Radboud University

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NatMEG

FieldTrip

Stimulus presentation and synchronization

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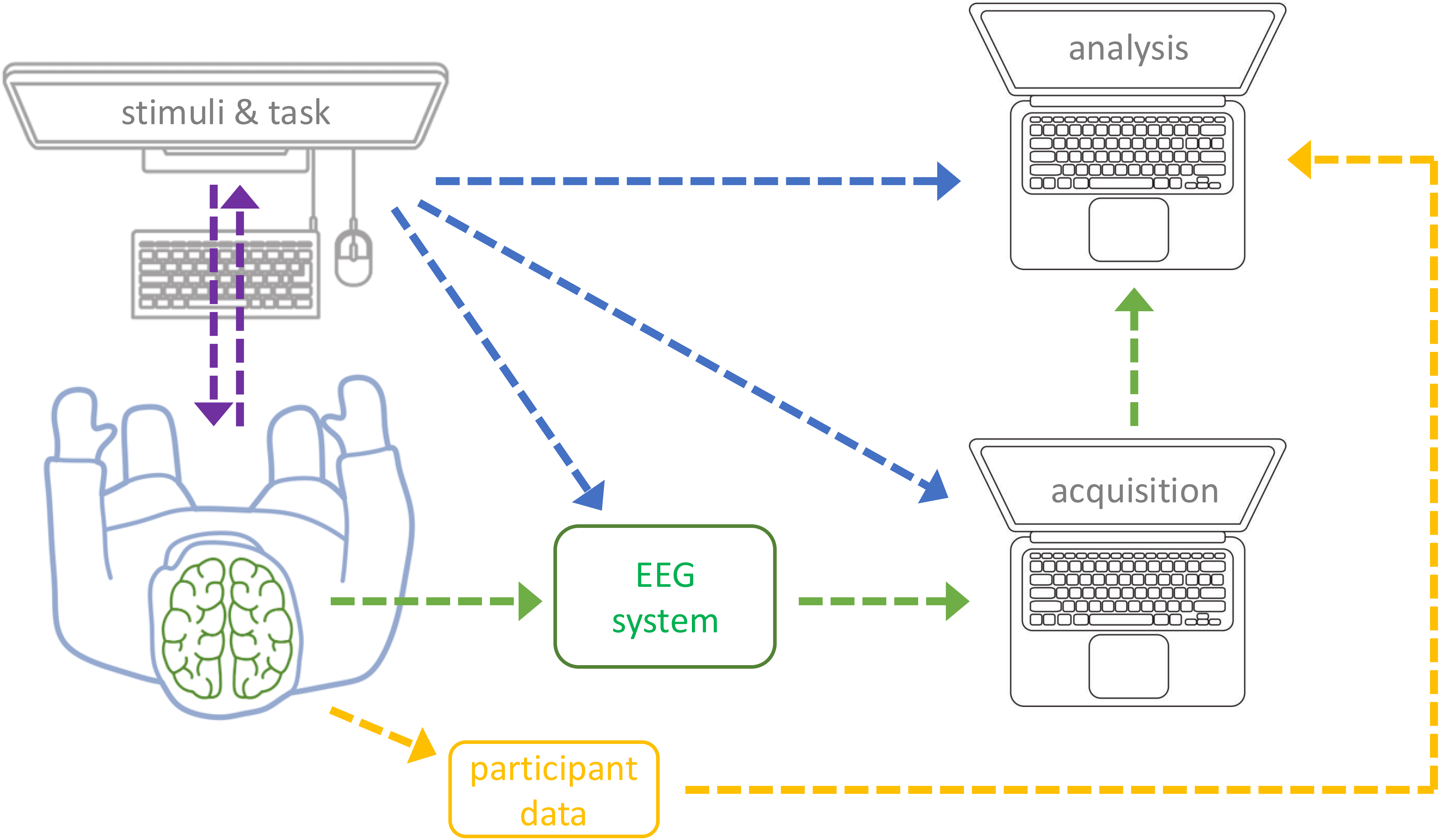
9-14 June 2025
Port Harcourt, Nigeria

African Brain Data Network


stimuli & task
analysis
acquisition
EEG
system
participant
data

Observational versus experimental studies

Observational:

- We observe without intervention, for example spontaneous EEG during sleep

Experimental

- We manipulate the experimental setup and conditions, for example by flashing a bright light or by asking the patient to hyperventilate

Most cognitive research is experimental

- We tell the participant what they should do and present stimuli in and record responses to very specific conditions

Experimental design and terminology

EEG experiments needs many repetitions

The brain is active with many things at once

The EEG signal is noisy

The brains of different people are not exact copies

Cognitive processes can be implemented differently

Many repeats of the experiment needed to make sense of the data

- Many trials (repeats within one participant
- Many subjects (repeats over subjects)

Baker et al (2021). Power Contours, https://doi.org/10.1037/met0000337

Experimental design

Event-related design

- Each trial is a different condition
- Conditions are random over trials

Block design

- All trials in a block are the same condition
- Each block is a different condition
- Conditions are random over blocks

Confounds

Counter balancing

Pseudo-random sequences

Behavioral task - terminology

Visit

Session

Block

Run

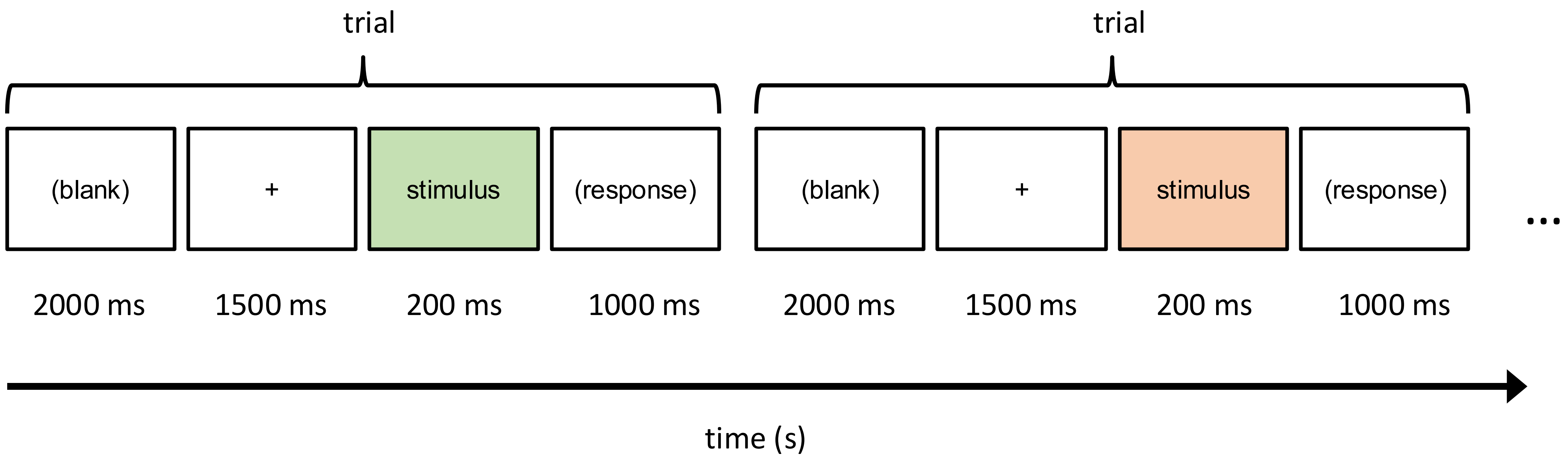
Mini-block

Trial

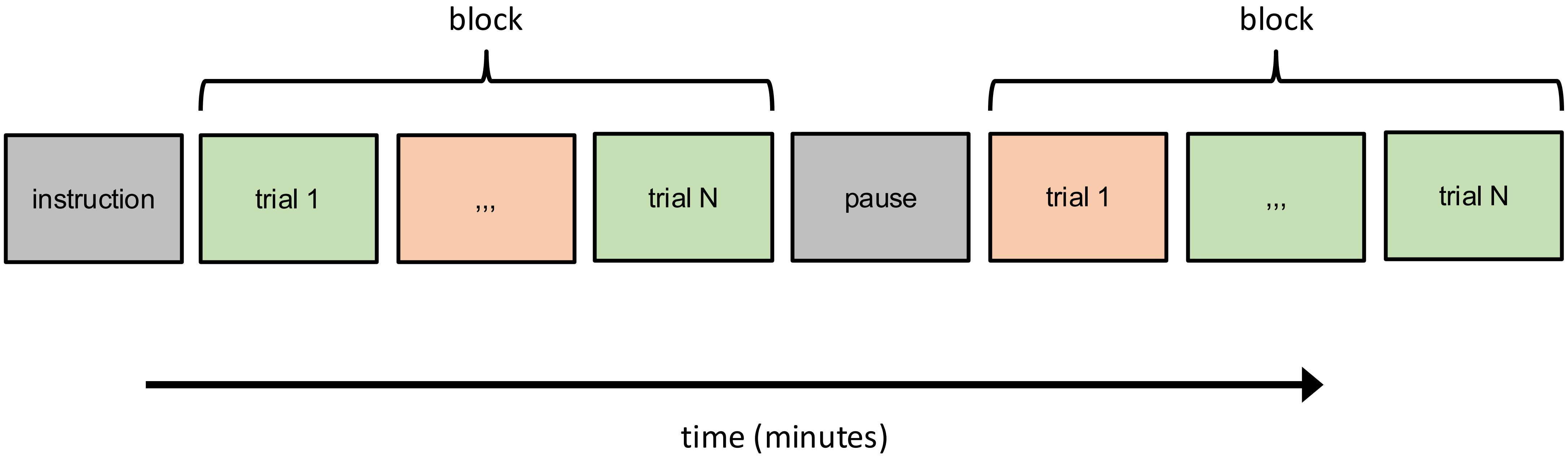
Inter-trial interval (ISI)

Inter-stimulus interval (ITI)

Experimental design



Experimental design, zooming out



Software

Stimulus presentation software

Can show text and images, play sounds and video.

Can record responses from the participant.

- Keyboard, mouse, joystick, audio (speech), special button boxes, …

Writes the stimuli and responses (with timestamps) to a log file.

Specific for EEG: can send ”triggers” for synchronization.

Usually the stimulus presentation software allows you to “program” an experiment in the form of a script.

It handles the instructions, training trials, experimental trials with stimuli, records responses, provide feedback.

Stimulus presentation software

Open Source and Free

- PsychoPy
- PsychoJS (from PsychoPy)
- OpenSesame
- ExPYriment
- jsPsych
- Lab.js

Open Source but not completely free

- Psychtoolbox (PTB) + MATLAB

Commercial (Paid) Software

- NBS Presentation
- E-Prime
- Gorilla (limited free tier)

Generic

- Unity or Unreal Engine
- Python-based (PyGame)

Experimental design and timing

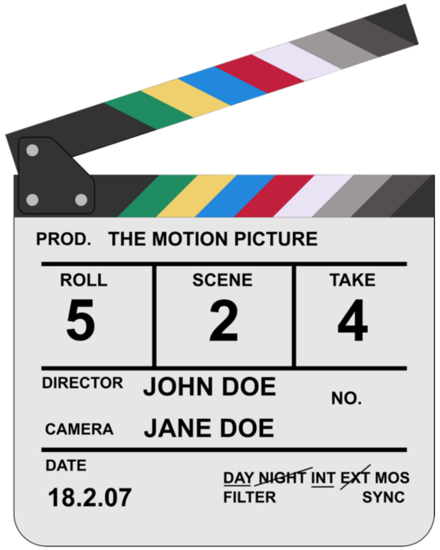
We want to know what the subject is doing or seeing at the **exact time.**

We write everything to the stimulus presentation **log file.**

We send a **trigger** to the EEG system at the start of every block,
this can indicate the condition as a number.

We send a trigger at the exact moment of the

- Start of the trial, this can indicate the condition
- Onset of the fixation cross
- Onset of the stimulus, this can indicate the stimulus characteristics
- Moment of the response
- (Moment of the feedback)



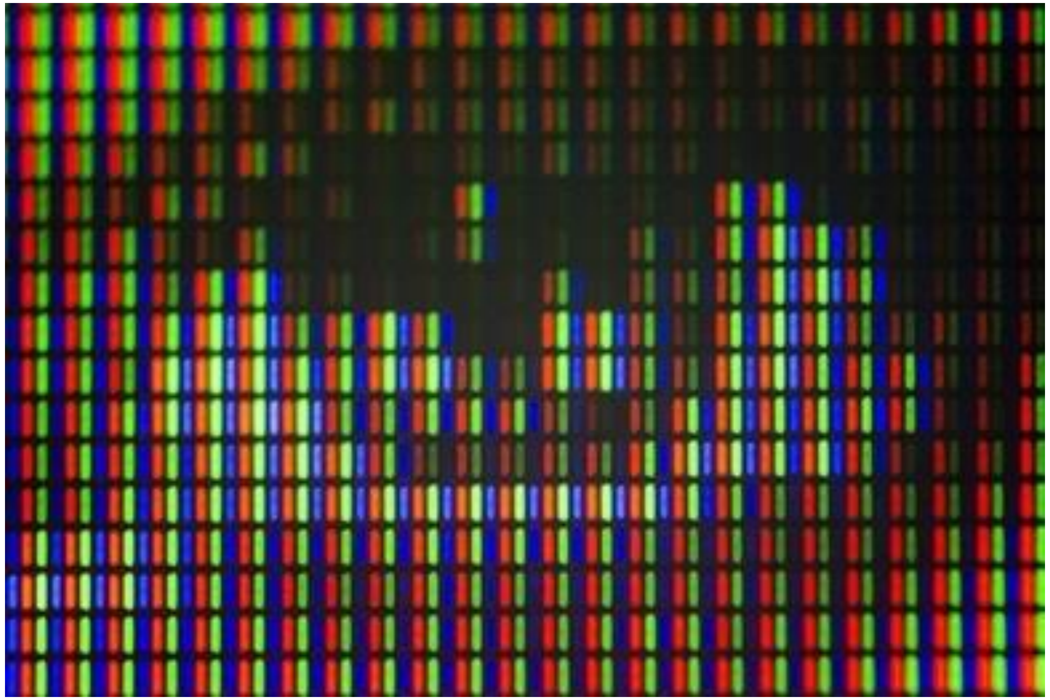
Computer screen

Presenting visual stimuli using a computer

Resolution (for example HD 1920x1080 pixels)

Screen refresh rate (for example 60Hz)

Drawing the screen takes some time -> at 60Hz one refresh takes 1/60 s = 16.667 ms



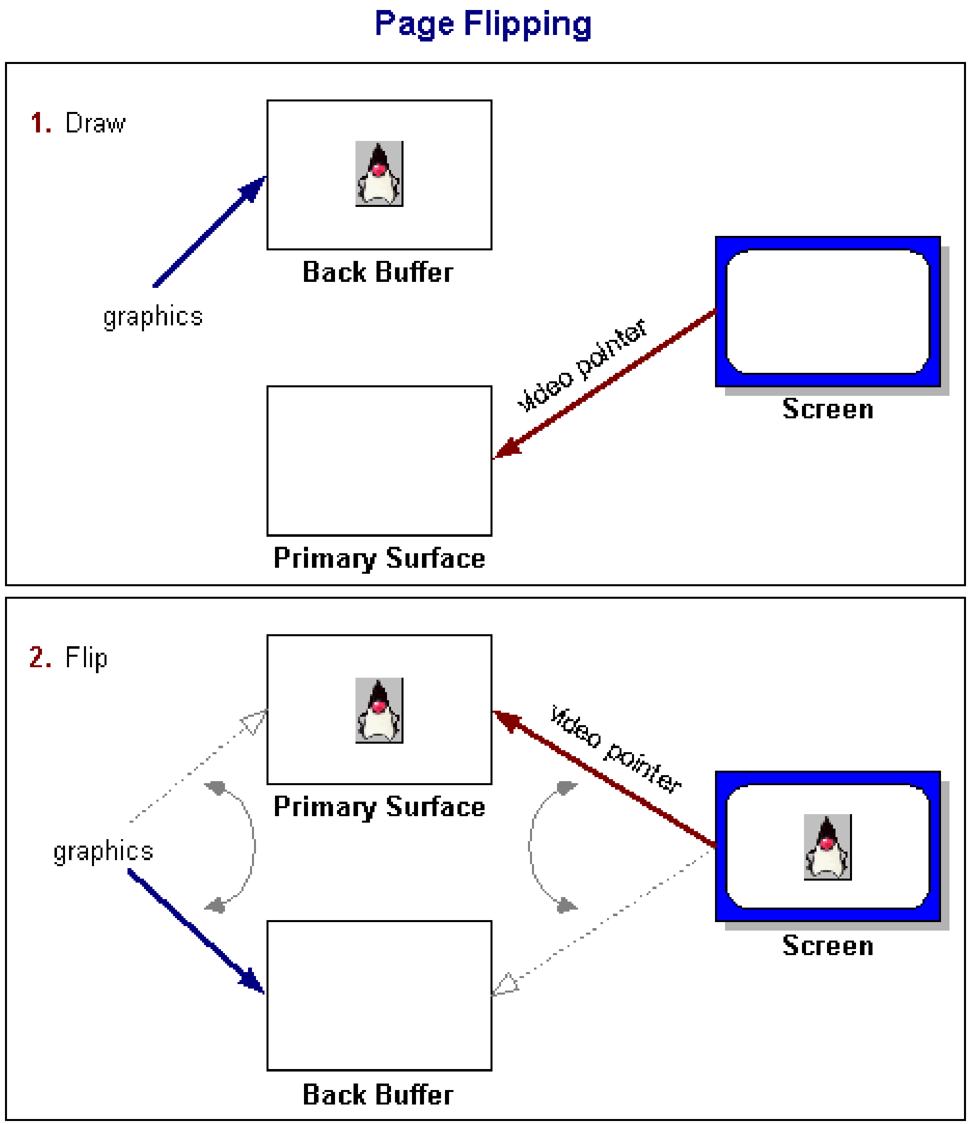
Presenting visual stimuli using a computer

You draw the screen in memory, this may take a few ms

The actual display of the screen is updated all at once, this takes 16.67 ms

Double buffer: draw in the “back buffer” and then flip that to the “front buffer”

We write the trigger *not* when we draw the screen, but when the screen flips



Trigger cable

Sending triggers to the EEG system

The EEG system amplifies the EEG voltage differences and digitizes then at a fixed rate of for example 500Hz.

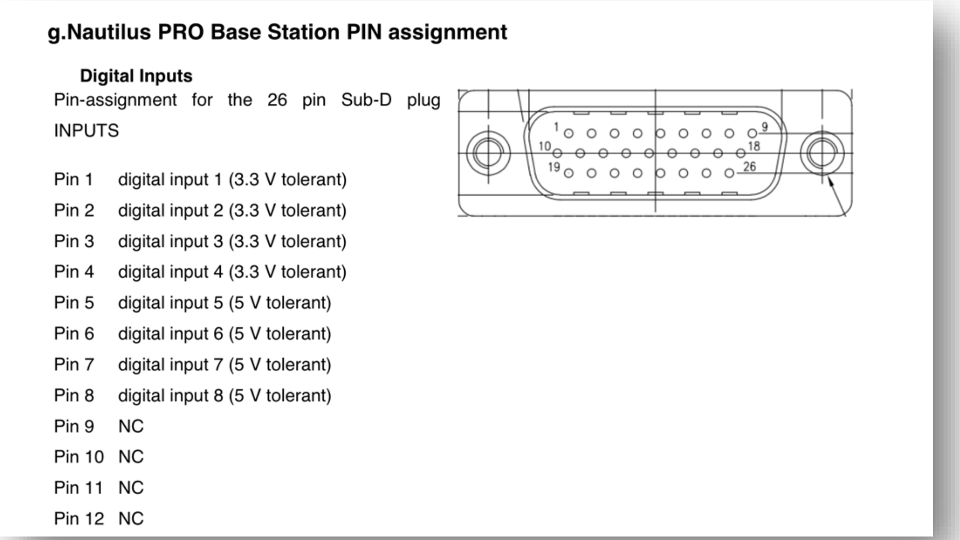
The EEG system often has a parallel input port.

Each pin of that connector represents one bit.

The pins accept TTL (transistor-transistor-logic) level signals between – and 5V (or 0 and 3.3V).

For example:

Fixation cross	1 = b00000001
Stimulus A	2 = b00000010
Stimulus B	4 = b00000100
Left hand response	8 = b00001000
Right hand response	16 = b00010000
Both hand response	24 = b00011000



g.Nautilus PRO Base Station PIN assignment

Digital Inputs

Pin-assignment for the 26 pin Sub-D plug

INPUTS

Pin 1	digital input 1 (3.3 V tolerant)
Pin 2	digital input 2 (3.3 V tolerant)
Pin 3	digital input 3 (3.3 V tolerant)
Pin 4	digital input 4 (3.3 V tolerant)
Pin 5	digital input 5 (5 V tolerant)
Pin 6	digital input 6 (5 V tolerant)
Pin 7	digital input 7 (5 V tolerant)
Pin 8	digital input 8 (5 V tolerant)
Pin 9	NC
Pin 10	NC
Pin 11	NC
Pin 12	NC

Decimal and binary numbers

With binary numbers we use two digits of symbols: 0 and 1, these are called “bits”.

As with decimal numbers we interpret them from right to left.

The rightmost bit represents 0 or 1 times 2^0

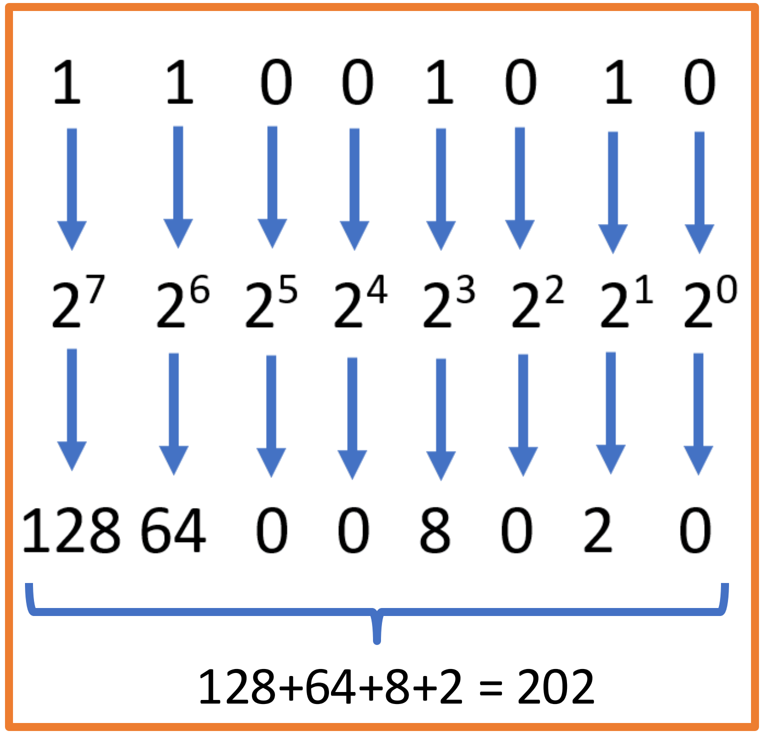
The second bit from the right represents 0 or 1 times 2^1

Binary 00000000 = decimal 0

Binary 00000001 = decimal 1

Binary 00000010 = decimal 2

Binary 11001010 = decimal 202 (= 2+8+64+128)



https://www.rapidtables.com/convert/number/binary-to-decimal.html?x=11001010

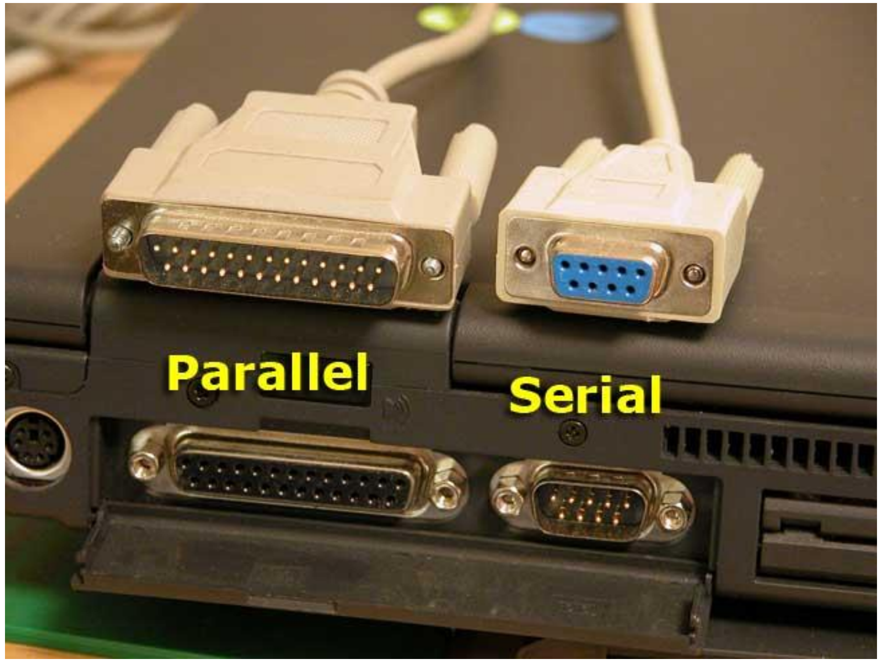
Parallel and serial ports

Serial ports were used for mouse, modems, etc.

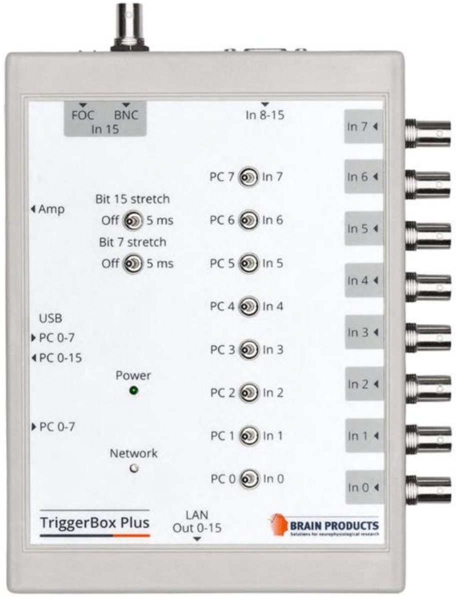
Parallel ports were used for printers.

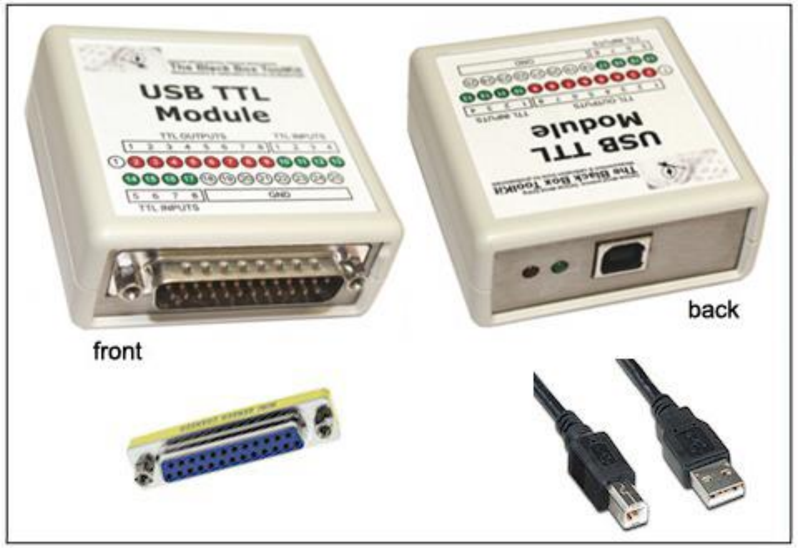
Nowadays all replaced by USB ports, especially on laptops.

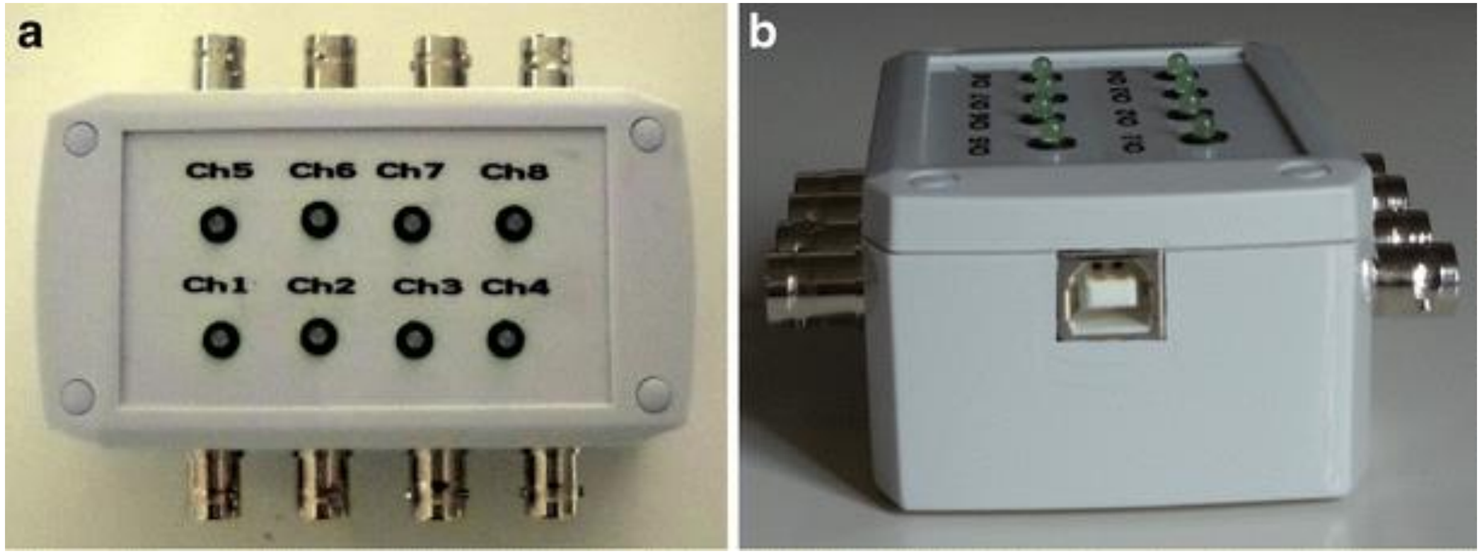
USB ports are serial in nature, but EEG systems still have pararell ports.



USB to parallel port converter







USB to parallel port converter

Some converters only do output, from the computer to the EEG system.

Some converters do both input and output.

Some converters only have 8 bits (like a parallel port), some have 16 or more.

Some converters also have extra inputs:

- for audio, so that you can detect the onset of a sound.
- for a photodiode (light sensor), so that you can detect the onset of the screen.

If you send the number “1”, the bit pattern changes shortly from b00000000 to b00000001, and then changes back.

Some converters allow you to specify how long the pulse should be “on”.

Some converters allow you to specify whether the pattern should ”stick” or not.

USB to parallel port converter – do it yourself (DIY)

Arduino is an open-source electronics platform based on low-cost and easy-to-use hardware and software for creating interactive projects.

Arduino Uno is one of these hardware boards

- USB input
- microcontroller
- 14 digital input/output pins

You can program it with C/C++ or Python

Many EEG labs use an Arduino board to build their own converter and button boxes.

USB to parallel port converter – do it yourself (DIY)

Documentation of the amplifier

What kind of connector?

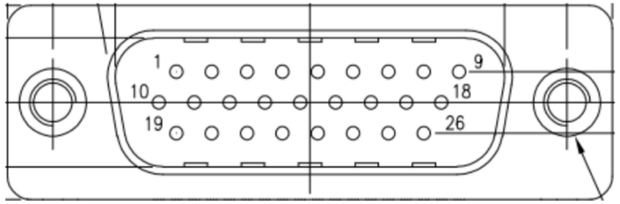
Which pins are used?

What voltage is used?

For example GTec Nautilus:

Digital Ins

Pin-assignment for the 26 pin Sub-D plug INPUTS



Pin 1 digital input 1 (3.3 V tolerant)
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Pin 5 digital input 5 (5 V tolerant)
Pin 6 digital input 6 (5 V tolerant)
Pin 7 digital input 7 (5 V tolerant)
Pin 8 digital input 8 (5 V tolerant)
Pin 9 NC
Pin 10 NC
Pin 11 NC
Pin 12 NC
Pin 13 NC
Pin 14 NC
Pin 15 NC
Pin 16 NC
Pin 17 + 3.3 V dc
Pin 18 + 3.3 V dc
Pin 19 GND
Pin 20 GND

What if the EEG system does *not* have a parallel in?

LabStreamingLayer (LSL)

- Library for MATLAB and Python
- Send time-stamped data over network
- LabRecorder records all incoming streams to an XDF file
- Stimulus software sends markers with timestamps
- EEG also needs to be send with timestamps

Analog input, can be used just like a TTL signal with one bit

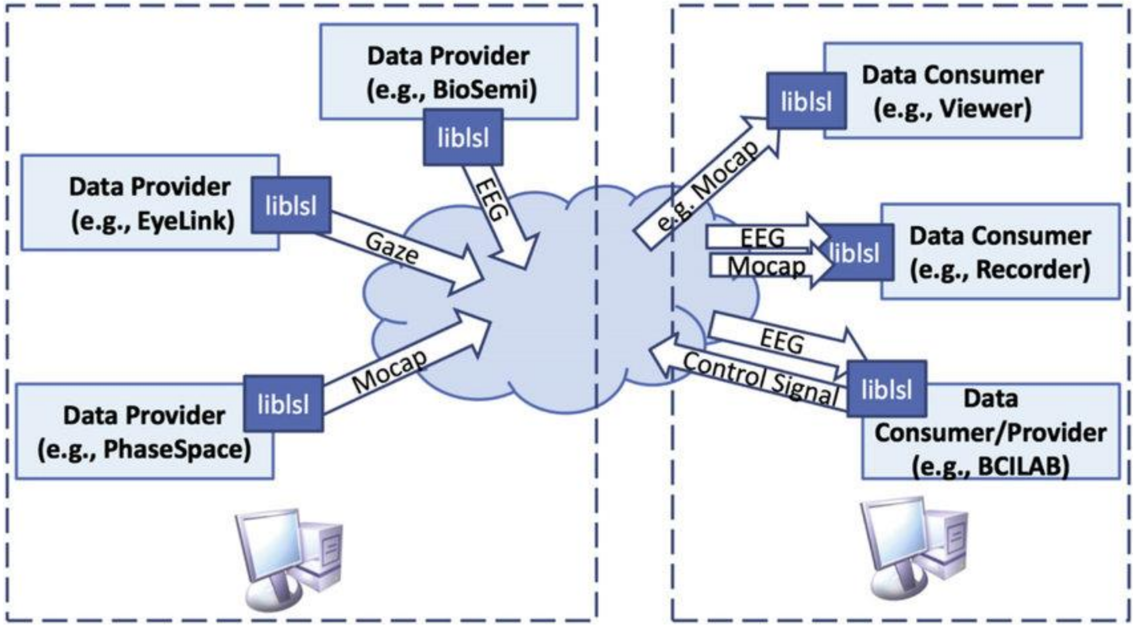
Button presses at start and end of experiment

What is LabStreamingLayer (LSL)

https://labstreaminglayer.readthedocs.io
https://www.biorxiv.org/content/10.1101/2024.02.13.580071v1

LSL is a software library implemented in C++ with wrappers for Python and MATLAB that sends data over the network.

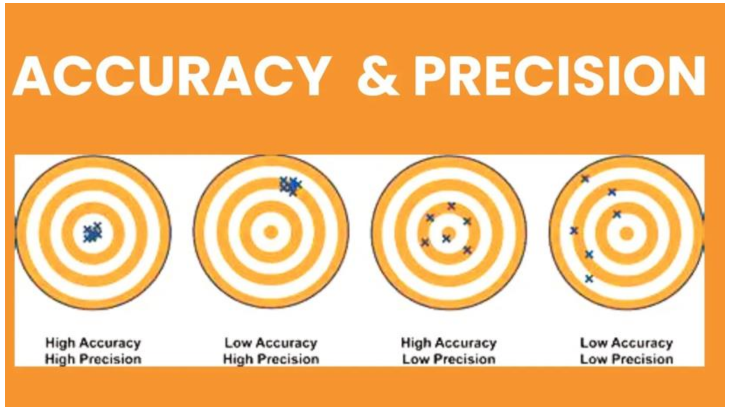
It has “outlets” and “inlets”. The flow of data (and markers) is configured by connecting these.



LabRecorder allows recording from multiple outlets, for example the EEG and the event marker stream.

Especially useful when using different hardware devices, connected to different computers. Can also be used to replace hardware trigger cables, but not as precise.

Delay and jitter = accuracy and precision

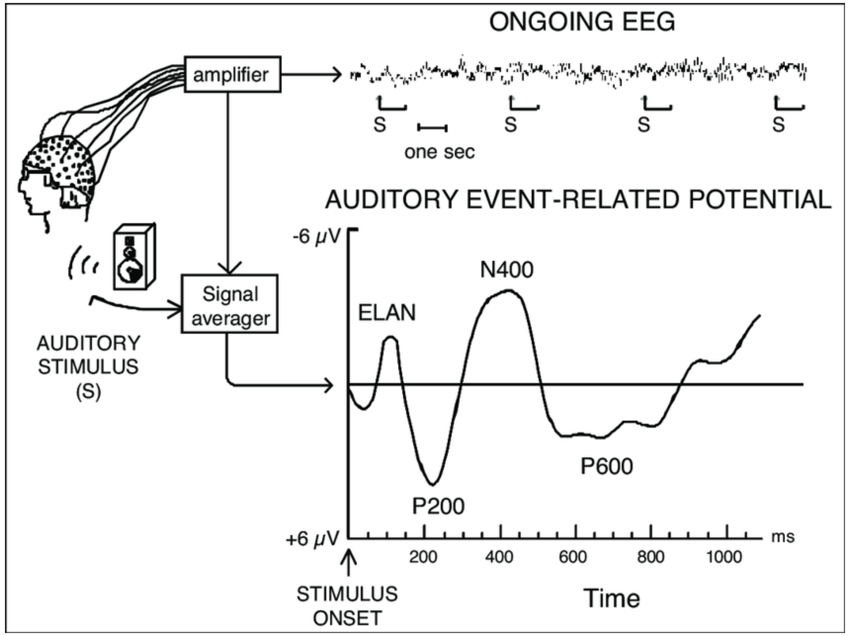


The "delay" represents the systematic time difference

The "jitter" represents the random time difference

The consequence of delay is that an ERP peak is later than expected.

The consequence of jitter is that the ERP "washes out" and gets smaller.



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