The discovery of the P300

- Sutton et al. 1965
  - Subjects presented with random or known sequences of tones.
  - Asked to guess the next tone.
  - Measured the effect of uncertainty on the ERP.

The Oddball Paradigm

- Take a Sequence of events.
- Add classification rule so that each event is in one of two categories.
- Assign task that can not be accomplished without the categorization of the events, present one category infrequently.

To resolve multiple components

- Obtain more detailed information about the topography of the components with a Dense Electrode Array.
The Raw Data: An Oddball study

Virtual electrodes 1 and 3

The Homunculus Bureaucraticus:
- There exists a processing system which monitors various aspects of behavior
- The system is designed to assure that the models of the environment governing information processing and behavior are consistent with reality
- The Deviance Components manifest the activity of the HB...

The Interrogation
- You ask the suspect:
  - Was the money on the chair?
  - Was the money by the radio?
  - Was the money under the palm tree?
  - Was the money under the aquarium?
  - Was the money under the mattress
- If we detect a differential response to the Aquarium we know that the subject knows more than she tells
A test of the concept

- Subject is assigned an espionage mission
- Details of the mission are memorized – e.g. Meet the man GREEN TIE give him the SNOW FILE...
- Mission executed
- Subject tested 24 hours later

Design of the test

- Subject given 5 arbitrary phrases to which he has to respond. (“targets”)
- The targets are embedded in a sequence of “frequents”
- 17% of the frequents are “Probes” - items related to the espionage mission

For “Innocent” subjects

- The “targets” elicit a large P300
- Neither the frequents nor the probes elicit a P300
- The subject has no information that makes the probes distinct

For “Guilty” subjects

- The “targets” elicit a P300
- The “frequents” do not elicit a P300
- The “probes” do elicit a P300
- Ergo: the subjects recognize the probes as distinct items

The Mental Prosthesis

- Allow subject to control a device using ERPs.

From a recent book...

“I have never even heard of the brain stem...I was brutally introduced to this vital piece of anatomy on Friday, 8 December, 1995, when a cerebrovascular accident put my brain stem out of action...In the past you simply died. But improved resuscitation...have now prolonged and refined the agony...
And he continues...

...You survive, but you survive with what is aptly known as “locked-in syndrome.” Paralyzed from head to toe, the patient is imprisoned inside his own body, his mind intact, but unable to speak or move...”

Jean-Dominique Bauby (1952 - 1997)

“In my case, blinking my left eyelid is my only means of communication...”


How did he “write”?

It is a simple enough system. You recall off the alphabet (less variations, see set) and type a blank at any rate large that the letter will be read. The maneuver is repeated for the letters that follow so that fairly soon you have a whole word, and then fragments of more or less intelligible sentences. That is how it is written. The key is that other visions are better than others. Because of sensory, automatic or otherwise, performances vary in handling the code.

Talking off the Top of Your Head

Farwell, L. and Donchin, E.
EEG Journal, 1988, 70, 510-523

The Context for the Brain Computer Interface (BCI)

- Individuals who have lost all motor control
- No residual muscular control. Not even an eye-blink.
- Yet, the mind is functioning and lost communication is the ultimate agony.
- Can one use the electrical activity of the brain as a communication channel? (The “mental prosthesis”)

The display

- Matrix of 6 by 6 characters
- Each row and each column intensified briefly every 125 msec
- Order of intensifications random
- Subject focuses attention on one cell
- Will attended rows and columns elicit a detectable P300?
The analysis process

- Acquire a 600 msec epoch following each intensification.
- As the critical event appears in a different position on each trial, overlap of successive ERPs is less of a problem.

And here is the actual Display

Average across subjects

- Note that the relevant items elicit a large P300
- Amplitude depends on Interstimulus interval
- 40 trials require 60 seconds - much too slow

How do we detect P300?

- Normative Data:
  - 80 “trials” of epochs known to include P300
  - 80 “trials” with no P300
- Using Stepwise Discriminant Analysis
  - Develop Discriminant Function to distinguish between the groups
- Apply that function on line to each trial.

Effectiveness issues

- One trial is one scan through the 6 rows and 6 columns.
- Trial duration = 12 * 125 = 1500 msec.
- So, best performance is 40 chars per second.
- BUT! Signal to noise ratio requires averaging.

The effects of Number of trials on speed

<table>
<thead>
<tr>
<th>N of trials in average</th>
<th>Characters per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>13.33</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>
The Bootstrapping method

- To assess accuracy of detection at different number of trials we used bootstrapping
  - Get 1000 samples of N trials each.
  - Average the N trials
  - Apply decision rule
  - Record percent correct detection as a function of N.

Single Trial Performance

- Percent of correct detections as a function of the number of trials and detection method
- We achieved 90% accuracy with an average of 10 trials.
- Or - 4 characters a minute

A more detailed look:


- We ported the program to a PC
- Used improved signal detection procedures
- Recorded from 10 able bodied and 5 wheel chair bound subjects

System performance

For on-line, real time, detection

- Develop the Subject’s Discriminant Function off line
- For row/column j, the discriminant score
  - \(DS(j) = \text{Sum}[A(t)\times EEG(t)]\)
  - For five time points t selected by SWDA
- Find row with Max DS(row) and column with Max DS (column)
Current analyses substantially increase the speed compared to Farwell and Donchin, 1988.
There was no significant difference in performance between wheelchair bound subjects and the other subjects.
There is a point in pursuing other improvement strategies.

Issues for current research
- Try the BCI with locked-in patients.
- Develop a menu-based system.
- Include predictive algorithms.
- Use smart keyboards.
- Develop portable system.
- Evaluate additional signal detection algorithms.

Thank you for your attention.