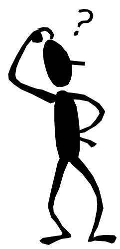
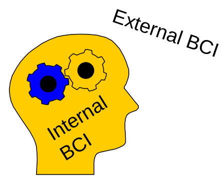
What is this BCI thing?

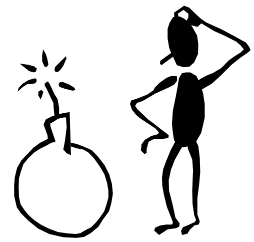




BCI - an interface which seeks to enable a user to communicate directly with a computer via the electrical signals from the brain

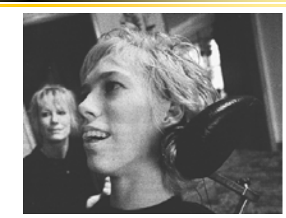
Reactions

- What do you think about the BCI idea?
  - Want to know more?
  - Invasive
  - Thought reading is possible
  - Not Useful
  - Skeptical



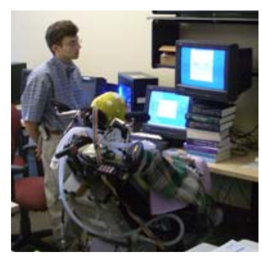
My introduction to BCIs

- *Controlling Computers with Neural Signals* - October 1996 issue of Scientific American



Useful?

- Locked in patients
  - Spinal Cord Injury
  - Amyotrophic Lateral Sclerosis (ALS – also known as Lou Gehrig's Disease)
    - 5,000 newly diagnosed cases/yr.
    - 300,000 living in the US now will eventually die from ALS



Other Uses?

- Military: brain-body actuated control
  - faster response times for fighter pilots
  - control of displays in a noisy environment where the user's hands are full
- Entertainment
- Other: carpel tunnel syndrome

Why not use Eye Movement Control?

- Not all patients have eye movement control.
- Since ALS is a degenerative disease, patients with eye movement control may lose it.
- Even for those with eye movement control, a BCI presents a viable alternative/addition for control.

Hans Berger

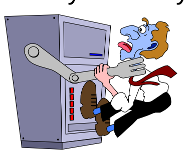
- a German psychiatrist
- 1929: publishes "On the Electroencephalogram of Man"

The First BCI [Vidal 1973]

"Can these observable electrical brain signals be put to work as carriers of information in man-computer communication or for the purpose of controlling such external apparatus as prosthetic devices or spaceships? Even on the sole basis of the present states of the art of computer science and neurophysiology, one may suggest that such a feat is potentially around the corner."

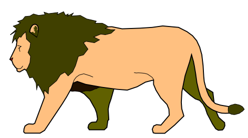
The First BCI [Vidal 1973]

- "The main computing power is provided by the [UCLA] campus IBM 360/91, which is equipped with an exceptionally large core memory of 4 Mbytes."



Evoked Potentials

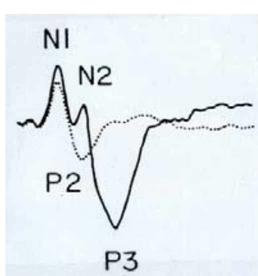
- changes in voltage potential that occur after a stimulus



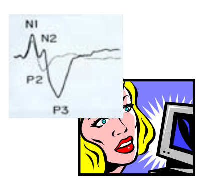
P3 evoked potential

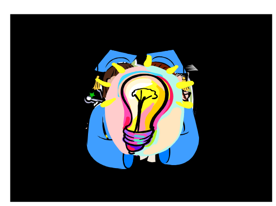
[Chapman 1964, Sutton 1965]

- a positive deflection in the EEG signal peaking approximately 300-400ms after a task relevant stimulus



Task Relevant Stimulus





P3 Character Recognition

- Donchin and Farwell in 1988
- You stare at a letter on the screen and count the number of times it flashes in order to pick the letter

A	D	G
B	E	H
C	F	L

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Driving Experiment

- Subjects were told to drive around the VR town and stop at red lights.
- In addition, all red lights are preceded by yellow lights, so the red light should elicit a P3 and the yellow light should not elicit a P3.

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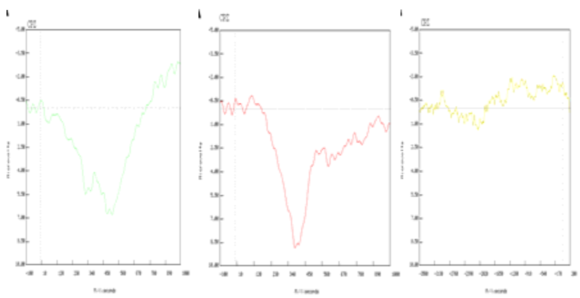
Results



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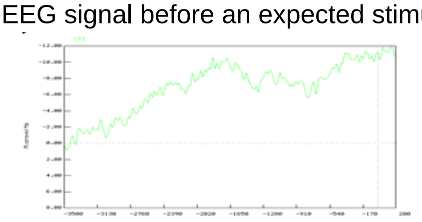
Contingent Negative Variation

[Walter 1964]

- a slowly increasing negative shift in the EEG signal before an expected stimulus



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VR Driving (1998)

- Can evoked potentials be reliably collected in a virtual environment?
  - Yes!
- Is the signal clean enough to do single trial analysis?
  - Yes!: 84.5% recognition accuracy
    - 90% of non-P3's recognized correctly
    - 65% of P3's recognized correctly

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Other P3 Application Results

- 56% on-line and 90% off-line recognition (Spencer et. al. 1999)
  - Using a discrete stepwise linear analysis
  - Used an average of around 4 trials
- 50% off-line (Polikoff et. al.1995)
  - Used single trials
- 80% off-line (Jung et. al. 1999)
  - Only looked at true positives (P3's), not true negatives (non-P3's)
  - Used single trials

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There are Tradeoffs between Performance and Recognition

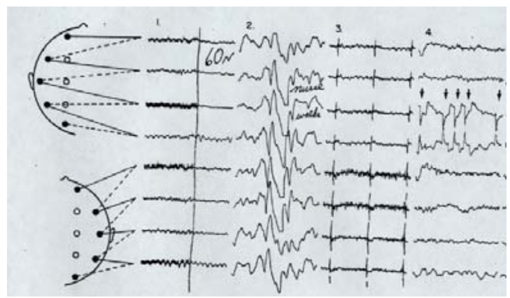
Two Dimensional Cursor Task (Polikoff et. al.)

- If single trials yield 50% recognition
  - Subject would need 30 steps to reach a goal of 10 steps in the target direction (2 minutes if 4 seconds/step).
- If an average of 3 trials yields 60% recognition
  - Subject would need 24 steps to reach the same goal (4.8 minutes at 12 seconds/step)
- If an average of 8 successive trials yields 85% recognition
  - Subject would need 14 steps to reach the same goal (7.5 minutes at 32 seconds/step)

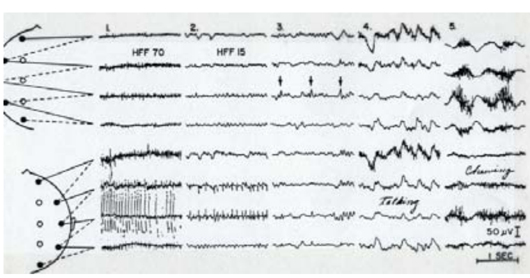
Difficulties

- microvolt signals from the scalp
- individual signal differences
- volume conduction over the scalp leads to signal “smearing”
- artifacts interfere: eye movement, muscle movement, 60 Hz

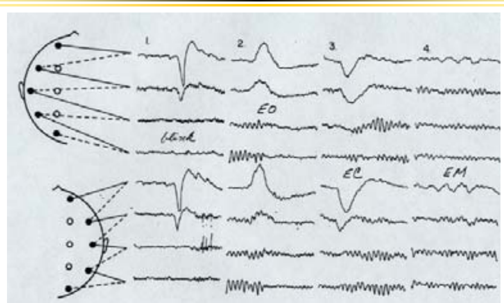
Artifact Examples



More artifact samples



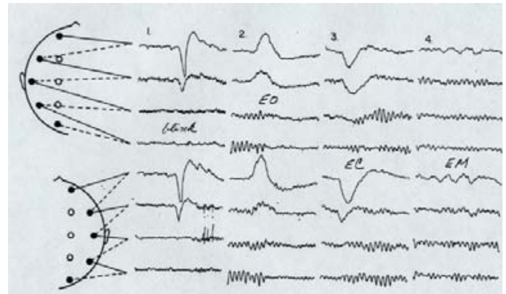
Hordes of Artifacts



Mind reading?

- scalp EEG signals are smeared over the head
- brains are individual
- scalp EEG signals come from large areas of underlying neurons

Hordes of Artifacts



Cursor Control

- A continuous task
- Subjects can learn to modify their mu rhythm amplitude to make a cursor go up or down
- Subjects who learn well will have around a 90-95% accuracy [Wolpaw et. al.]
- Not all subjects are able to learn biofeedback within a reasonable time

Slow Cortical Potential

- a slow positivity/negativity over a large portion of the head which a person can be trained to induce through the use of biofeedback techniques

Thought Translation Device

[Birbaumer, Nature vol. 399, 1999]

- 75-85% correct recognition
- alphabet is split into two halves and the subject picks one half until a single letter is picked
- 2 characters chosen per minute
- the first letter written this way took 16 hours!

Environmental Control

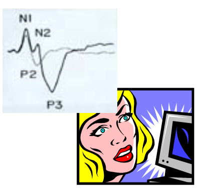
Main Experimental Question

- Is there a difference in control while immersed in a virtual environment vs. just staring at a computer screen?

The Application

- 9 subjects in an experiment in a VR apartment living room
- 5 possible actions: turn on/off 3 objects (light, stereo, tv) and say Hi or Bye to a graphics figure
- All feedback is visual
- On-line rec. and eye movement reduction
- In order to obtain P3's for the item that needs to be controlled, we have a clear button on each item that occasionally flashes red

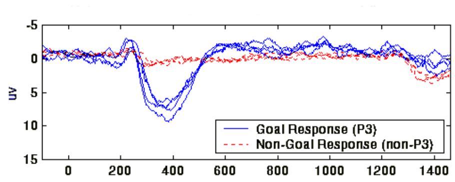
How the P3 is evoked



The Experiment

- Training: 5 minutes sitting in the room and counting the occurrences of the red button flash on the light
- 5 minutes trying to obtain given goals with the following conditions given in a random order:
  - showing the apartment on a monitor
  - in the VR helmet with a fixed head view
  - fully immersed in the VR helmet

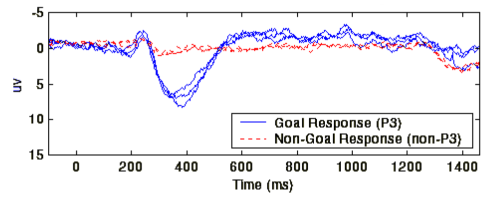
Grand Averages for Different Environments



Throughput (items/minute) in Different Environments

	Subjects	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*Ave*
Conditions											
VR		*3.8*	*3.7*	*4.5*	*3.3*	*1.9*	*1.7*	*2.6*	*3.1*	*0.9*	*2.83*
MONITOR		*4.5*	*5.6*	*6.1*	*3.5*	*1.2*	*1.2*	*3.3*	*2.9*	*1.3*	*3.29*
FIXED SCREEN HMD		*3.0*	*3.2*	*4.3*	*3.8*	*2.4*	*1.7*	*3.3*	*2.7*	*0.7*	*2.79*

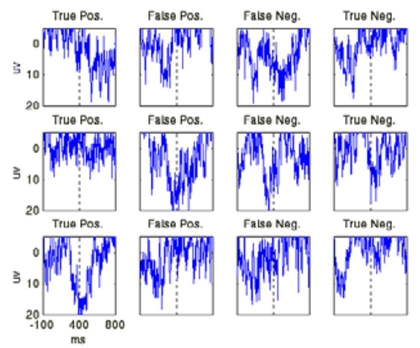
Grand Averages over Time of Task



Throughput (items/min) over Time of Task

	Subjects									
Conditions	1	2	3	4	5	6	7	8	9	Ave.
First Condition	3.0	3.2	4.3	3.5	1.2	1.7	3.3	3.1	0.9	2.69
Second Condition	4.5	3.7	4.5	3.3	2.4	1.7	3.3	2.9	1.3	3.07
Third Condition	3.8	5.6	6.1	3.8	1.9	1.2	2.6	2.7	0.7	3.16

Recognition: Is there always a P3?



Pilot Experiment with Eye Tracking

- The results indicated that subjects are not always paying attention to the control goal

Can the Interface Affect Throughput?

	Subjects		
Conditions	*6*	*8*	*9*
MONITOR	*1.2*	*1.3*	*2.9*
MONITOR with Diff. Colors	*1.8*	*1.7*	*5.0*

What Other Uses?

- Current Brain-Computer Interface systems are slow and prone to error, can we improve them?
- What if they could be more accurate?