université PARIS-SACLAY | FACULTÉ DES SCIENCES D'ORSAY

Paris-Saclay University

Master Biology and Health

UE Technologies in neurosciences

- Visualy Evoked Potential *(VEP)* -

Academic year 2024-2025

EVOKED POTENTIALS (EPs)

Definition :

- Variation of the electrical potential induced synchronously in a population of excitable cells in response to a stimulus presentation.

- The stimulation can be of different nature: electrical, magnetic (TMS) or can be a sensory stimulus (tactile (SSEP), auditive (AEP), visual (VEP) …etc).
- EPs are used in different contextes :
  - In fondamental research: to asses how the nervous system works (sensory or motor systems) and to study the cerebral processes of cognition (neural bases of intenal representations, mechanisms of attention, …etc).
  - In clinical research: to diagnose pathologies (multiple sclerosis, tumor, …etc) or nervous system dysfunction, in addition to other medical examinations.

In human, EPs recording are generaly made with the use of non-invasive techniques such as the recording of electroencephalography (EEG) using surface electrodes or the magnetoencephalography (MEG).

SPATIO-TEMPORAL LIMITS OF NEUROTECHNOLOGIES

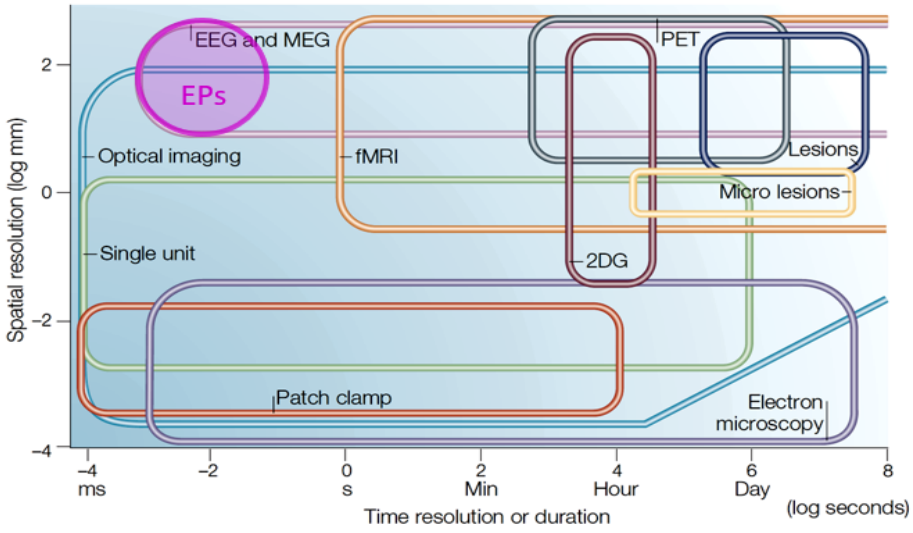
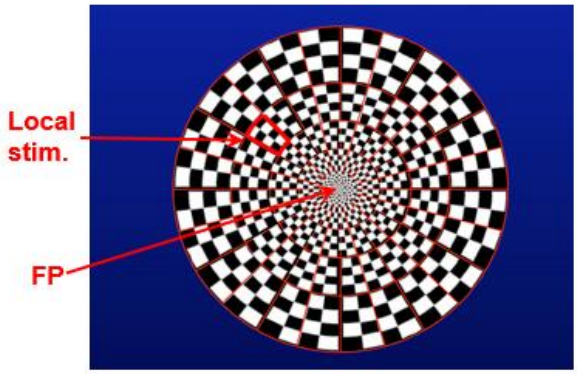


Figure 7 | Some available tools to meet the challenges of neuroscience. The spatiotemporal capabilities of each technique are depicted by the coloured rectangles. Optical imaging covers almost the entire area (including VSDI, imaging based on intrinsic signals, ion imaging (such as calcium or sodium), confocal imaging, multi-photon imaging and more). Fortunately, several optical imaging techniques can be combined in a single experiment. Other valuable techniques can also be integrated with optical imaging. EEG, electroencephalography; fMRI, functional MRI; MEG, magnetoencephalography; PET, positron emission tomography; 2DG, 2-deoxyglucose post-mortem histology.

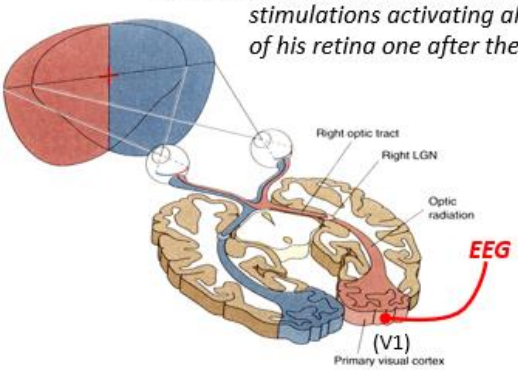
Grinvald A, Hildesheim R. VSDI: a new era in functional imaging of cortical dynamics. Nat Rev Neurosci. 2004 Nov;5(11):874-85.

VISUAL EPs : AN EXEMPLE OF CLINICAL APPLICATION

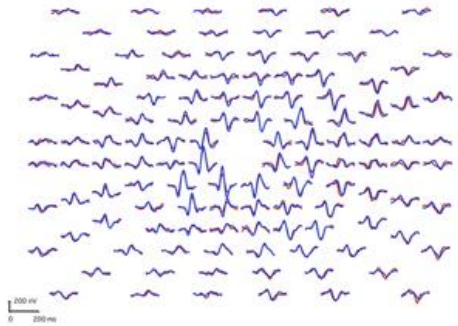
Multifocal VEPs

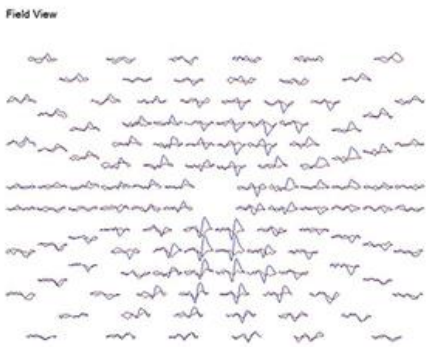


In this clinical examination, the subject stare at a fixation point (FP) in the center of the stimulation grid and receives local stimulations activating all parts of his retina one after the other.



- *Normal subject*





(VEP induced at the back of the skull, just above the visual cortex (V1), when visual stimuli are presented respectively on the right (red traces) and left (blue traces) retina).

Hood et al. (2008)

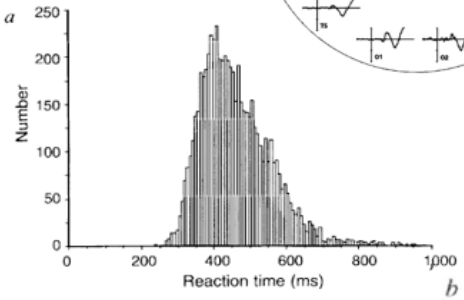
VISUALLY EPs : AN EXEMPLE IN FONDAMENTAL RESEARCH

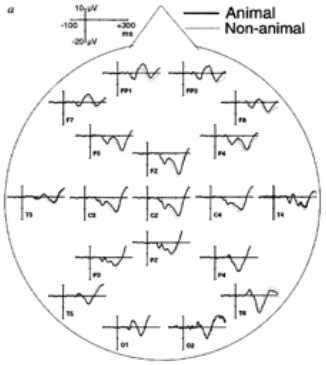
LETTERS TO NATURE

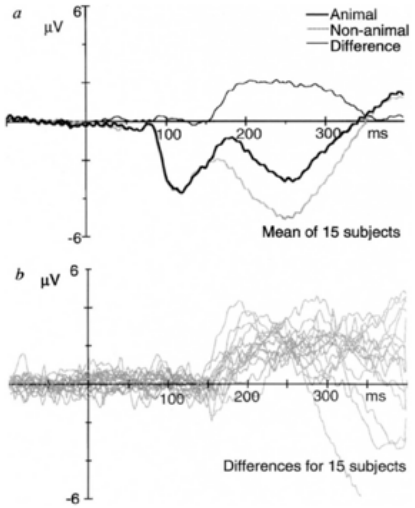
Speed of processing in the human visual system

Simon Thorpe, Denis Fize & Catherine Marlot

NATURE · VOL 381 · 6 JUNE 1996







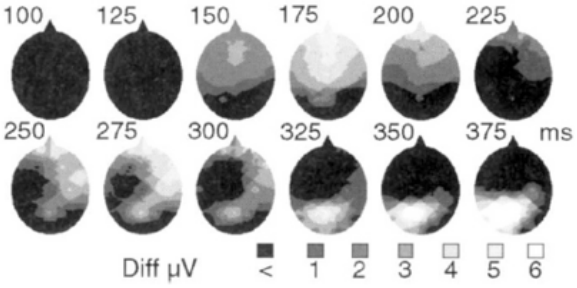


FIG. 1 Behavioural performance measures. a, Distribution of reaction times on target trials for the 15 subjects participating in the study (7 males and 8 females, aged between 22 and 45 years of age), each of whom performed at least 700 trials (range, 700-2,000). **Subjects pressed a button to start a sequence** of trials and, after an interval of 1 to 2 seconds, an image was presented at the center of the screen. A small fixation cross was present before and after stimulus presentation. Subjects were instructed to **release the button** if they saw an animal (**'go'** trials), and to **keep their finger on the button** otherwise (**'no-go'** trials).

REMINDER ON ELECTROENCEPHALOGRAPHY (EEG)

- Brain activity recording technique developed by Hans Berger nearly a century ago (1929).
- EEG is a non-invasive technique that involves recording global activity of brain regions using electrodes placed on the surface of the scalp.
- Spectral analysis of the EEG signal makes it possible to extract informations about brain state and functions.

- EEG is used :

<u>1) in research :</u> to study different brain states during sleep and awakening and their neuromodulatory systems regulation, as well as brain processes of cognition (basis of attention, decision making …etc.).

<u>2) in clinic :</u> examination during development, diagnosis of pathologies (sleep disorders, epilepsy, tumor …etc.) or brain trauma (injury, stroke, coma …etc.).

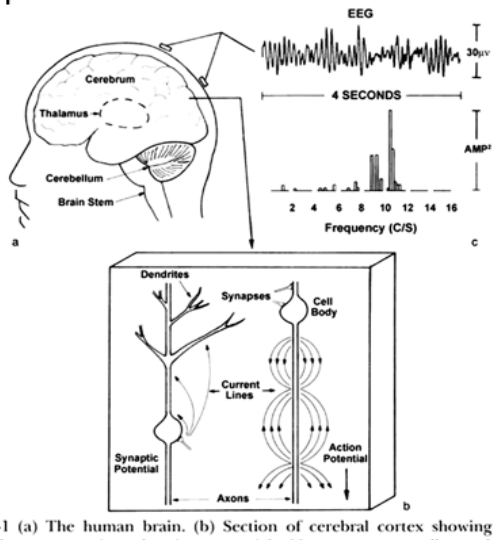
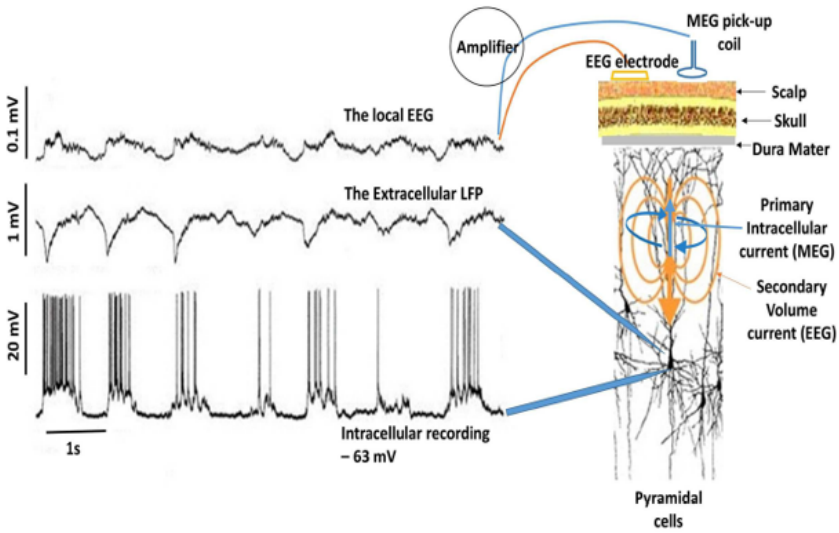


Figure 1-1 (a) The human brain. (b) Section of cerebral cortex showing microcurrent sources due to synaptic and action potentials. Neurons are actually much more closely packed than shown, about 10^5 neurons per mm^2 of surface. (c) Each scalp EEG electrode records space averages over many square centimeters of cortical sources. A four-second epoch of alpha rhythm and its corresponding power spectrum are shown.

Electric Fields of the Brain: The Neurophysics of EEG (2006) P.L. Nunez and R. Srinivasan; books.google.com

NEURONAL BASIS OF EEG SIGNAL



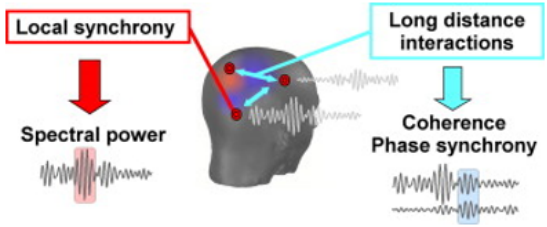
The EEG recorded at the surface of the skull (*), is the image of the sum of currents (*associated with synaptic potentials and action potentials*) generated in the cortical network just below the recording electrode site.

In the right part of the figure, Blue and orange arrows represent respectively the primary currents (produced at the cell level) and secondary (produced in the volume of cortical tissue) which are at the basis of the EEG.

(*) Note that when electrodes are positioned below the skull, in direct contact with the brain, one rather speak about Electrocorticogram (ECoG).

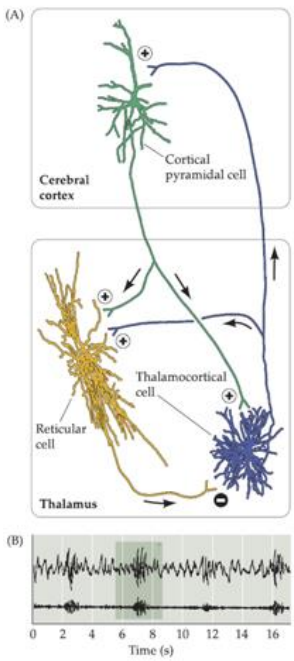
Delta activity recorded from pyramidal neuron of a cat in the somatosensory cortex during deep sleep. Bottom trace: depolarization and action potential of a neuron recorded intracellularly at 1 mm depth. Middle trace: LFP recorded in the extracellular space. Top trace: EEG recorded by mean of an electrode located on the brain surface. Note the missing neuronal spiking after the third cycle in the bottom trace, is reflected in the corresponding LFP and EEG. [adapted from Contreras and Steriade].

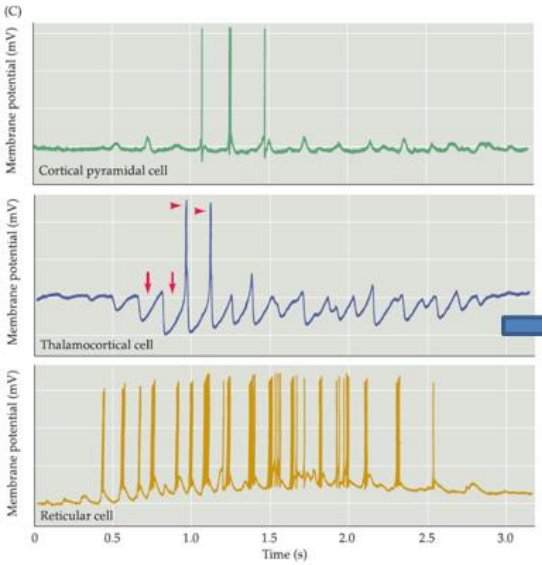
Adjamian (2014) Front.Neurol.

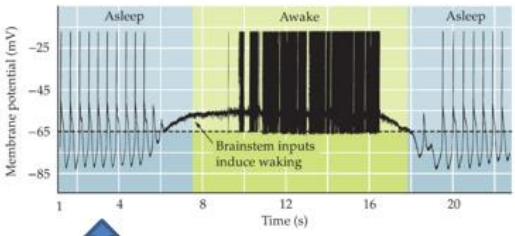


M.Besserve and J.Martinerie 2011 IRBM

ORIGINE DU SIGNAL EEG

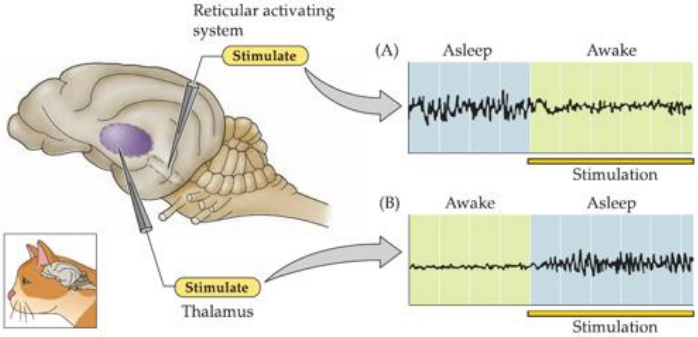






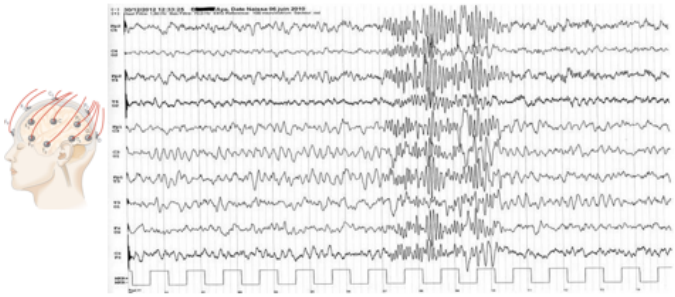
(McCormick and Pape, 1990)

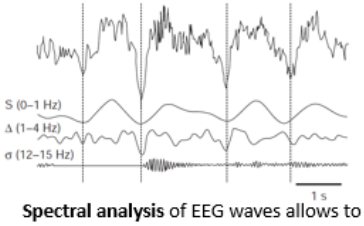
Oscillations of cortical activities which can be observed in EEG, reflect interactions between the cerebral cortex and sub-cortical structures (such as the thalamus nuclei and modulatory centers).



(H.Magoun, 1952)

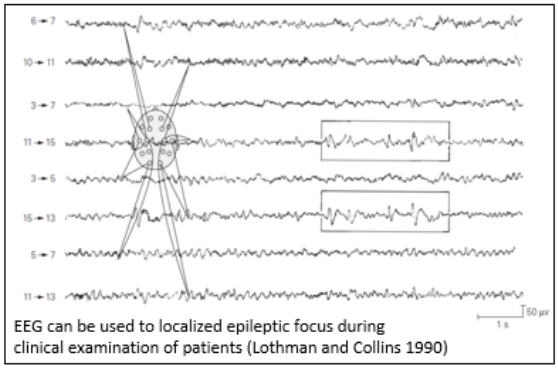
EEG RECORDINGS & BRAIN STATES





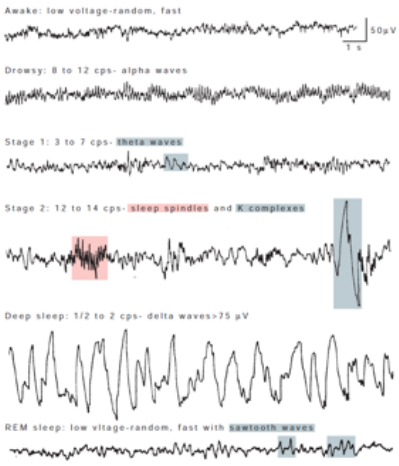
Spectral analysis of EEG waves allows to classify different brain states.

- **Awakening** is generaly characterized by a **desynchronized** activity of cortical neurons, which leads to an EEG signal containing fast waves (high frequency fluctuations) of low amplitude.
- **During sleep**, slow waves of large amplitude (low frequency) are observed. They reflect the degree of **synchronization** of activities of cortical neurons



EEG can be used to localized epileptic focus during clinical examination of patients (Lothman and Collins 1990)

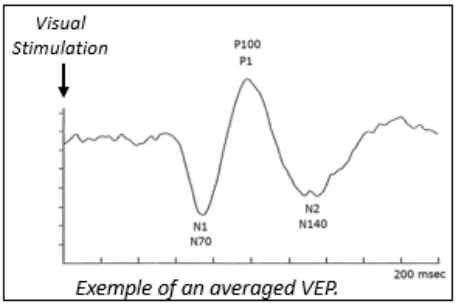
EEG variations during wake/sleep cycle.



2008 L.Squire et al. Fundamental Neuroscience (3rd edition)

OBJECTIVES OF LABORATORY WORK

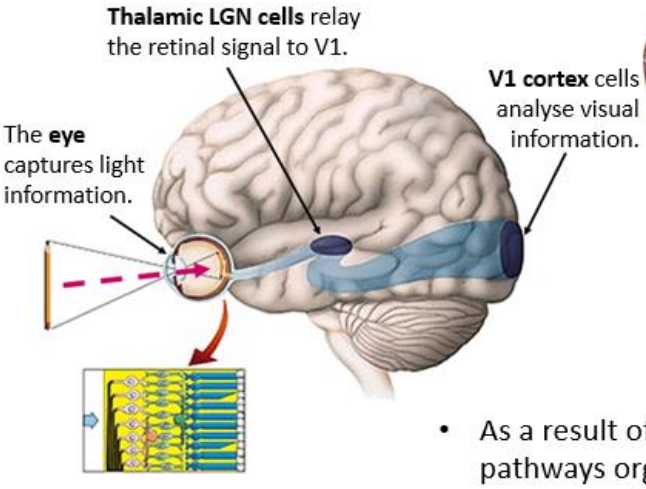
- To assess the integrity of the visual pathways on human subjects from the recording of visual evoked potentials (VEP) on the brain occipital region.
- EEG recordings will be done at the occipital skull surface (just above the visual cortical area) with a 16-electrodes EEG head-set.
- Stimuli used in this experiment (Flash ou alternating checkerboard) are the ones classically used during clinical examination of patients.
- Variations of VEP electrical signal being of a much smaller amplitude (of a range of few µV) than the EEG fluctuation, they can only be extracted from the raw EEG signal by averaging responses of a large number of trials.
- The averaging allows to extract the evoked signal (i.e., the VEP) from the « background noise » of the global brain activity (i.e., the EEG).

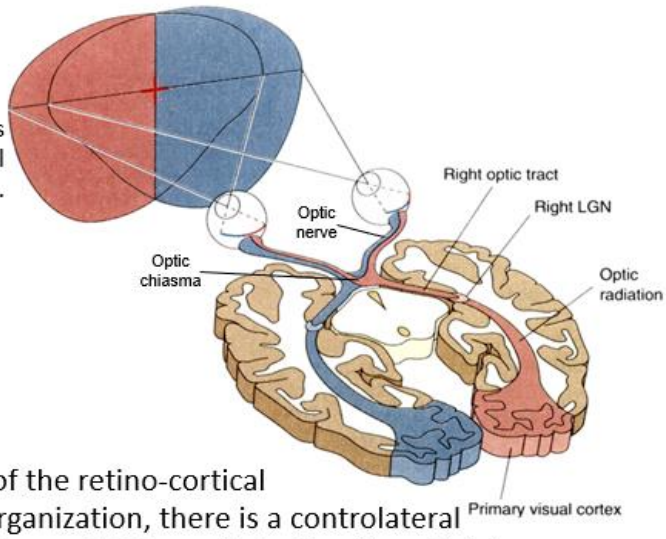


Exemple of an averaged VEP.

REMINDER ON THE VISUAL PATHWAYS ORGANIZATION

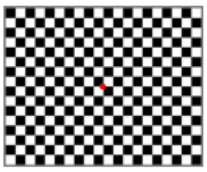
- Photoreceptors detect the light signal and transduce it into a nervous message.
- Retinal signal is then transmitted to the retinal ganglion cells (RGC) which in turn transmit it to thalamic lateral geniculate nucleus (LGN) cells.
- Afterwards, LGN cells relay the visual signal up to the occipital part of the brain, in the primary visual cortex (V1) were it is analyzed.





- As a result of the retino-cortical pathways organization, there is a controlateral representations of right and left visual hemifields.

EXPERIMENTAL SET-UP

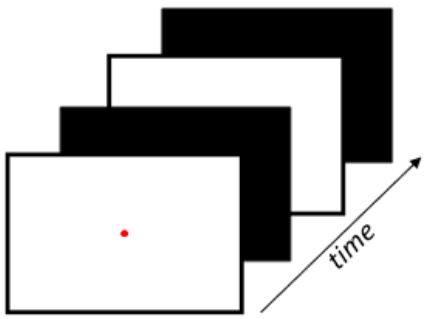


MATERIAL & METHODS

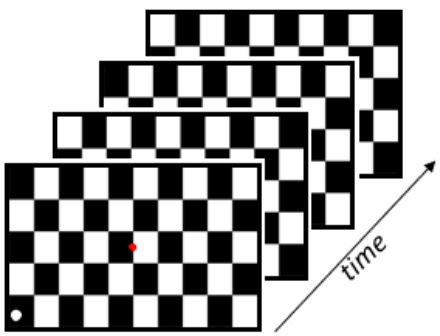
- Subject with a 16-electrodes EEG head-set
- Recording at occipital electrodes (O1 & O2).
- Distance from the stimulation screen : 0,6 to 0,8m.
- Visual stimuli used : either « Flash » or « alternating checkerboard ».
- Repetitive stimulus presentation (>100 times at 1-2Hz).
- Computation of VEP grand average.

INSTRUCTIONS

- Stay fixed and relaxed in front of the visual stimulation screen in a dim light environment.
- Stare at the fixation point (red dot) at the center of the screen.
- Avoid artifacts (head or eye movements, eye blinks …etc) which perturbate the recordings.



"Flash"



"Checkerboard"

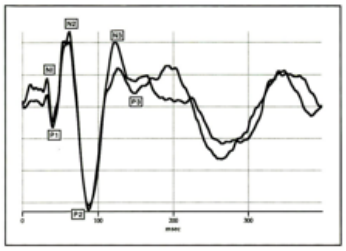
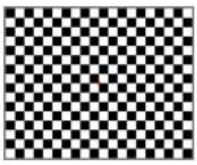


FIGURE 1: Normal flash visual evoked potential (VEP) recorded from the midline occipital area, referenced to the central midline. Two trials of 100 averages are superimposed. Negative polarity is shown as an upward deflection, positive polarity as a downward deflection. Waves are labeled according to standard nomenclature.

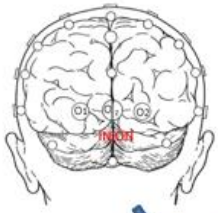
VEP EXPERIMENTAL SET-UP

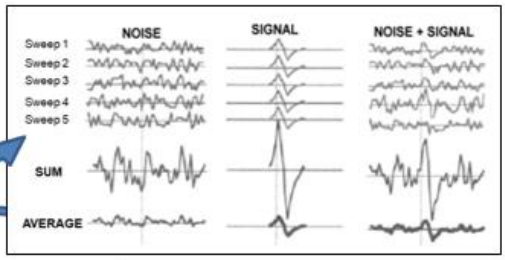
EEG amplitude 10-300 µV vs. VEP amplitude 2-10 µV

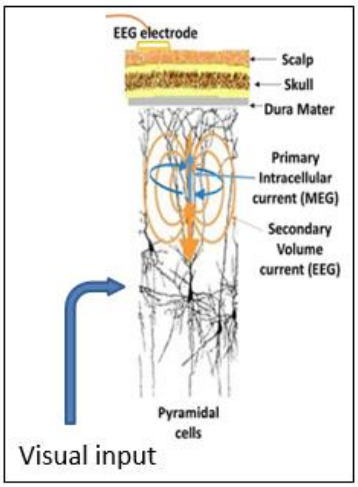


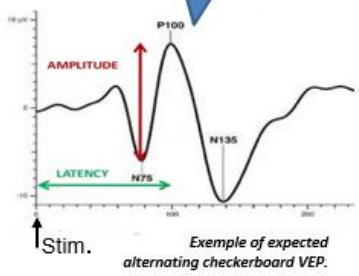
VEP extraction is done by averaging

- Stimuli are **repeated** (> 100 times).
- VEP is recorded uring a **post-stimulus period** (0-300ms).
- Computation of the **average VEP**.

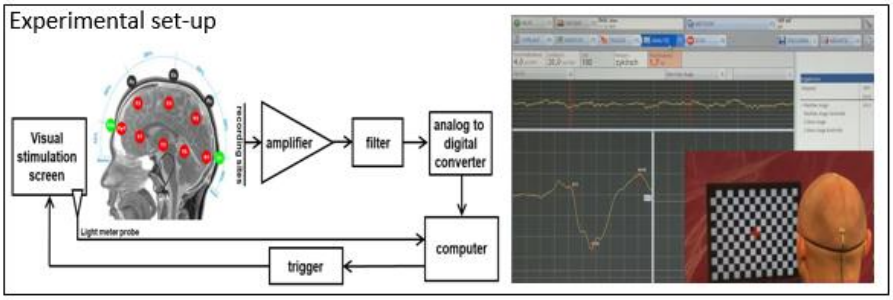








Exemple of expected alternating checkerboard VEP.



https://ecampus.paris-saclay.fr/course/view.php?id=164641#section-6

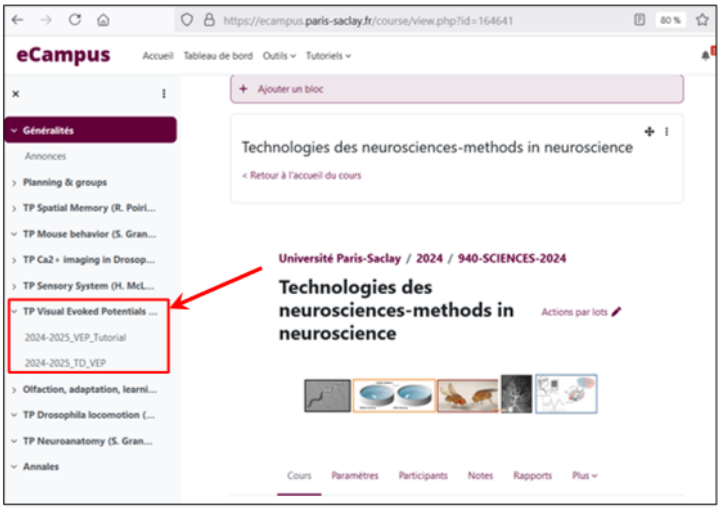
BEFORE & DURING THE LAB WORK

TO DO BEFORE THE PRACTICAL SESSION :

1) Download and read the "2024-2025_VEP_Tutorial" as homework before the lab session (*).

2) Download the figures of the directed Study in "2024-2025_TD_VEP" (*).

*(*) **Files are available on e-Campus** platform, in the "Visual Evoked Potentials" course of the "Technologies des Neurosciences/Methods in Neuroscience" teaching unit.*



TO DO DURING THE PRACTICAL SESSION :

1)Make the experiments allowing you to record and compute the VEP as described in details in the instructions of the "VEP Tutorial".

2)With the 2files (.XLSX & .DOCX) available on computers used for to run experiments:

a) Compute averages and standart-deviations of the amplitude and latencies of VEPs waves using the “2024-2025_VEP Measurements spread-sheet.XLSX”.

b) Write the report of your group using your VEP data and the “2024-2025_VEP_Report.DOCX”.

CAUTION: All parts of the experiment have to be done during the time of the lab-session and have to be saved on the PC computer used during your practical work.