Four Hospitals, One Trust, One vision

Oxford University Hospitals NHS
NHS Trust

Review of Brain Computer Interfaces (BCIs): What is the current state of play, and are they good enough for use with AT?

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RAatE November 2011

Presentation summary

- Section 1:
  - Overview of BCIs
- Section 2:
  - Achievements of and developments of BCIs
- Section 3:
  - Suitability of BCIs for AT

Section 1: Overview of BCIs

- What is a BCI
- How detect intentions at the brain
- EEG

What is a BCI?

- Brain Computer Interface

BCI

What is a BCI?

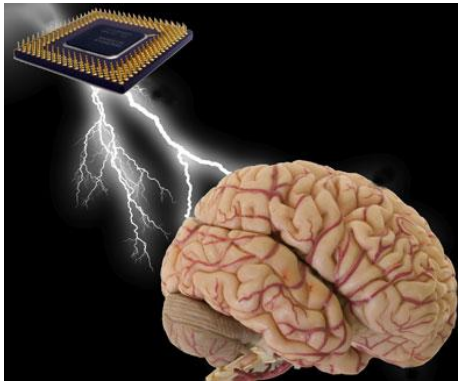
- Brain
  - We make conscious decisions
  - Intentions sent via nerves
  - Movements made with muscles
- If something goes wrong
  - Brain functions perfectly
  - Unable to control movements
  - Locked in
- Detect intentions at brain
  - Send to computer
  - From there
    - Wheelchairs, environmental controls, communication, prosthetic arms…

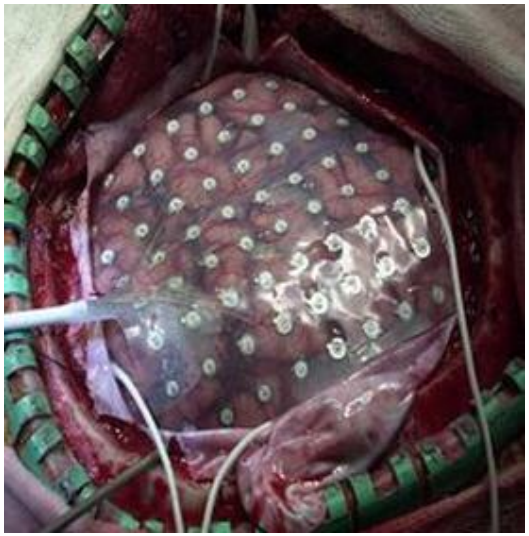
How detect intentions at brain?

- 100 billion neurones in brain
- 100mV signal when each fires
- EEG (ElectroEncephaloGraphy)
  - Invasive
  - Non-invasive

Invasive detection

- Electrode array implanted directly on brain
  - More precise understanding of what happens at brain
  - Requires brain surgery





Non-invasive detection

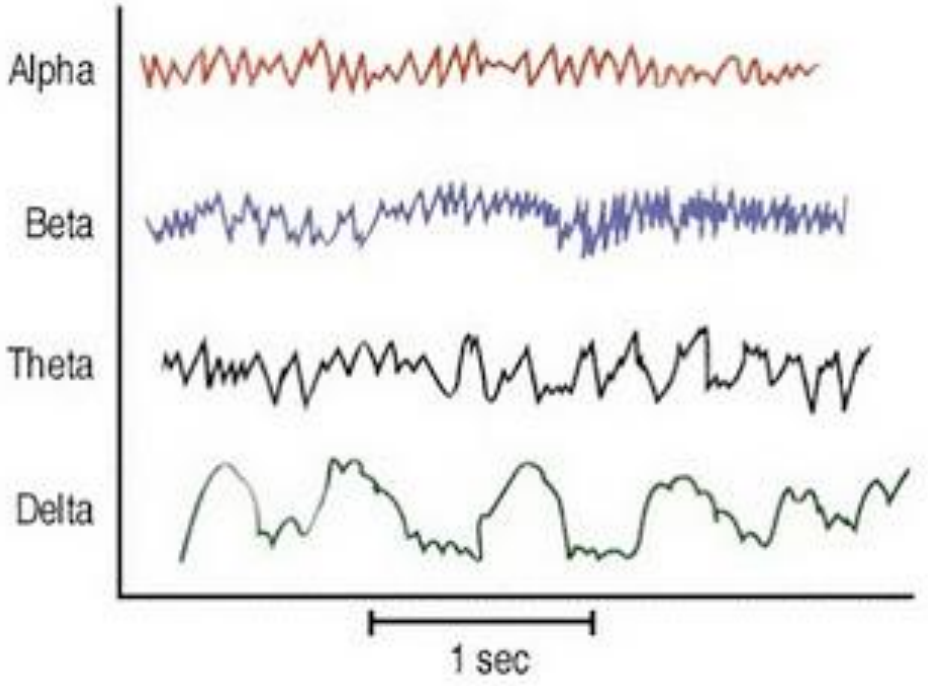
- Surface EEG

Surface EEG

- Electrodes on scalp
  - Each electrode detects electrical signal from billions of neurones
  - Change is only a few μV

How interpret EEG signals?

- Traditional categories by frequency



How interpret EEG signals?

- Denotes level of attention / engagement
- Not generally suitable for controlling AT device
- Better interpretation methods needed

Summary of Section 1

- BCIs (Brain Computer Interfaces) aim to
  - Detect intentions at the brain
  - Send them to computer
  - Use to control AT devices
- Most suitable method is currently Surface EEG

Section 2: Achievements and developments of BCIs

- Methods of interpreting EEG signal
  - Slow Cortical Potentials
  - Sensorimotor Rhythms
  - P300 signals
- Control of AT devices
- Commercial developments

Slow Cortical Potentials (SCP)

- Have a low, irregular frequency
  - Voltage oscillates over 0.5 – 10 seconds
- Users given visual feedback on SCP levels
- Can learn to control whether SCPs are positive or negative

Slow Cortical Potentials

- “Thought Translation Device”
- Computer screen displays alphabet, divided in 2
- Users adjust SCPs to positive or negative to select correct half of screen
- Process repeated until single letter chosen

Slow Cortical Potentials

- Tested on 5 patients locked-in with advanced stage MND
- Users trained for 1-2 hours/week for several weeks or months
- 3 were able to write successfully, with speeds of 2-36 words / hour

Birbaumer N, Kubler A, Ghanayim N, Hinterberger T, Perelmouter J, Kaiser J, Iversen I, Kotchoubey B, Neumann N, Flor H (2000) *The thought translation device (TTD) for completely paralyzed patients*. IEEE Trans Rehabil Eng, 8, p190–192

Sensorimotor Rhythms

- Recorded near motor and sensory areas of brain
- Relies on visual imagery
- Requires training

Sensorimotor Rhythms

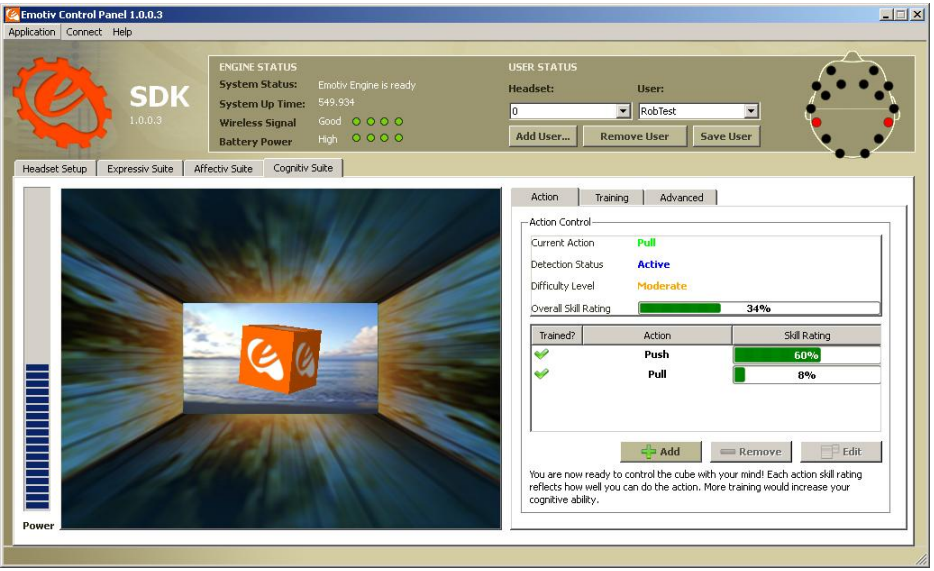
- Toyota / Rikken group video

Sensorimotor Rhythms

- Users think “left” or “right” 100 times each
- BCI system learns to distinguish between these two thoughts
- 6 healthy subjects drive wheelchair to endpoint on left or right
- 80% success

Tanaka K, Matsunaga K, Wang H (2005) *Electroencephalogram based control of an electric wheelchair*, IEEE Transactions on Robotics, 21(4) p762-6.

Sensorimotor Rhythms



Sensorimotor Rhythms

- EPOC Neuroheadset (Emotiv, USA)
- $299
- MSc project
  - 3 non-impaired subjects had 95% success in choosing between “push” and “neutral” after 1 week

P300 Evoked Potentials

- Peak in EEG signal
- 300 ms after stimulus presented
- Signal evoked automatically - no training required

P300 video

P300 Evoked Potentials

- Screen displays letters in 6x6 grid
- Rows and columns highlighted at random
- User concentrates on desired letter
- P300 response evoked when chosen letter highlighted

P300 Evoked Potentials

- Healthy subjects
- Trade-off between accuracy and speed
  - 1 word / minute = 100% accuracy
  - 8 words / minute = 80% accuracy

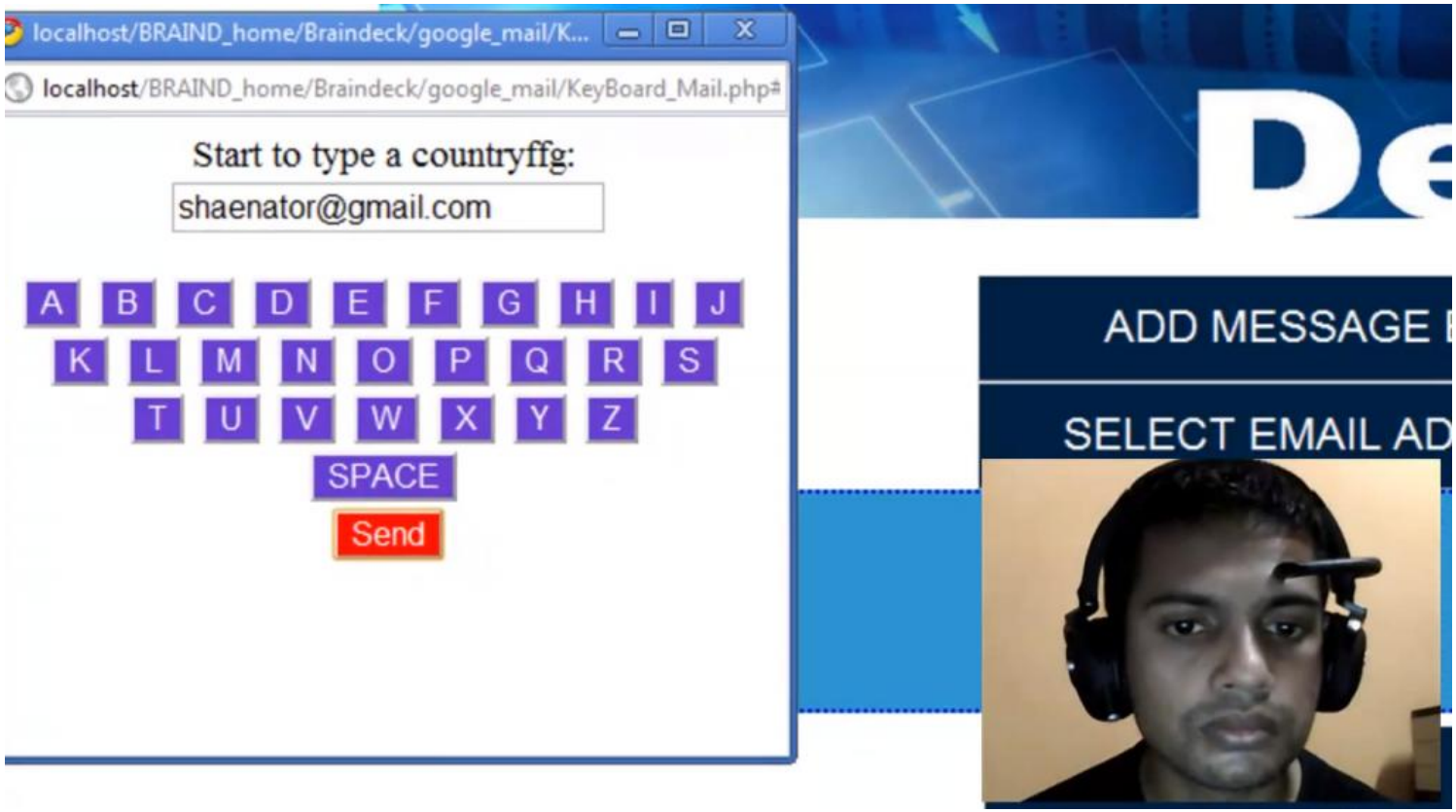
Donchin E, Spencer KM, Wijesinghe R (2000) *The mental prosthesis: assessing the speed of a P300-based brain–computer interface*. IEEE Trans Rehabil Eng, 8, p174–179

P300 Evoked Potentials

P300 Evoked Potentials

- Intendix
- Commercial Company founded on University research
- £10,000

Shamil Jauffer



Shamil Jauffer

- Absent presenter
- Software engineering undergraduate
- Used NeuroSky headset ($99)
- Single electrode
- Decrease in alpha waves when blink
- Select letter from keyboard

Section 2 Summary

- There are methods of determining intent from EEG signal
- Demonstrated ability to:
  - Spell
  - Drive wheelchair
- Commercial products are appearing
  - Often cost effective

Section 3: Suitability of BCIs for AT

- Negatives
- Positives

Negatives

- Difficult to set up
- Slow to make a selection
- Relatively unreliable
- Very slow progress
  - 25 years old
  - Moore's law – computer processor power doubles every 2 years

Negatives

- Target audience – locked in syndrome?
  - Eye gaze
  - Switch access / eye blink
- Sensorimotor – locked in syndrome
  - Motor imagery difficult?
  - Training effort difficult?
- P300 – locked in syndrome
  - Improvement on switching?

Positives

- Popular equipment
  - Mass production reduces costs
- European projects
  - TOBI – (Tools for Brain Computer Interaction)
    - P300 Brain painting
    - Document browsing
  - DECODER
    - Detect consciousness
    - Provide Yes / No response

Positives

- Auditory P300
- Enormous potential
  - Prosthetic arm
  - Human trials
  - Word detection

Section 3 Summary

- Not quite there yet…
- …but it could be soon!

Thanks for listening

- Any questions?