ERP Components and the Application in Brain-Computer Interface

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The 1st HCI and Digital Health Forum:
Technologies and Business Opportunities between China and UK

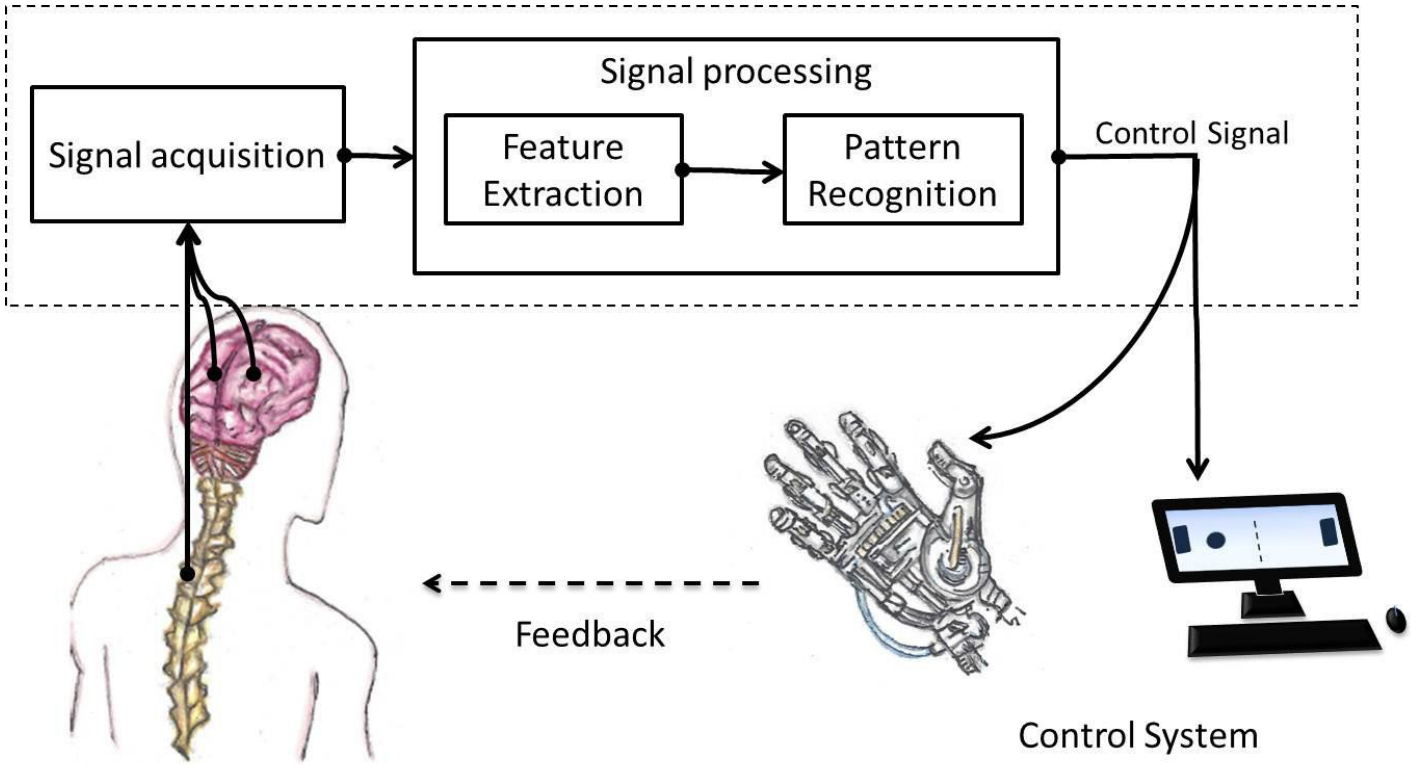
Healthcare needs

- Humans have bodily interaction with the environment mainly with limbs

- Control of limbs impaired due to stroke etc.
- Loss of limbs
- And more…

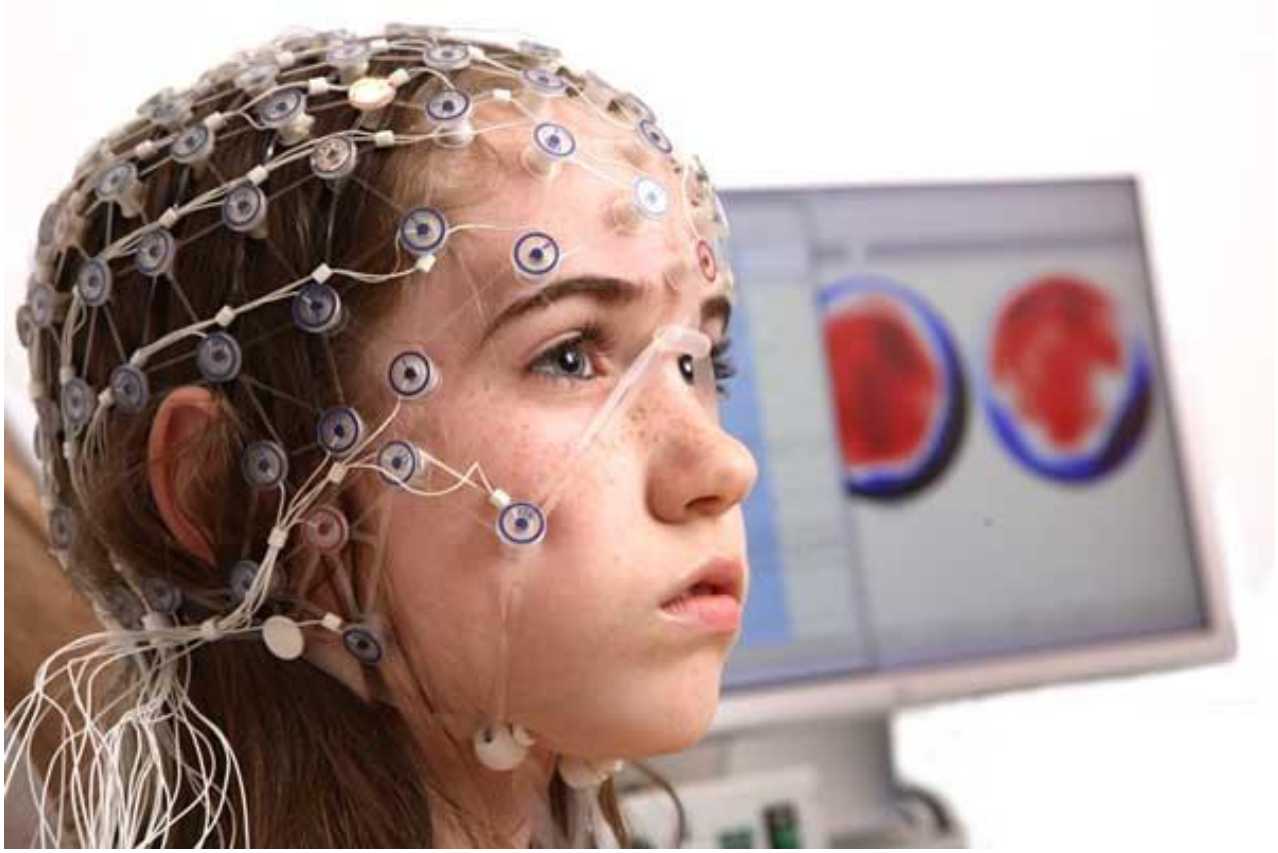
Brain-computer interface (BCI)

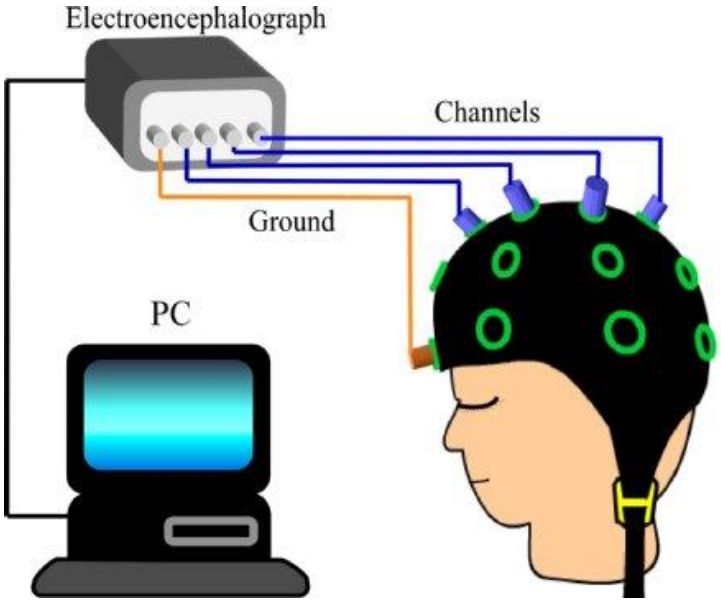
- To control external device using signals from the brain



Electroencephalograph (EEG)

- Brain electrical activities recorded from scalp surface

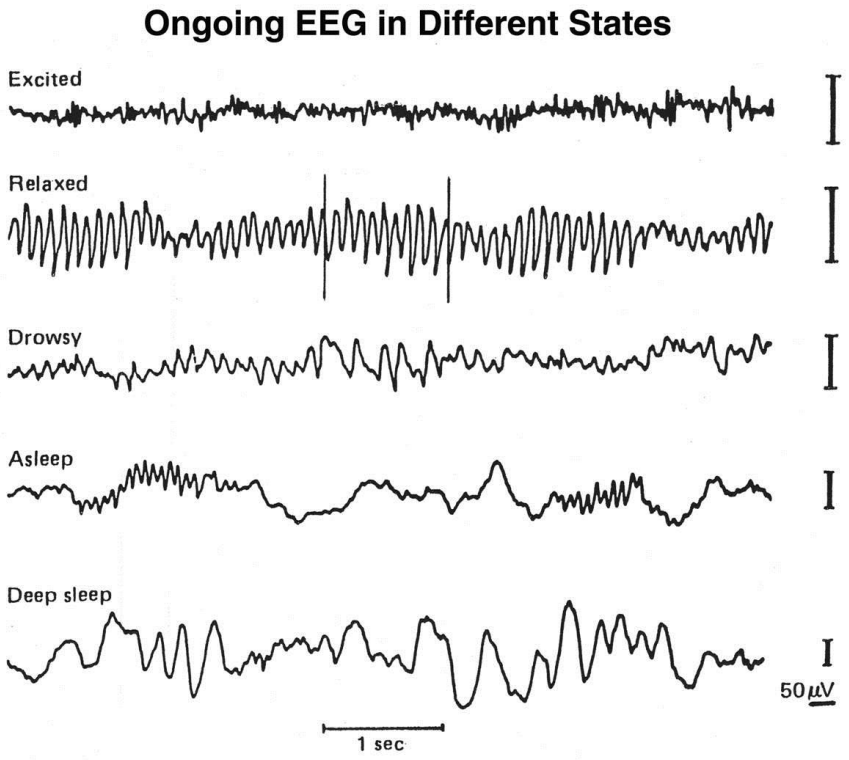



Electroencephalograph
Channels
Ground
PC

Fp1-F3
F3-C3
C3-P3
P3-O1
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp2-F8
F8-T8
T8-P8
P8-O2
Fz-Cz
Cz-Pz
X7-A1
EKG

Why EEG?

- Non-invasive (no implant needed)
- Excellent time information: real-time responses
- Sensitive to mental status



Application 1

P300 Speller

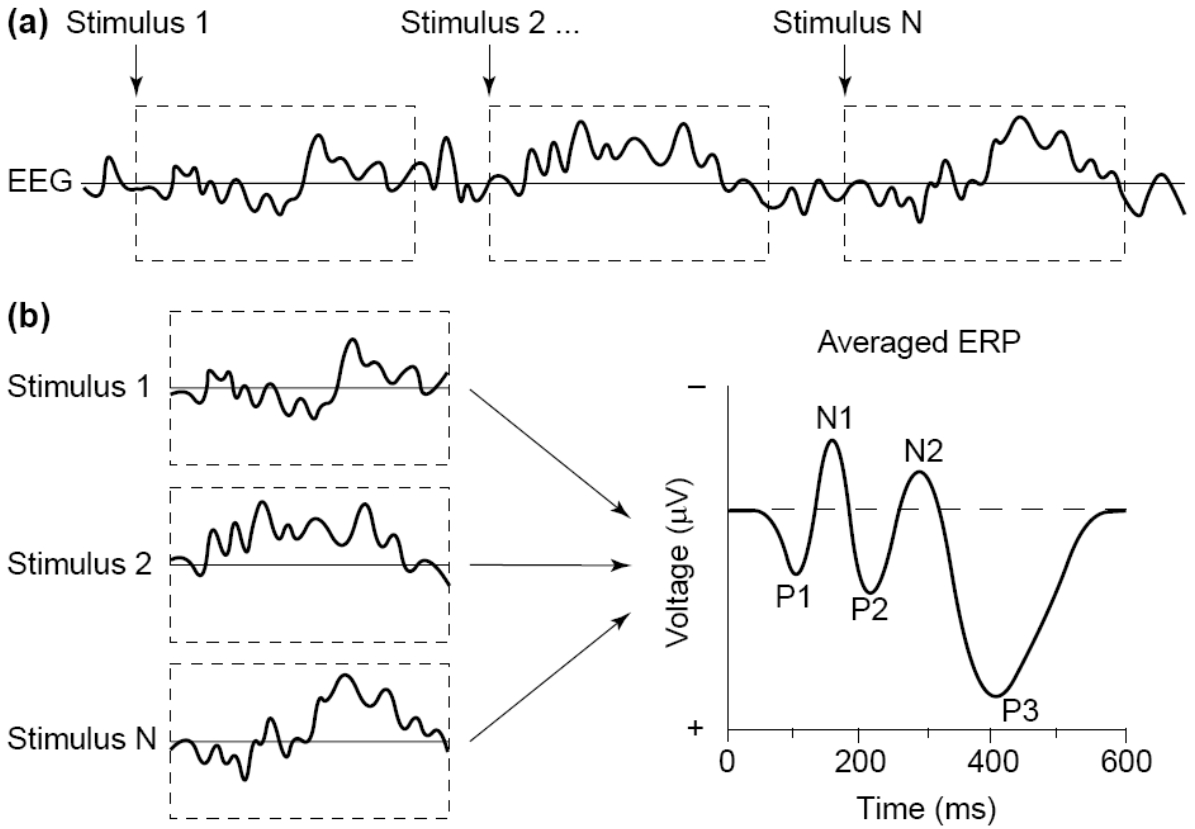
ERP

Event-related potential (ERP)

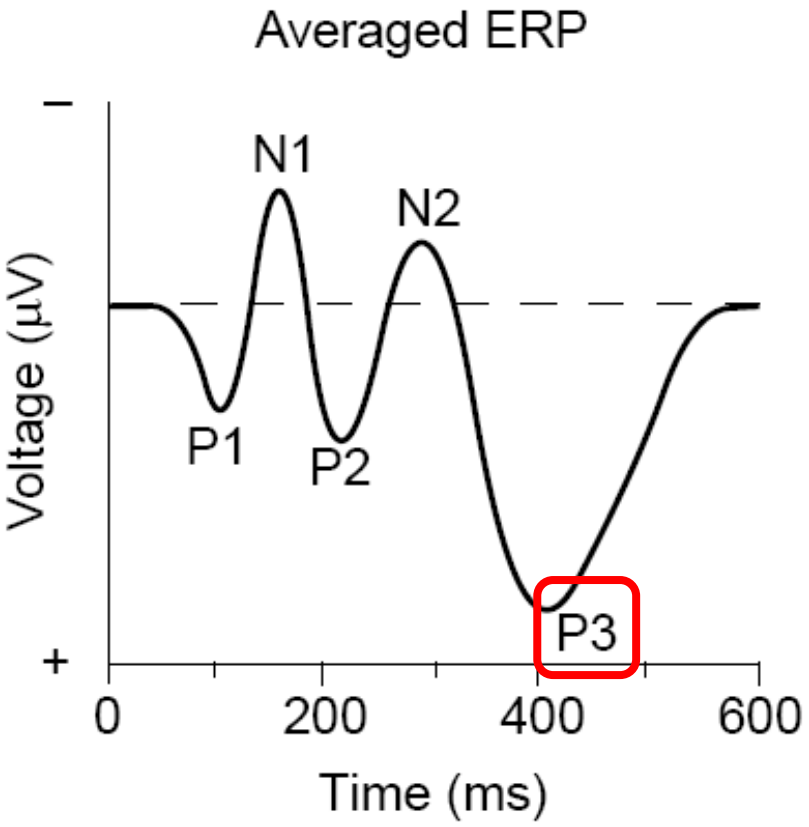
- Electrical responses triggered by sensory, cognitive, or motor *events*, and embedded in EEG
- An event could be a visual/auditory stimulus, an execution of a cognitive function, or a manual response
- ERPs are time-locked to the events (always occurring at the same time relative to the events)

Averaging process

- ERPs are typically generated with an averaging process: responses time-locked to events will remain; noise and responses not time-locked will cancel out



Noise is greatly reduced in ERPs, resulting in much cleaner waveforms (but usually with dozens to hundreds of trials!)

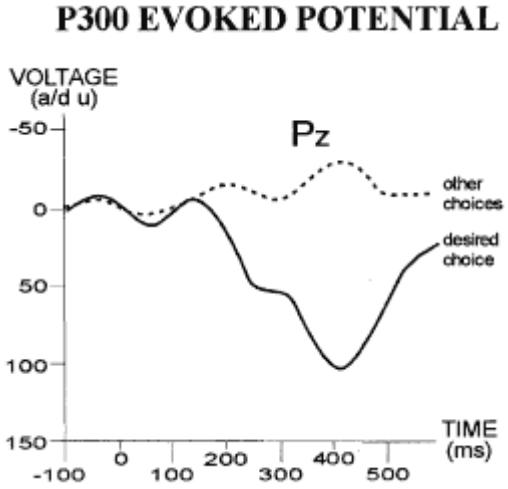


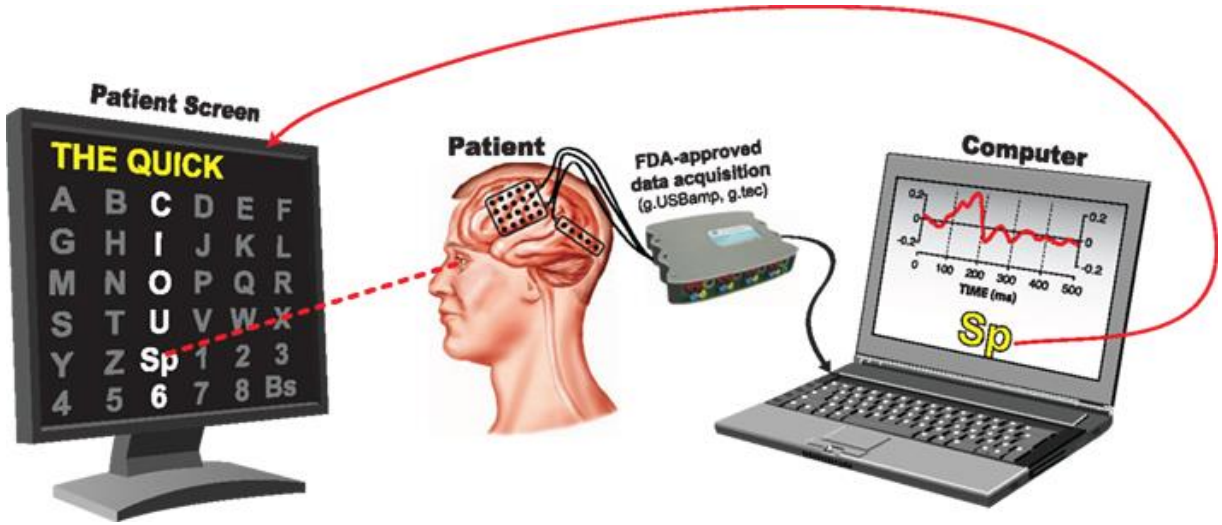
- Averaging is not needed for certain strong ERP activities, such as P3 (also known as P300) in visual ERPs
- This *single-trial* ERP is used in BCI for better efficiency

P300 speller

- Letters are highlighted to generate P300
- ERP recorded from the parietal scalp surface
- Enhanced when the stimulus is attended/desired

- Stronger P300 indicates letter selection





Usage

- Design 1: letters are organised into groups; once the group is selected, the group will expand for the individual letters to be selected

- Design 2: letters (shown as a grid) will be randomly highlighted one by one

- Design 3: one row or column of the letter grid is highlighted each time (the target is decided by a combination of row and column)

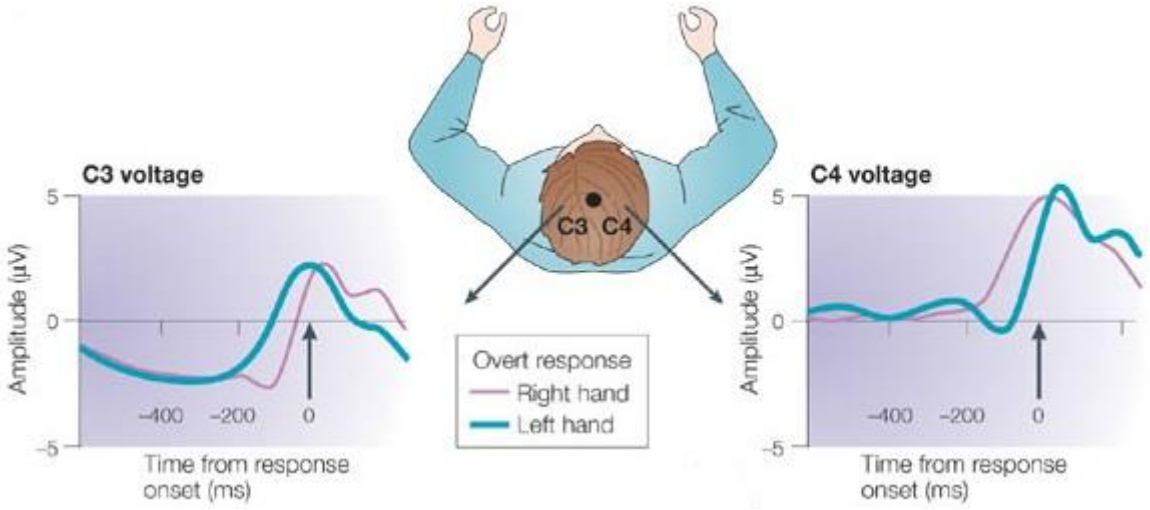
A B C D E F
G H I J K L
M N O P Q R
S T U V W X
Y Z 1 2 3 4
5 6 7 8 9 0

Application 2

Lateralised Readiness Potential (LRP)

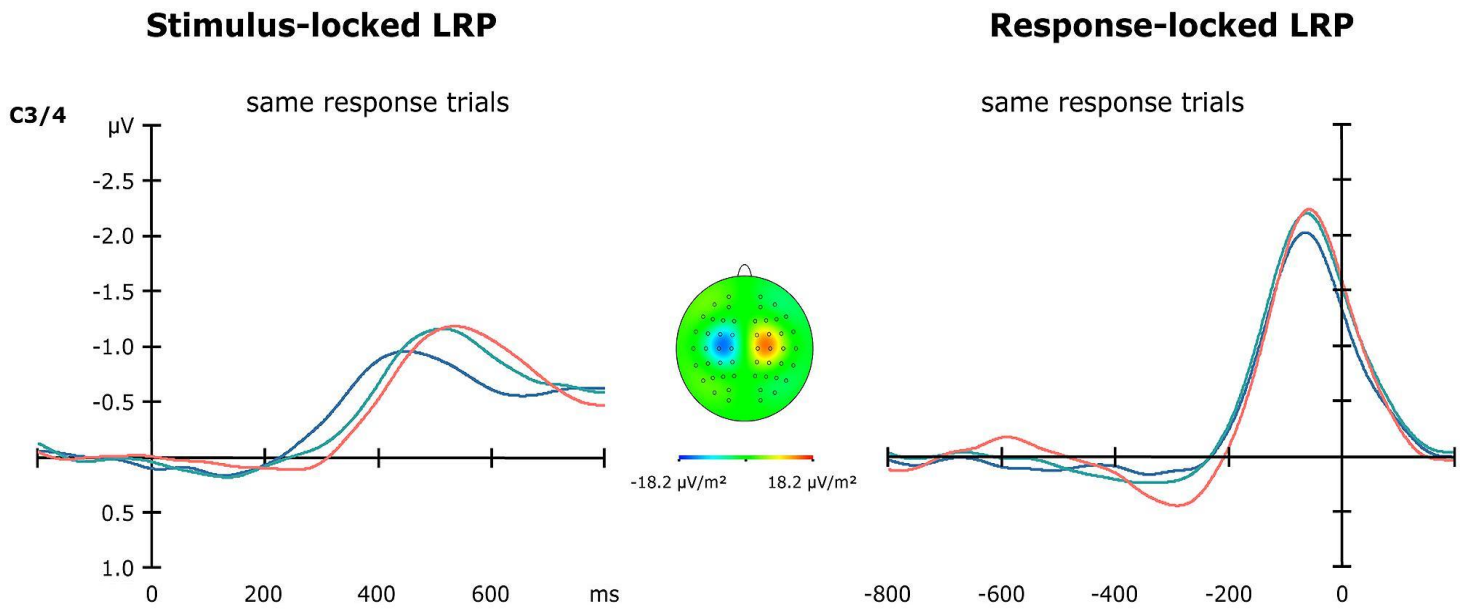
LRP

- Lateralised readiness potential (LRP): ERPs associated with hand movement preparation
- Negativity over the *contralateral* central area of scalp surface (e.g. more negative over the left central area if moving the right hand)



LRP

- Two ways to show LRP: relative to the stimulus onset time or the manual response time
- The LRP occurs before the manual movement is made (therefore the term ‘readiness’)



No action needed

- LRP is still evident even when people perform *imaginary* movement in their mind

- This means that movement decisions can be detected in LRPs without the need of making the movements

Usage

- Two-option selection: left vs. right
- Less powerful than P300 because LRP is weaker
- Less accurate: currently ~85%
- Advanced algorithms needed to extract the signal

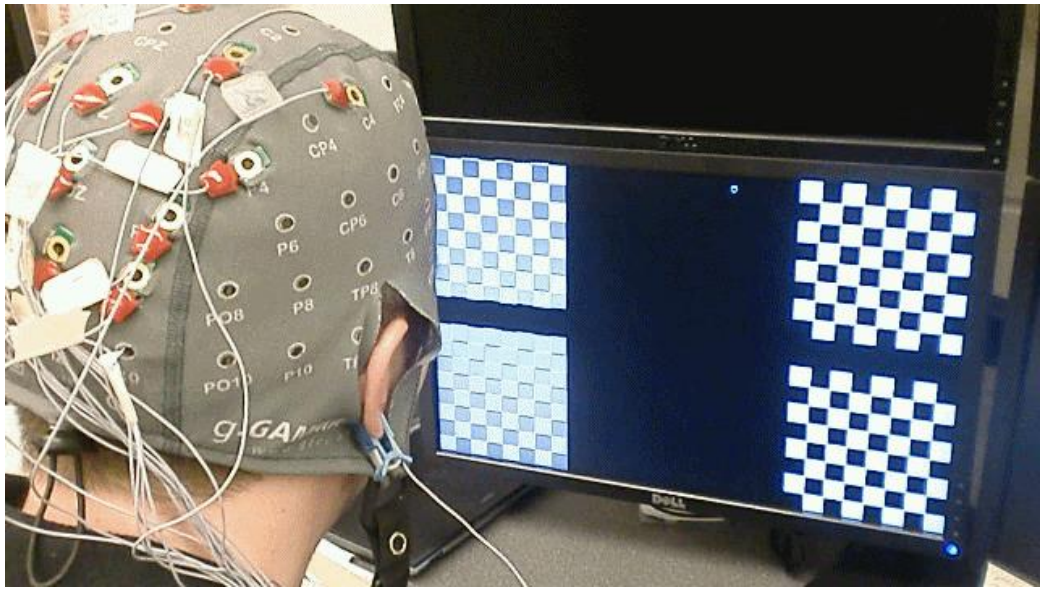
- But, its usage is very natural: no stimulus-selection mapping is needed
- May be the new trend

Application 3

Steady-State Visual Evoked Potential (SSVEP)

SSVEP

- Steady-state visual evoked potential (SSVEP): electrical brain responses to repetitive visual stimuli at specific frequencies (flickers)

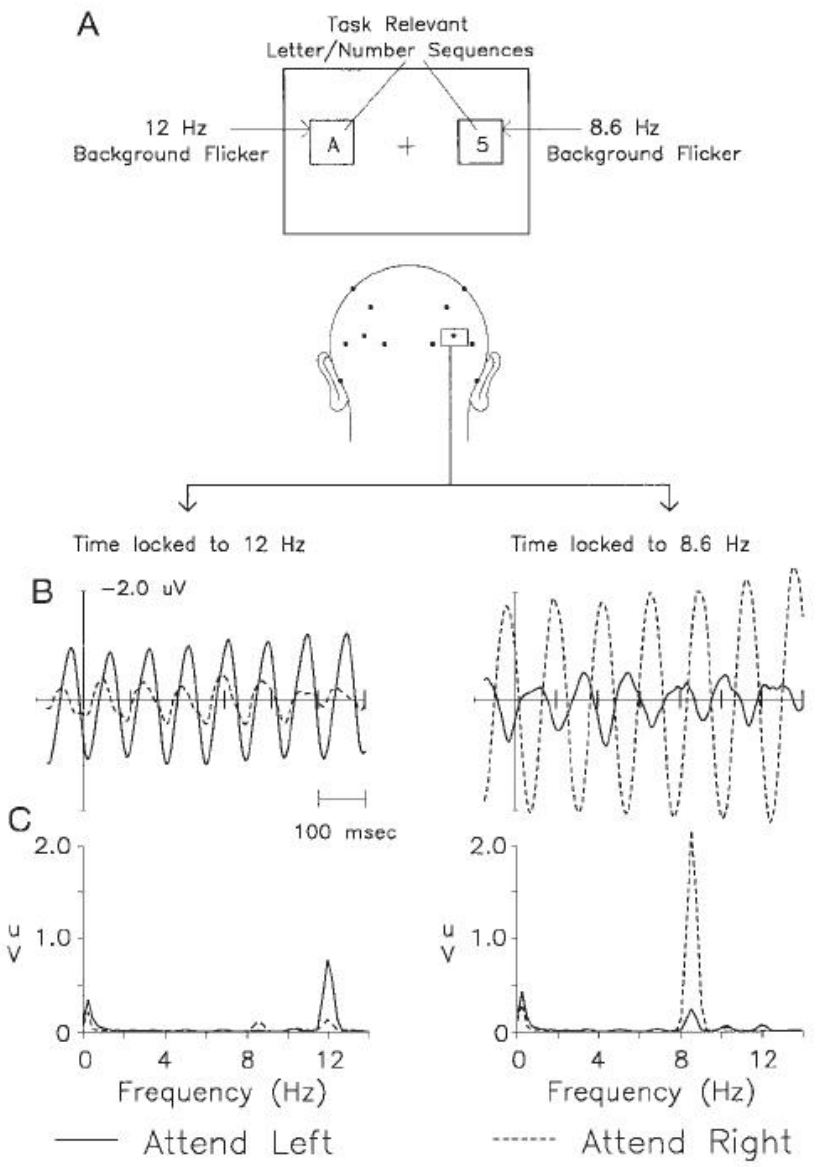


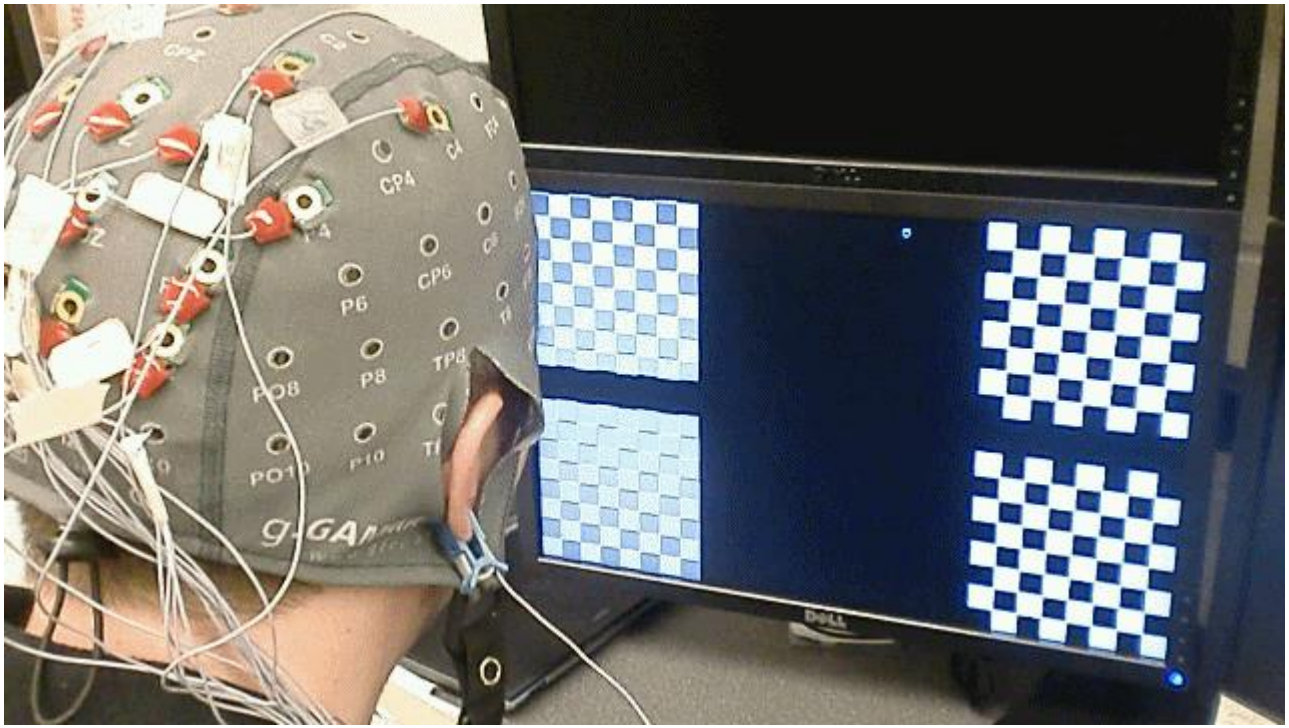
SSVEP

- Can be seen as many superimposed ERP waveforms in response to the repetitive stimuli
- SSVEP has the strongest activity at the stimulation frequency mainly over the posterior scalp surface
- Frequency range: usually 5-80 Hz (higher or lower frequencies generate very weak SSVEPs)

SSVEP

- Nearly sinusoidal oscillatory response having the same frequency as the stimulus
- Sensitive to attention status
- Quantifiable in the frequency domain and can be extracted from background EEG





https://www.youtube.com/watch?v=PsSPKnD9XsM

Usage

- Can simultaneously check EEG (SSVEP) responses to several frequencies (multiple choices)
- But it is difficult to discriminate between choices if too many frequencies are used
- Flickering stimuli could be a potential problem for epileptic patients (possibility of inducing epileptic seizures)

To Summarise

ERP is a very powerful tool for BCI with real-time precision

1. P300 speller with letter grid
2. LRP with movement decisions
3. SSVEP with flickering stimulation

Thanks!