 - Increase cognitive performance
 - Enhance language & math ability
 - Improve attention span
 - Aid problem solving, memory & coordination



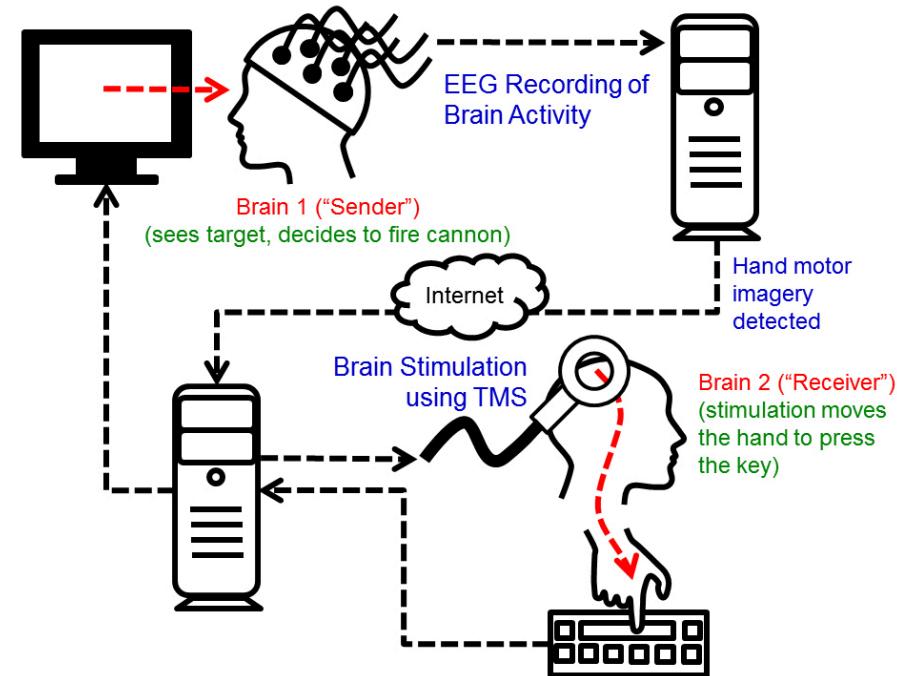
Transcranial Magnetic Stimulation (TMS)

- Similar strength to MRI
- Magnetic induction of electrical currents.
- Used to treat brain conditions.
- Produces:
 - Flashes of lights in vision
 - Muscular activity
 - Slight cognitive degradation



Brain-to-Brain Input at University of Washington

- EEG from brain
- Transmitted over internet
- Replayed through TMS to another brain
- Output to computer

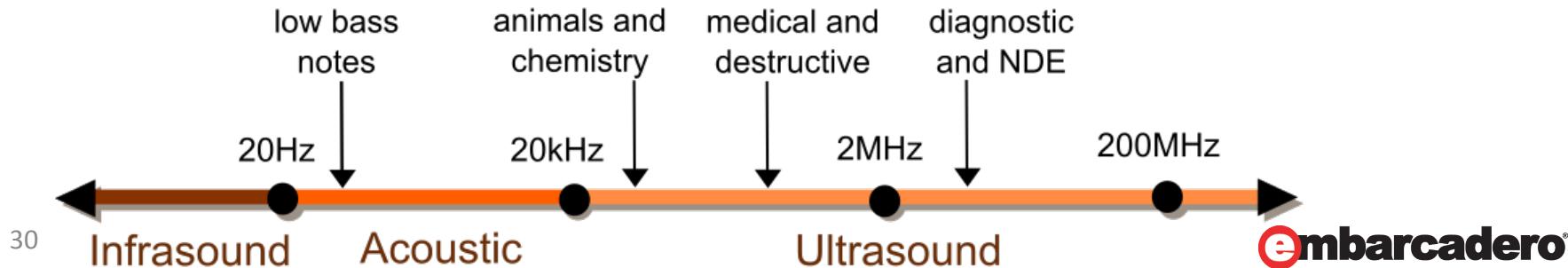


Ultrasonic Transcranial Stimulation Device

- 2000 patent from Sony (US6584357 B1)
 - Finer targeting than TMS
 - *Theoretically* invoking sensory experiences
 - Continued research and patents (US7350522 B2)

*Speculative work,
“There were not any
experiments done.”*

<http://www.newscientist.com/article/mg18624944.600> - <https://www.google.com/patents/US6584357> - <https://www.google.com/patents/US7350522>



Ultrasonic Neuromodulation For Spatial Resolution

- Virginia Tech Carilion Research Institute study published in Jan 2014 *Nature Neuroscience*
 - Used “targeted ultrasound” to boost “sensory perception”
 - The ultrasound waveform used in the study “alters the balance of synaptic inhibition and excitation between neighboring neurons within the cerebral cortex.”
 - Targeted an area of the brain as small as the size of an **M&M**
 - “This finding represents a new way of noninvasively modulating human brain activity with a better spatial resolution than anything currently available.”

"In neuroscience, it's easy to disrupt things. We can distract you, make you feel numb, trick you with optical illusions. It's easy to make things worse, but it's hard to make them better. These findings make us believe we're on the right path."



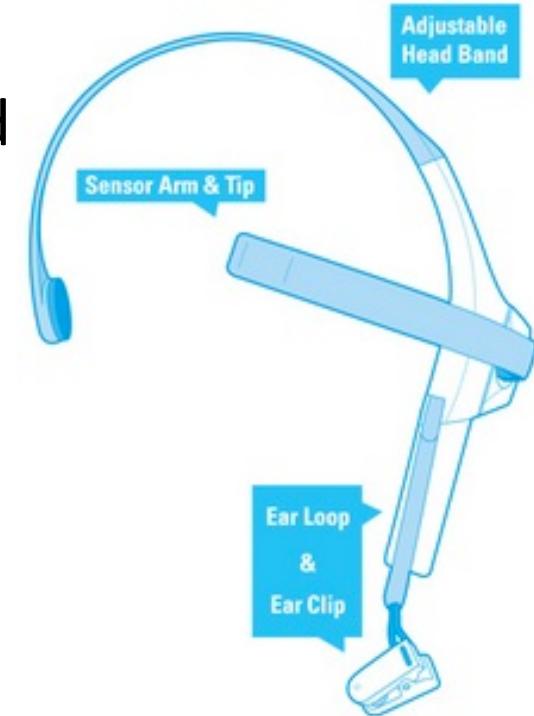
-- William "Jamie" Tyler, Assistant Professor
Virginia Tech Carilion Research Institute

Consumer

BRAIN-COMPUTER INTERFACES (Read-only)

NeuroSky's MindWave (also in XWave headsets)

- EEG with 1 “dry” electrode
- Measures “attention,” “meditation” and eye-blanks
- Bluetooth communication
- SDK for iOS, Android, PC & Mac
- \$129.99 to \$79.95 retail neuroskey.com
- Hacking:
 - <http://makezine.com/2011/05/10/behind-the-brain-blinker/>
 - <http://hackaday.com/2012/12/20/modifying-an-eeg-headset-for-lucid-dreaming/>



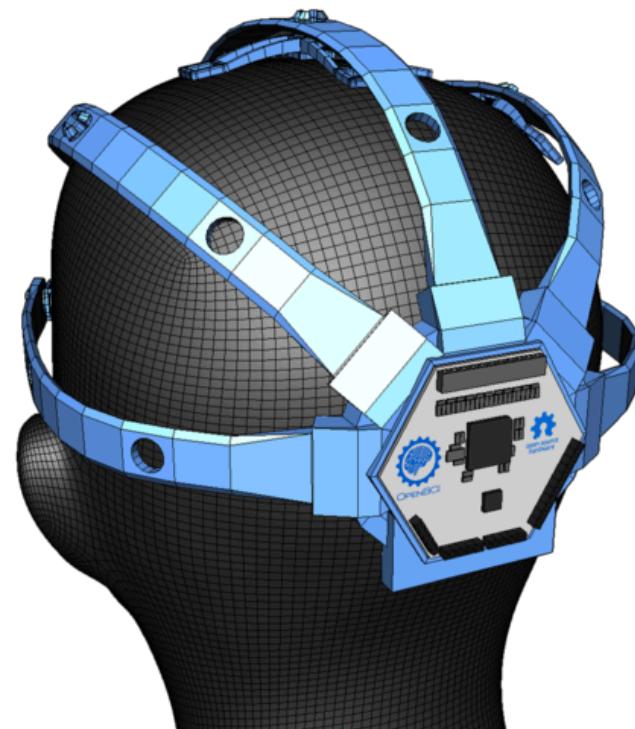
Interaxon's Muse

- 7 “dry” EEG sensors via Bluetooth
- IngieGoGo Funded
- 4 hour battery
- SDK for Java, Python, Objective-C, C, & C++ on iOS, Android, OS X, Windows & Ubuntu
- \$269 Expected soon
- www.interaxon.ca/muse



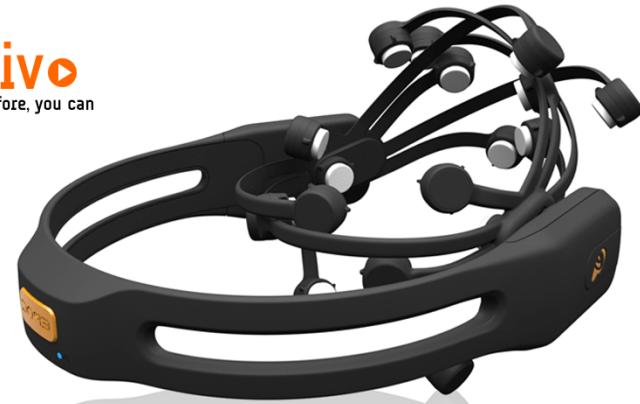
OpenBCI

- Open source hardware & software
- Bluetooth, Arduino, EEG
- 8 “wet” Electrodes per board (can daisy chain boards)
- KickStarter Funded
- \$324 expected April 2014
- www.openbci.com



Emotiv EPOC

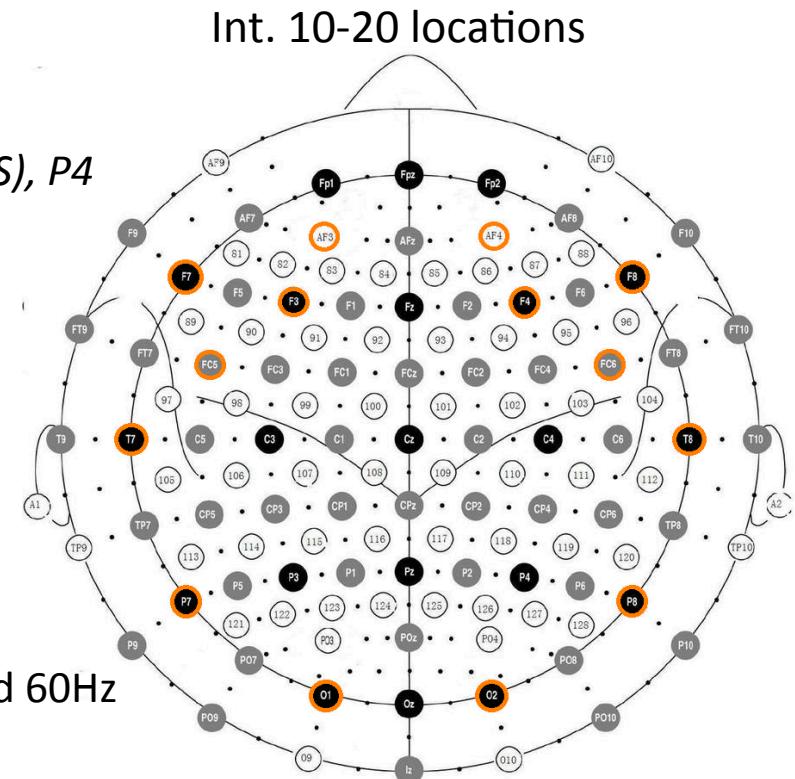
emotiv
you think, therefore, you can



- 16 “wet” electrodes
 - 14 EEG – read brain waves
 - 2 reference electrodes
- Two-axis gyroscope to read head movements
- 4 mental states, 13 conscious thoughts & facial expressions – 4 Processing suites
- Wireless (proprietary & encrypted) connection to Windows, Linux or Mac
- \$500 Dev kit, or \$299 headset alone (no raw EEG*)
- www.emotiv.com

Further Specs

- Channels:
 - AF3, AF4, F3, F4, F7, F8, FC5, FC6, P3 (CMS), P4 (DRL), P7, P8, T7, T8, O1, O2
- Battery:
 - 12 hours operation
- Sampling rate:
 - ~128Hz (2048Hz internal)
- Resolution:
 - 16 bits (14 bits effective) 1 LSB = 0.51 μ V
- Bandwidth:
 - 0.2 - 45Hz, digital notch filters at 50Hz and 60Hz
- More information:
 - http://emotiv.wikia.com/wiki/Emotiv_EPOC



Emotiv Insight

- Coming soon – 2014
- KickStarter funded (\$329)
- 5+2 channels “dry” sensors:
 - AF3, AF4, T7, T8, Pz
 - Reference: CMS, DRL
- Bluetooth 4.0 LE
- Data rate: 128 samples per second per channel
- Resolution: 0.51uV least significant bit
- Battery Life: 4+ hours
- SDK: Android, iOS, Mac, Linux and Windows Platforms





More Details on the
EMOTIV EPOC

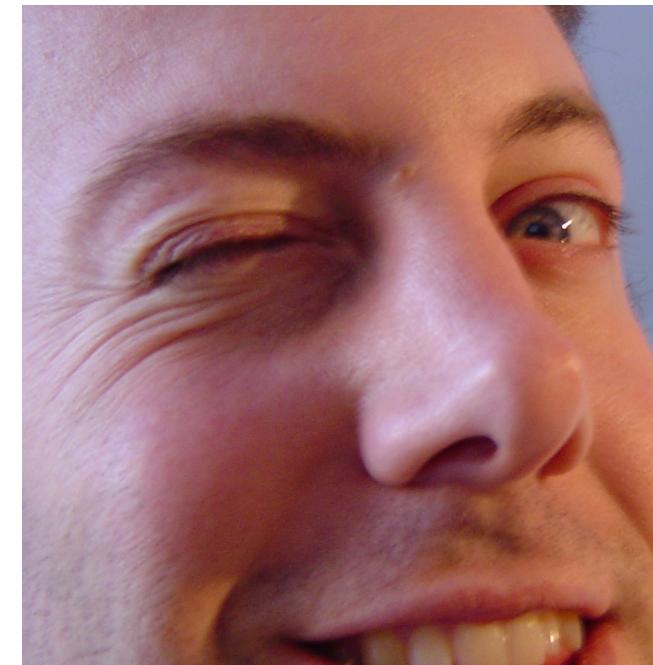
Affectiv Suite

- Detect emotions / mental states
 - Excitement
 - Engagement / Boredom
 - Meditation
 - Frustration
- Passive detection
- Variable levels of each
- Short & long term tracking



Expressiv Suite

- Detect facial expressions
 - Eyelid & eyebrow positions
 - Wink, blink, furrow
 - Horizontal eye movement
 - Smile, laugh, clenching & smirking
- EEG sensors picking up signals to muscles (not brain waves)
- Very fast (10ms)



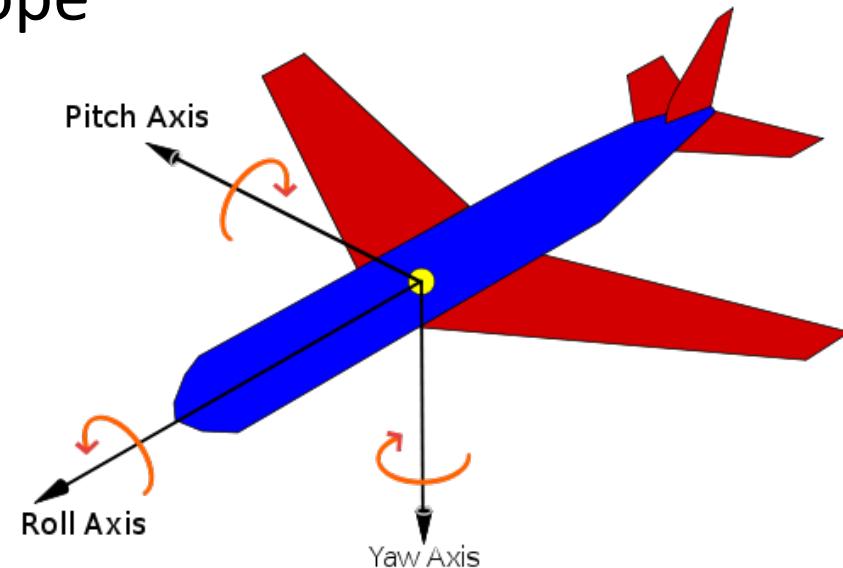
Cognitiv Suite

- Detect conscious thoughts
 - Requires training
- Detect 13 thought patterns
 - (Only 4 at a time)
 - 6 Movements: Left, right, up, down, forward, pull
 - 6 Turns: CW, CCW, left, right, sway-back, sway-forward
 - 1 Visualization: Disappear
- Slight lag in detection



Head Rotation Suite

- Built in solid state gyroscope
- Tracks angular velocity of head movement
 - Yaw & Pitch
 - No roll detection
- Separate from EEG



emotiv
you think, therefore, you can



Demonstration

EMOTIV EPOC

Emotiv EPOC SDK

- Platforms
 - Windows
 - Mac OS X
 - Ubuntu
 - Fedora
- Official Languages
 - C / C++ / Objective-C
 - C# (.NET)
- Unofficial
 - Python
 - Object Pascal / Delphi

Code Sample in C - EmotivSuite

```
EmoEngineEventHandle eEvent= EE_EmoEngineEventCreate();
EmoStateHandle eState      = EE_EmoStateCreate();
unsigned int userID       = 0;
while (...) {
    int state = EE_EngineGetNextEvent(eEvent);
    // New event needs to be handled
    if (state == EDK_OK) {
        EE_Event_t eventType = EE_EmoEngineEventGetType(eEvent);
        EE_EmoEngineEventGetUserId(eEvent, &userID);
        // Log the EmoState if it has been updated
        if (eventType == EE_EmoStateUpdated) {
            // New EmoState from user
            EE_EmoEngineEventGetEmoState(eEvent, eState);
            // Log the new EmoState
            logEmoState(ofs, userID, eState, writeHeader);
            writeHeader = false;
        }
    }
}
```

Raw EEG Data (Hack)

- Reverse engineered the communication
- Access to RAW EEG data
- Non-processed data
- C & Python support
 - <https://github.com/qdot/emokit>



Demonstration

EMOTIV EPOC SDK

Tools in the SDK

- EmotivControl Panel
 - General use & testing
- EmoKey
 - Assign input to keys
- EmoComposer
 - Simulate input
- Examples & Documentation



The question of the day ...

**Is thought the
future of wearable input?**

Which leads us to . . .

Will Big Brother spy on our thoughts?

MindTunes

- 3 disabled musicians
- Collaborated with DJ Fresh and tech
- Created dance track with Emotiv EPOC
- www.youtube.com/watch?v=HyF4ZxGhPHw
- Full documentary
<http://www.youtube.com/watch?v=PgfxKZiSCDQ>



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More Information

- Email
 - jim.mckeeth@embcadero.com
- Emotiv EPOC
 - www.emotiv.com
- Emotiv Insight
 - www.emotiv.co
- Get the code (updated soon)
 - <http://delphi.org/tag/brain-computer-interface/>