1. **EEG: historique**
2. ***Principes (activité des cellules pyramidales)***
3. ***Les potentiels évoqués tactiles***
4. ***Les sources d'activité cérébrale et somesthésie***
5. ***Les fréquences d'oscillation et les processus associés***

1875

Première publication informant de l'existence d'activités électriques dans le cerveau d'animaux (lapin, singe)

FORTY-THIRD ANNUAL MEETING
OF THE
BRITISH MEDICAL ASSOCIATION.

Held in EDINBURGH, August 3rd, 4th, 5th, and 6th, 1875.

PROCEEDINGS OF SECTIONS.

SUBJOINED are abstracts of most of the papers presented to the several Sections of the Association at the Annual Meeting. The papers themselves, as opportunities occur, will be published in full in the

sight, was one which he had localised by an entirely different method, viz., that of noting the variations in the electrical currents of the brain as caused by functional exercise.—Dr. FRASER and Dr. SMITH followed, and the latter expressed the general sense of the meeting in thanking Dr. Lauder Brunton for ably explaining Dr. Ferrier's views.

SECTION F.—PHYSIOLOGY.

Wednesday, August 4th.

DR. BURDON SANDERSON, F.R.S., President, took the Chair at 2 P.M.

Transference of the Long Tendon of the Biceps Muscle from the Scapula to the Humerus in Chronic Disease of the Shoulder. By JOHN STRUTHERS, M.D., Aberdeen.—Dr. Struthers explained how the tendon, say in a rheumatic shoulder, being no longer of any use, was removed from the upper bone and joined on to the lower bone, by which its use was thereby to some extent preserved. The steps of this process were narrated, and the subject was further elucidated by the exhibition of specimens. Adhering to the lower bone by the effects of excited action, the part of the tendon within the joint, having become functionless, was seen in various stages of passing away, while the attachment of the lower bones, on which the muscle pulls, became gradually stronger till the adaptation was completed. Dr. Struthers remarked that this might be called a pathological process; but pathological processes were also physiological processes; and, he expected that in future, the study of these processes would throw much light on questions connected with the origin and adaptation of healthy structures.

Experiments on Change of the Bodily Temperature consequent on Section of the Cord in the Cervical Region. By J. BURDON SANDERSON, M.D., LL.D., F.R.S., London.

The Electric Currents of the Brain. By RICHARD CATON, M.D., Liverpool.—After a brief *résumé* of previous investigations, the author gave an account of his own experiments on the brains of the rabbit and the monkey. The following is a brief summary of the principal results. In every brain hitherto examined, the galvanometer has indicated the existence of electric currents. The external surface of the grey matter is usually positive in relation to the surface of a section through it. Feeble currents of varying direction pass through the multiplier when the electrodes are placed on two points of the external surface, or one electrode on the grey matter, and one on the surface of the skull. The electric currents of the grey matter appear to have a relation to its function. When any part of the grey matter is in a state of functional activity, its electric current usually exhibits negative variation. For example, on the areas shown by Dr. Ferrier to be related to rotation of the head and to mastication, negative variation of the current was observed to occur whenever those two acts respectively were performed. Impressions through the senses were found to influence the currents of certain areas; *e. g.*, the currents of that part of the rabbit's brain which Dr. Ferrier has shown to be related to movements of the eyelids, were found to be markedly influenced by stimulation of the opposite retina by light.

The Localities Principle of Instinctive Power. By LAWSON TAIT, F.R.C.S.Ed., Birmingham.—Mr. Tait communicated the results of certain experiments he had made, for the purpose of separating the elicer-

BEVERIDGE, M.D., Aberdeen.—The death of this man occurred almost immediately after his first descent for the season. There was no defect in the apparatus, and his companion who descended with him was unaffected; it could not, therefore, be due to deficient supply of air. On a previous occasion, this man had, under similar circumstances, nearly lost his life. It also was his first descent for the season. It was usual for divers on descending for the first time to experience a feeling of oppression and a sensation as if the head would burst. This, as a rule, passed very quickly away, and nothing further was observed in the way of discomfort till after leaving the water, when there was very often a sensation of giddiness, sometimes an attack of sickness, and in many cases a flow of blood from the nose and mouth. Most men after a few trials became accustomed to the work and suffered no inconvenience, but some did not do so, and always suffered in some way on leaving the water. These symptoms were undoubtedly due to the varying pressure on the vessels on the lungs, and in the above case had produced complete stoppage of the pulmonary circulation. This view was confirmed by the *post mortem* examination. The heart was large, pale, and flabby; its cavities were empty of blood; the lungs were intensely gorged with dark fluid blood. The air-tubes, beginning at the fauces, were much congested, dark purple in colour; and the smaller bronchi were partially filled with dark frothy blood. Other organs were also loaded with dark blood. The heavy pressure (in this case doubled) would cause partial stoppage of the lung-circulation, throwing back the venous blood on the right side of the heart, and thus inducing insensibility and suffocation, while the quick taking off of the pressure could allow all those vessels to fill to the utmost, thus producing the great gorging of all the bronchial surface, and the complete emptying of the cavities of the heart.—In the discussion that ensued, several gentlemen expressed doubts as to the cause of the man's death, suggesting that, although one of the diving-bells was safe, the other might not have been so, and that this might not have been ascertained on account of the connecting-tube being out of order.

Thursday, August 5th.

Physiological Acoustics. By J. G. MCKENDRICK, M.D., Edinburgh.—Dr. McKendrick gave a demonstration on physiological acoustics, with the view of illustrating the results of the researches of Helmholtz regarding the quality of musical sounds. After pointing out that Helmholtz had discovered that a musical note consisted, not of one tone, but of a series of tones, Dr. McKendrick proceeded to show this by means of an ingenious contrivance devised by Dr. Koenig of Paris. In a series of interesting experiments, it was shown how a tone could be decomposed, as it were, into its fundamental harmonics, and in this way an actual flame-picture of it be obtained.

Effect of Division of the Sympathetic Nerve of the Neck in Young Animals. By WILLIAM STIRLING, D.Sc., M.D., Edinburgh.—Dr. Stirling said that the division of the sympathetic nerve in the neck, for instance, of a young rabbit or dog was, in the first place, followed by the ordinary symptoms of the operation. As the animal grew, however, it was found that the ear of the side in which the nerve was divided grew more than that on the other side. The hair of the ear upon this side became stronger than on the opposite side; and, lastly, the temperature of the affected part continued higher than that of the other side for several months together.

Richard Caton
1842-1926

~1908

Existence d'oscillations neuronales chez l'Homme (10 Hz)
(perception extra-sensorielle? phénomènes paranormaux?)

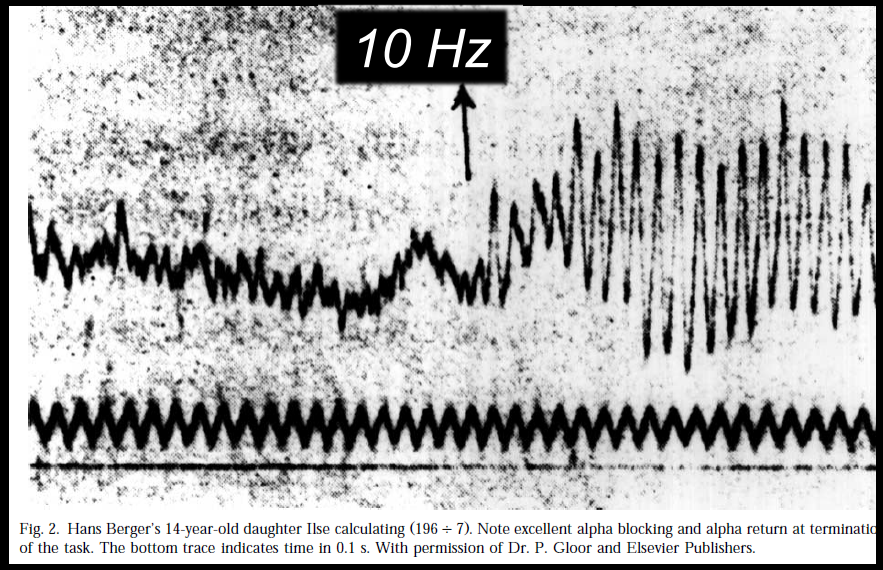


Fig. 2. Hans Berger's 14-year-old daughter Ilse calculating (196 ÷ 7). Note excellent alpha blocking and alpha return at terminatio of the task. The bottom trace indicates time in 0.1 s. With permission of Dr. P. Gloor and Elsevier Publishers.

Hans Berger
1835-1911

Différentes techniques d'imagerie cérébrale

Imagerie par résonance magnétique (IRM)

Résolution temporelle: 1 seconde
Résolution spatiale: ~1 mm
(surperficie, profondeur)

Magnétoencéphalographie (MEG)

Rés. temporelle: 1 ms
Rés. spatiale: ~3 mm (analyse de sources)

Electroencéphalographie (EEG)

Rés. temporelle: 1 ms
Rés. spatiale: ~7 mm (analyse de sources)

Différentes techniques d'imagerie cérébrale

Imagerie par résonance magnétique (IRM)

> 7 millions d'euros €

Magnétoencéphalographie (MEG)

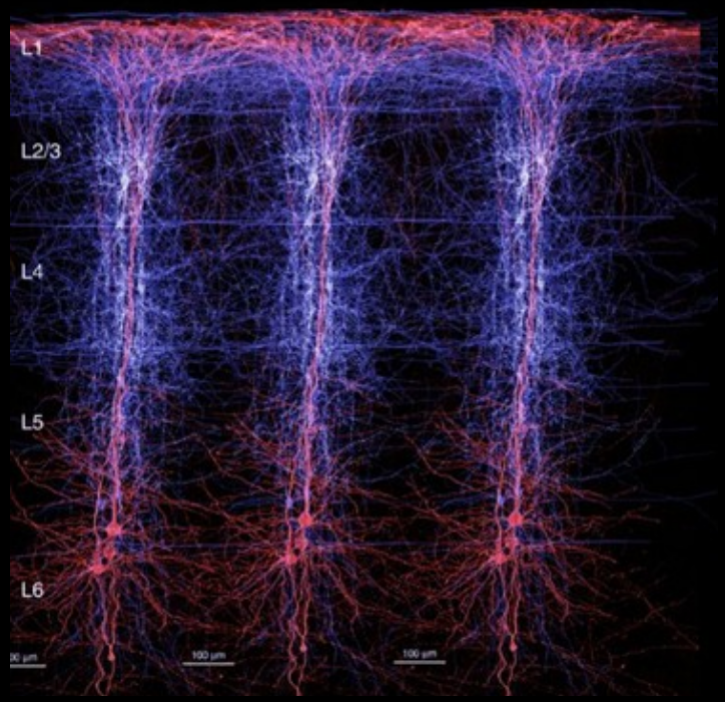
~1.5 million €

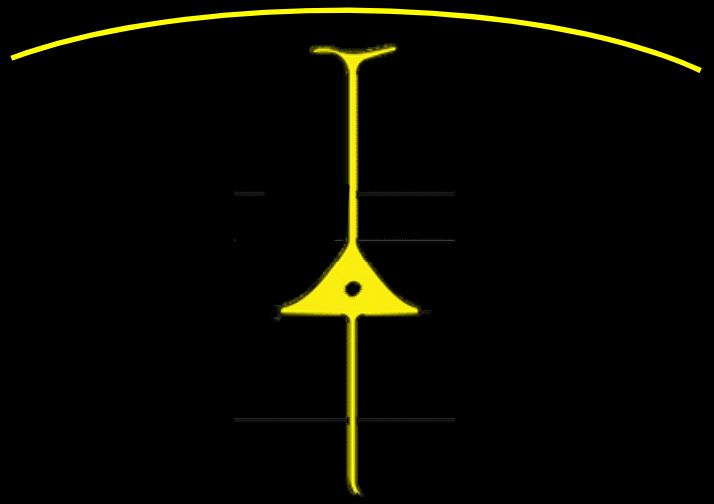
Electroencéphalographie (EEG)

~30 000 €

2. Principes (activité des cellules pyramidales)

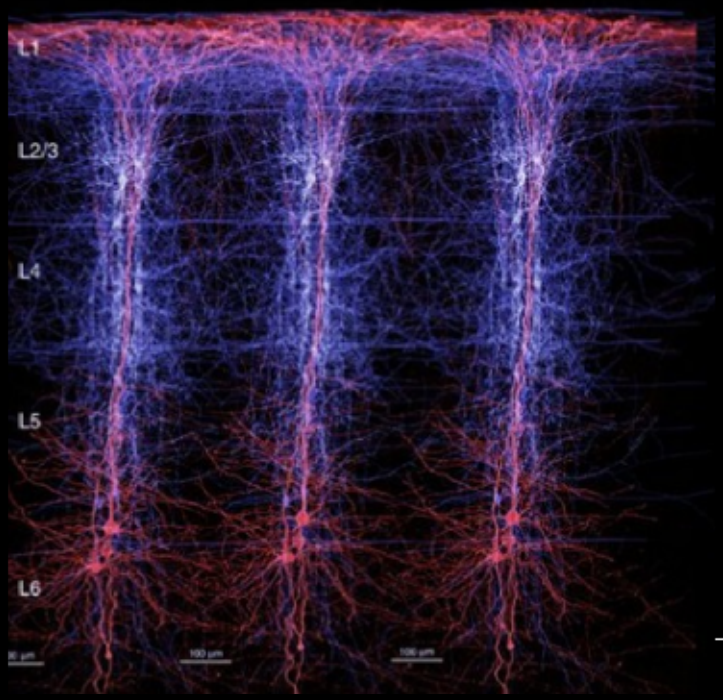
Les électrodes sur la surface du crâne détectent "essentiellement" l'activité des cellules pyramidales du cortex (Betz)

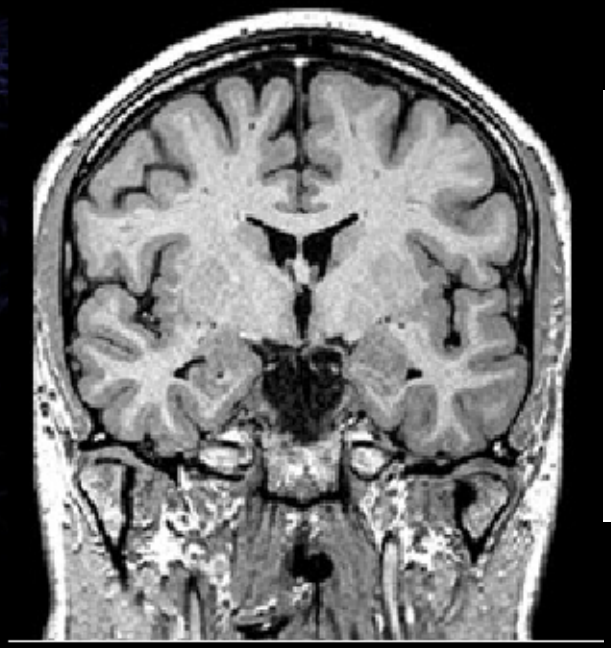




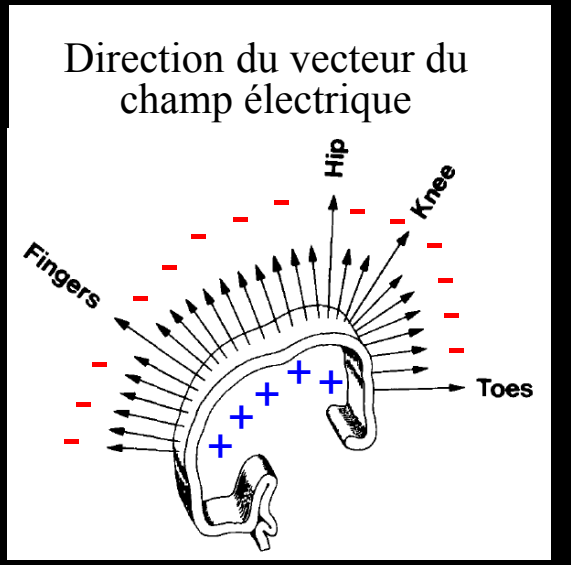
Mais, pour complexifier l'affaire….

Les axones des cellules pyramidales sont orientés perpendiculairement par rapport à la surface corticale qui est "cafi" de sillons



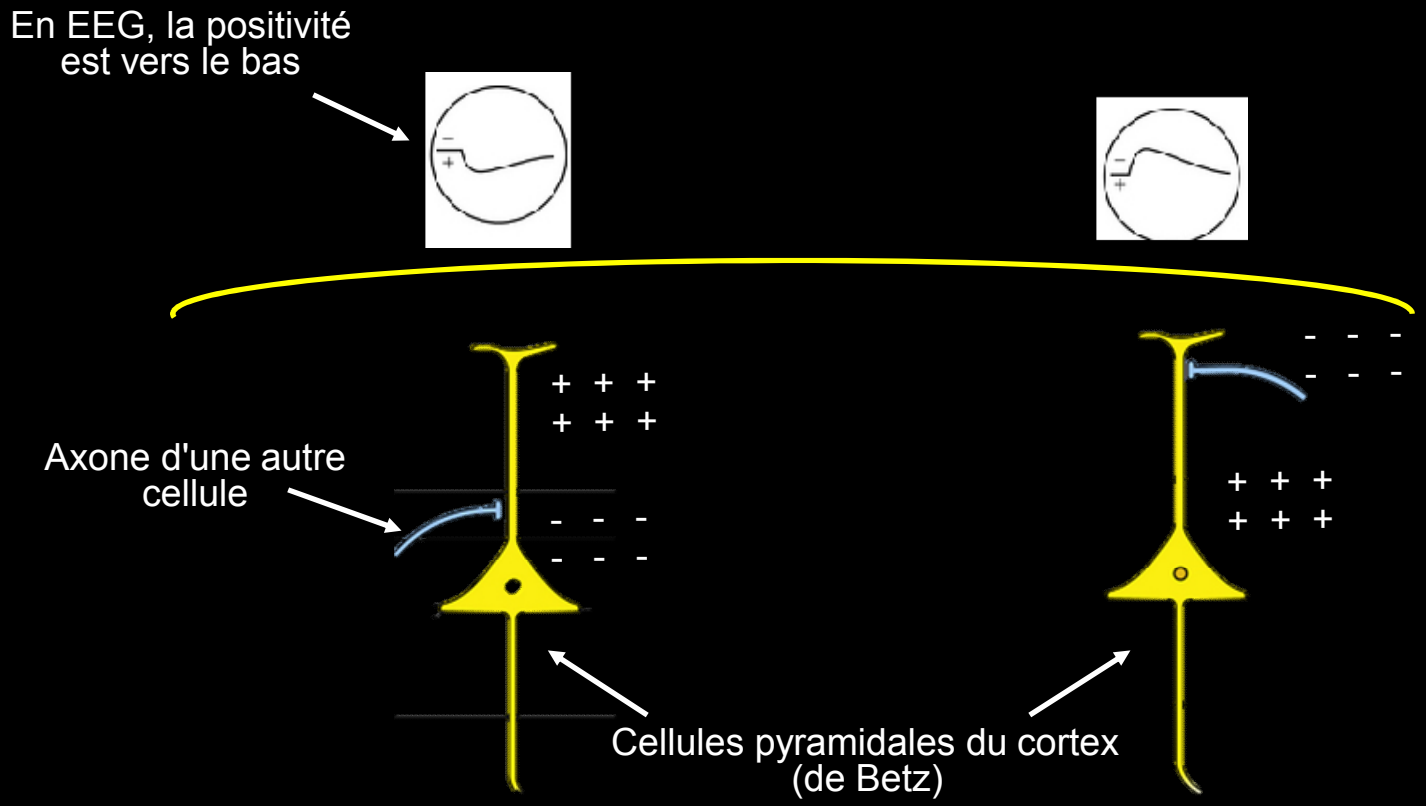


Surface corticale de ~2.5 m^2
dans un petit volume
(plusieurs sillons!)



Boschert & Deecke (1986)

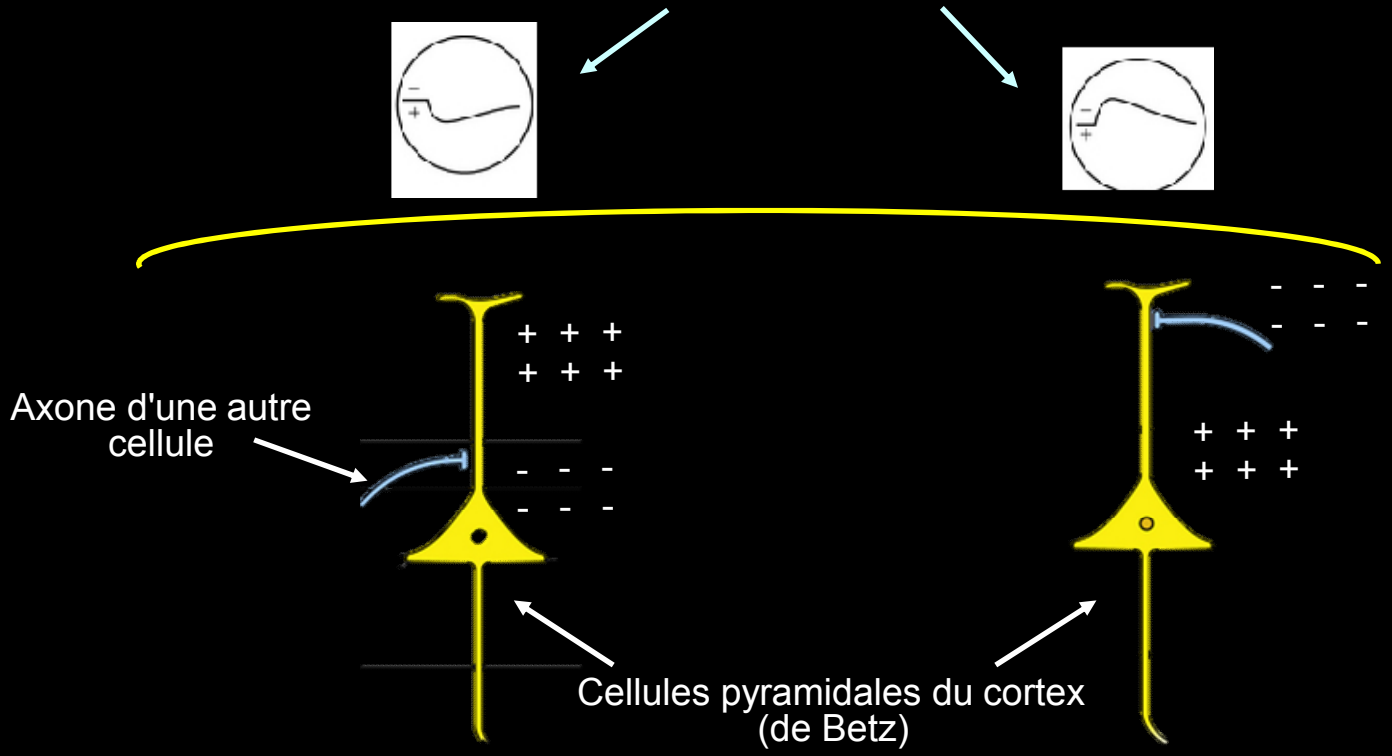
La polarité du signal enregistré ne permet pas de dire si l'activité corticale reflète une activation ou une inhibition



La polarité dépend de la distance synapse-corps cellulaire

La polarité du signal enregistré ne permet pas de dire si l'activité corticale reflète une activation ou une inhibition

Nécessite l'activation synchrone dans le temps
et l'espace d'environ 100 000 neurones !
(le voltage s'additionne)



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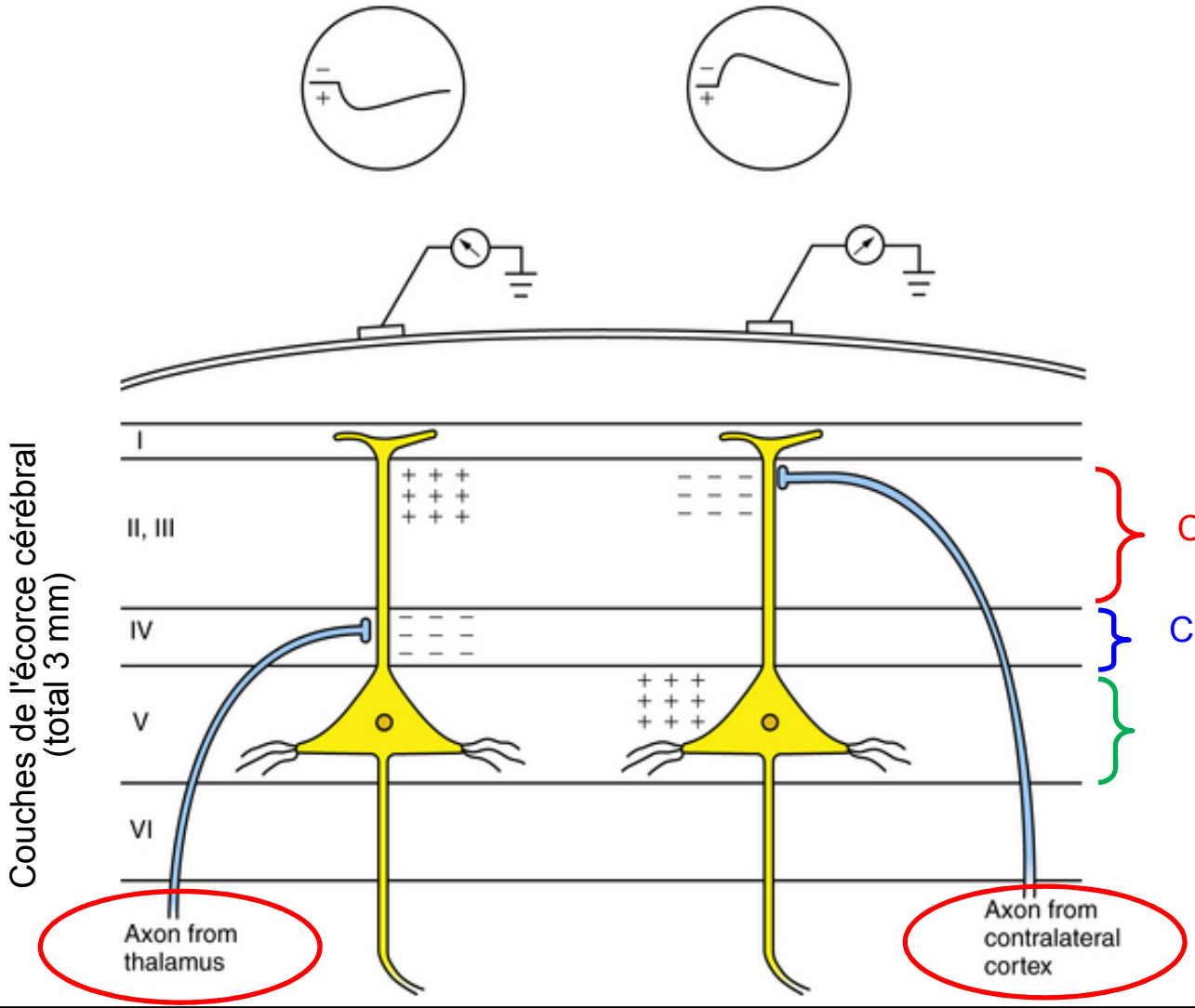

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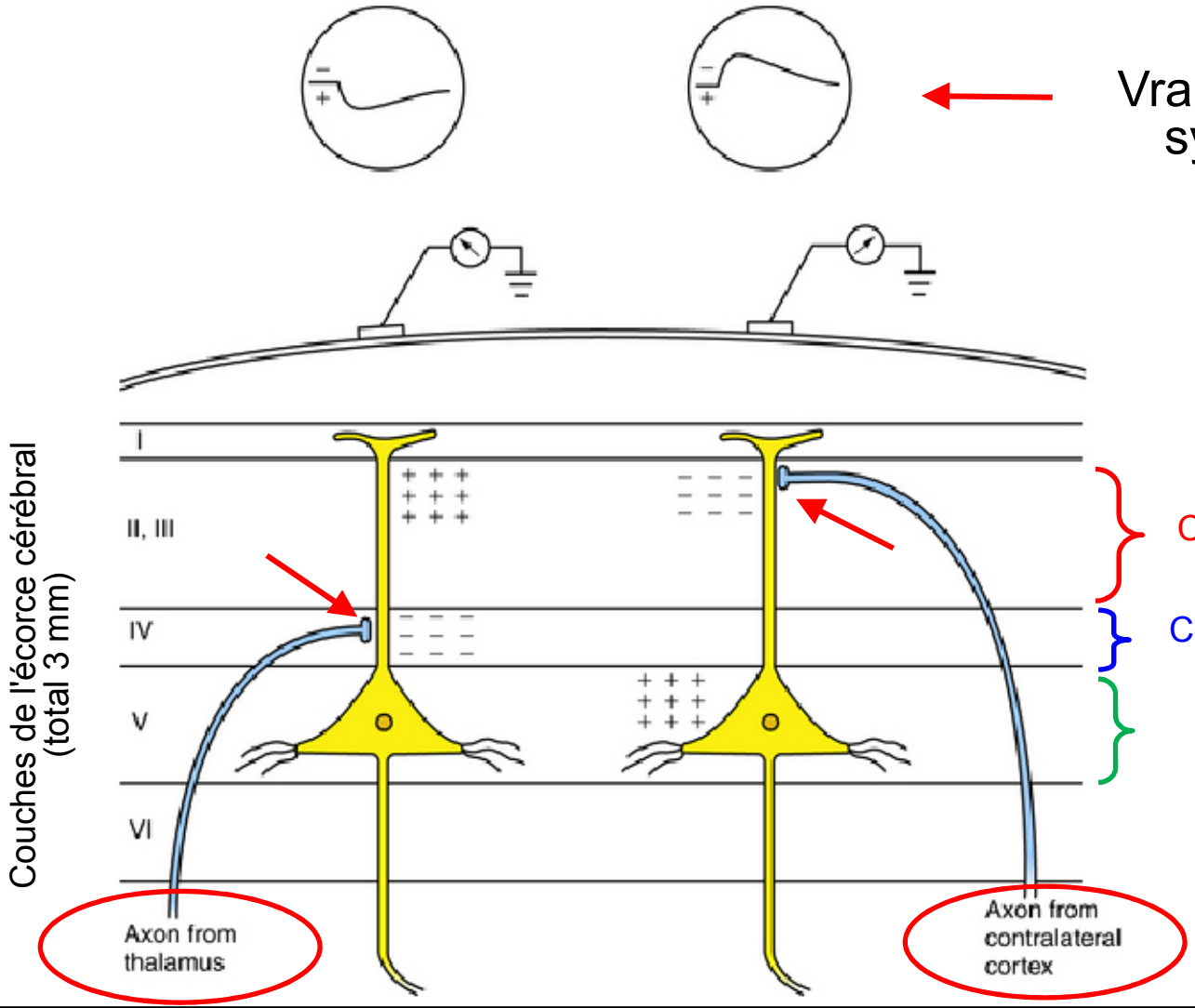


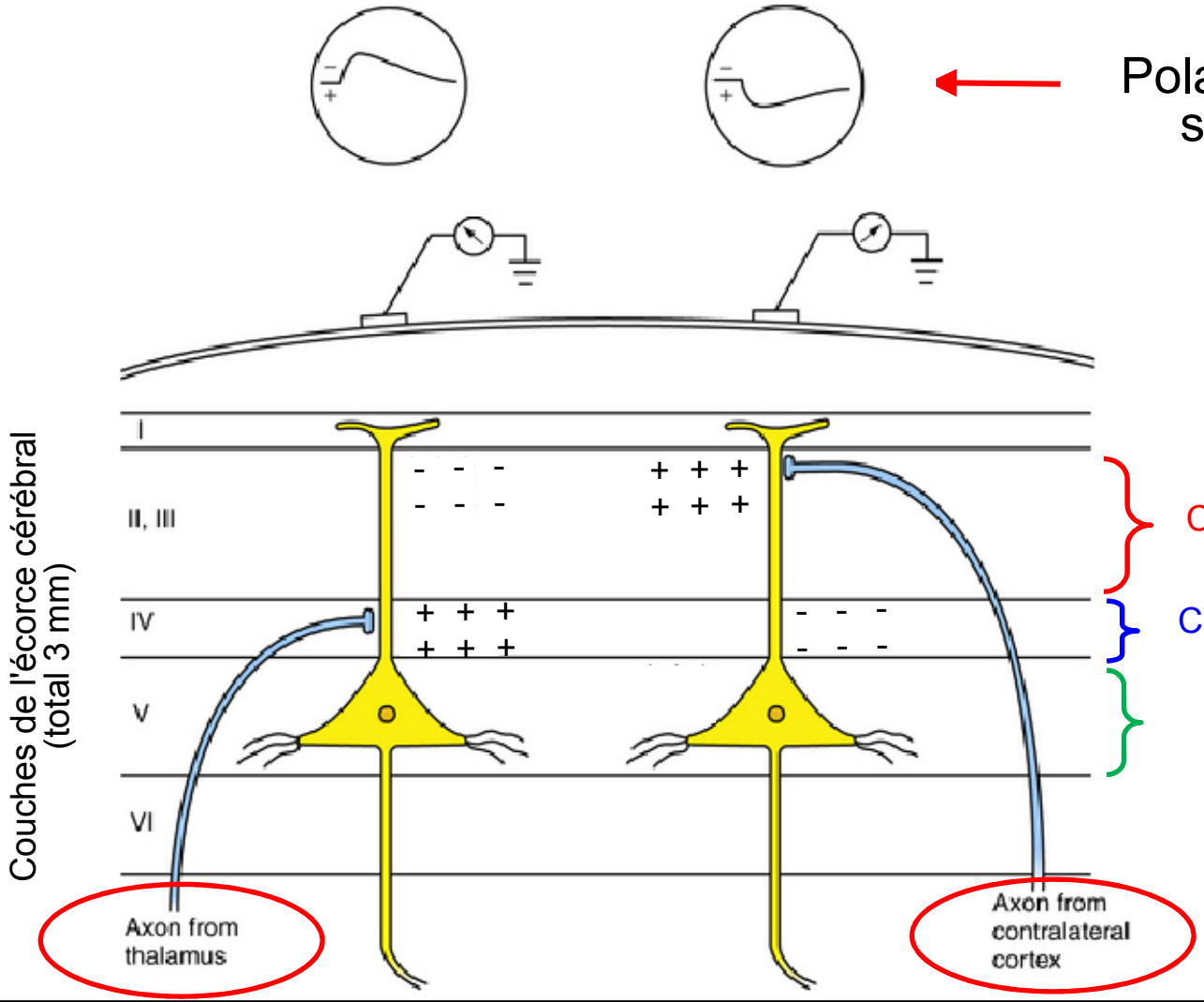
Vrai uniquement pour des synapses excitatrices

Connexions synaptiques INTRA-corticales

Connexions synaptiques EXTRA-corticales

Corps des grosses cellules pyramidales

La polarité du signal enregistré ne permet pas de dire si l'activité corticale reflète une activation ou une inhibition



Polarité inversée pour des synapses inhibitrices

Connexions synaptiques INTRA-corticales

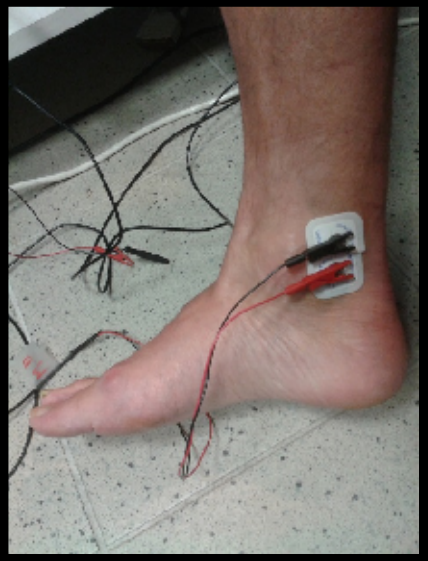
Connexions synaptiques EXTRA-corticales

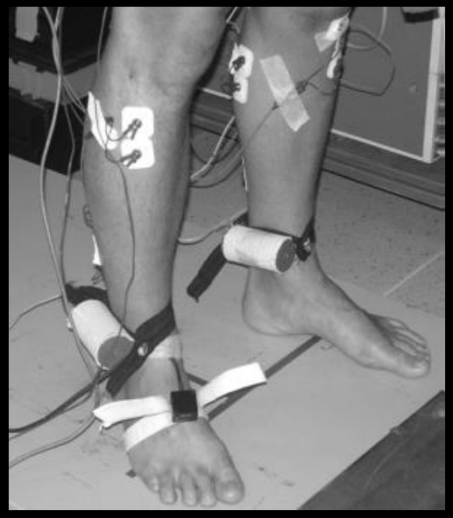
Corps des grosses cellules pyramidales

La polarité dépend EGALEMENT de la nature excitatrice ou inhibitrice des synapses

Heureusement, certaines consistences existent!

Par exemple, les potentiels évoqués somatosensoriels (précoces) et les potentiels évoqués moteurs sont de polarité négative.





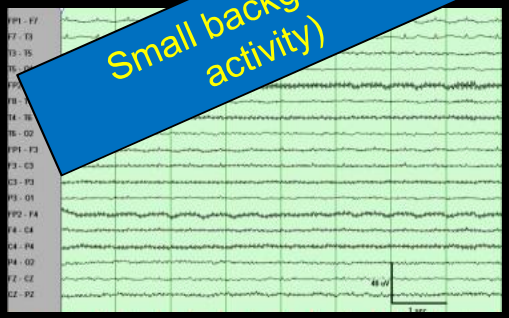
3. Les potentiels évoqués sensoriels (tactiles)

Cette analyse nous permet de connaitre la quantité d'afférence qui arrive au niveau cortical et à quel moment

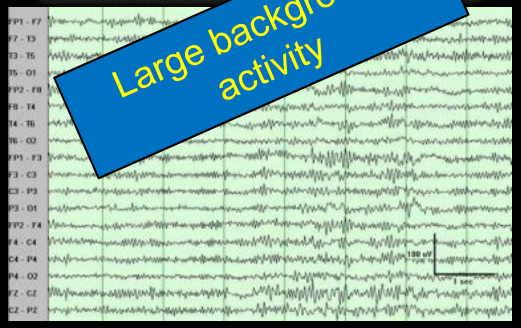
Potentiel évoqué: une technique prévilegiée pour étudier le traitement des informations sensorielles

La sensibilité des neurones aux entrées sensorielles dépend de leurs activités de base (Chawla 1999, Nature Neuroscience)

Traitement sensoriel négligeable



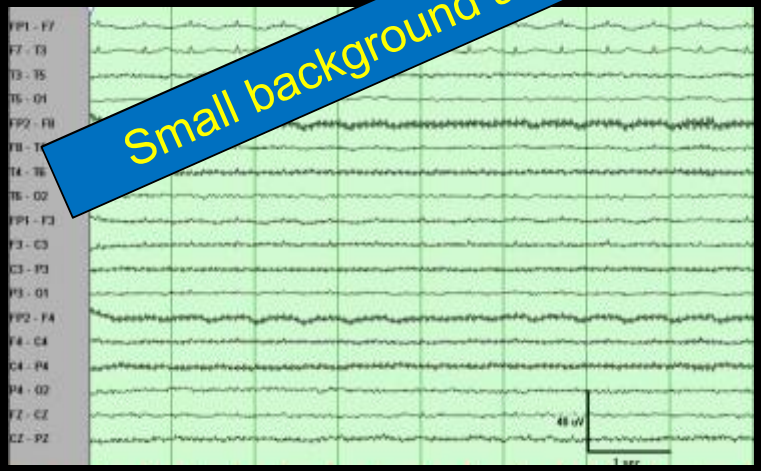
Traitement sensoriel important



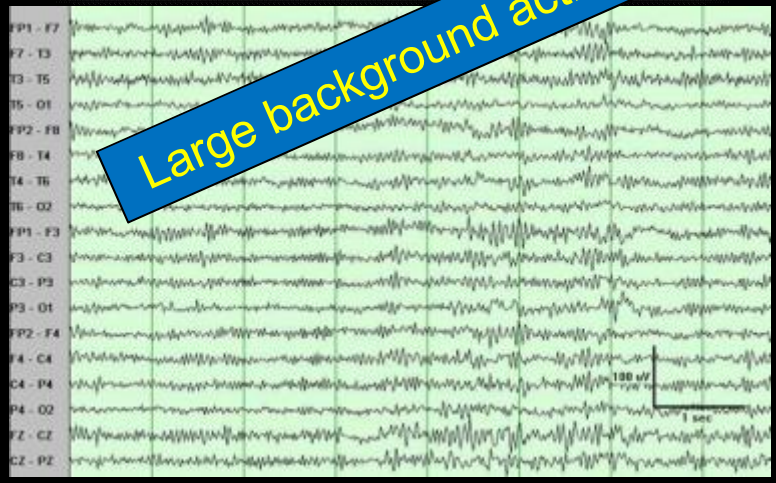
Traitement sensoriel négligeable

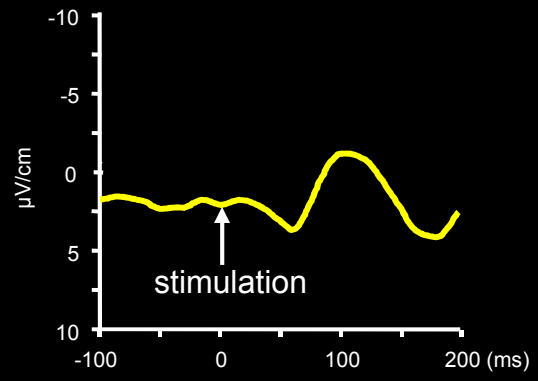
Traitement sensoriel important

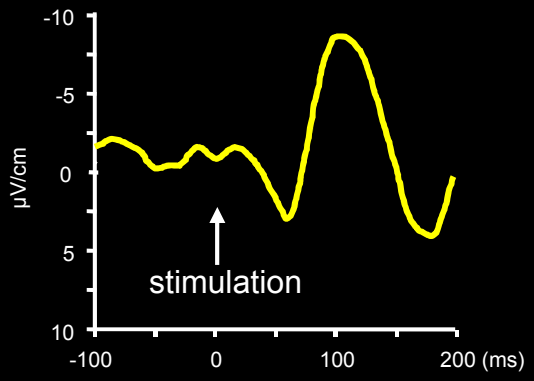
Small background activity)



Large background activity



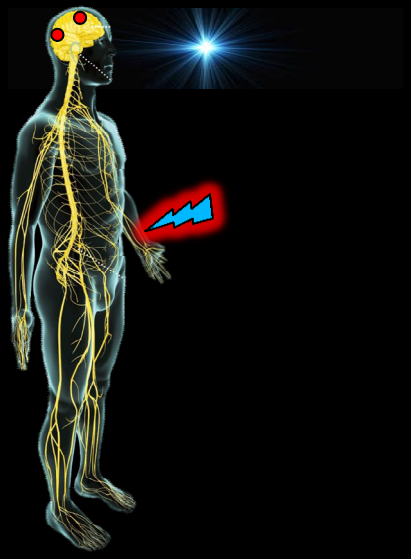




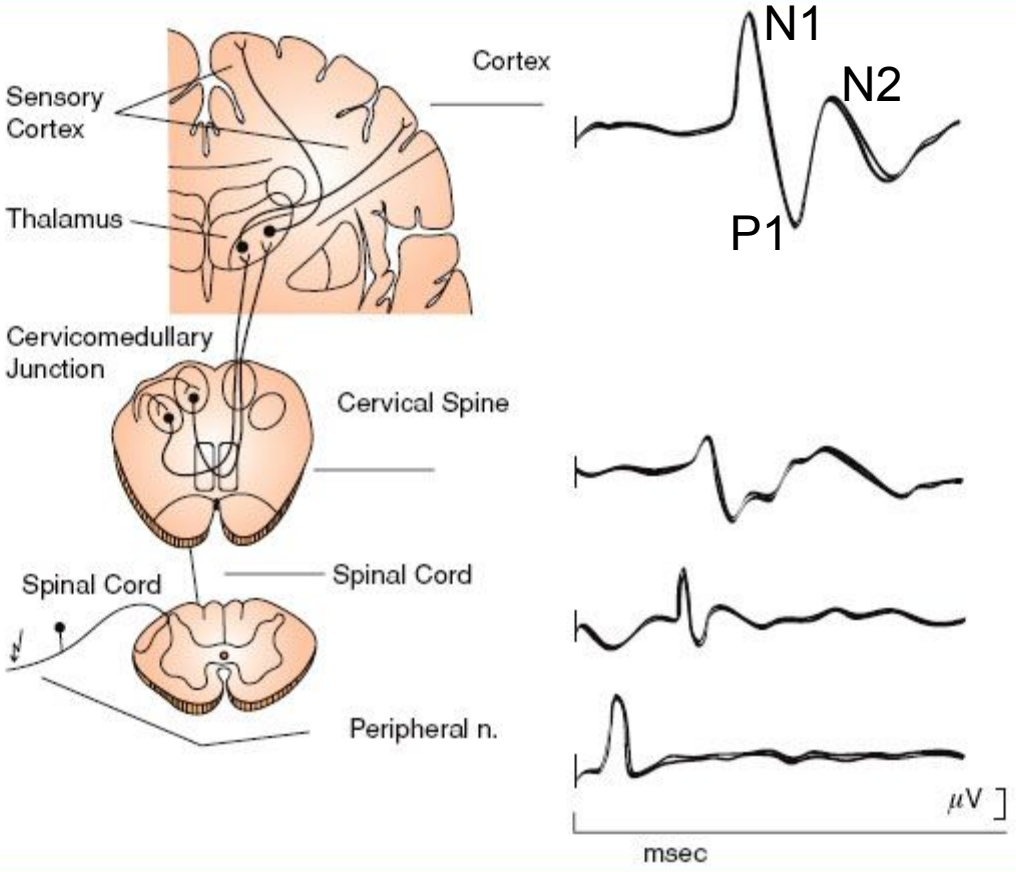
Potentiel évoqué: une technique préviligiée pour étudier le traitement des informations sensorielles

La sensibilité des neurones aux entrées sensorielles dépend de leurs activités de base (Chawla 1999, Nature Neuroscience)

DONC



L'amplitude des potentiels évoqués (ex: visuels, somatosensoriels, auditifs, olfactifs) permet de déterminer l'importance des modalités sensorielles dans une tâche donnée



Quantification

Amplitude
(N1-P1, P1-N2)

Latence des pics (N1, P1, N2, etc.) peut refléter la complexité des processus (surtout les pics plus tardifs)

Potentiel évoqué sensoriel
(sensory evoked potential)

→

Réponse évoquée par une stimulation sensorielle (tactile)

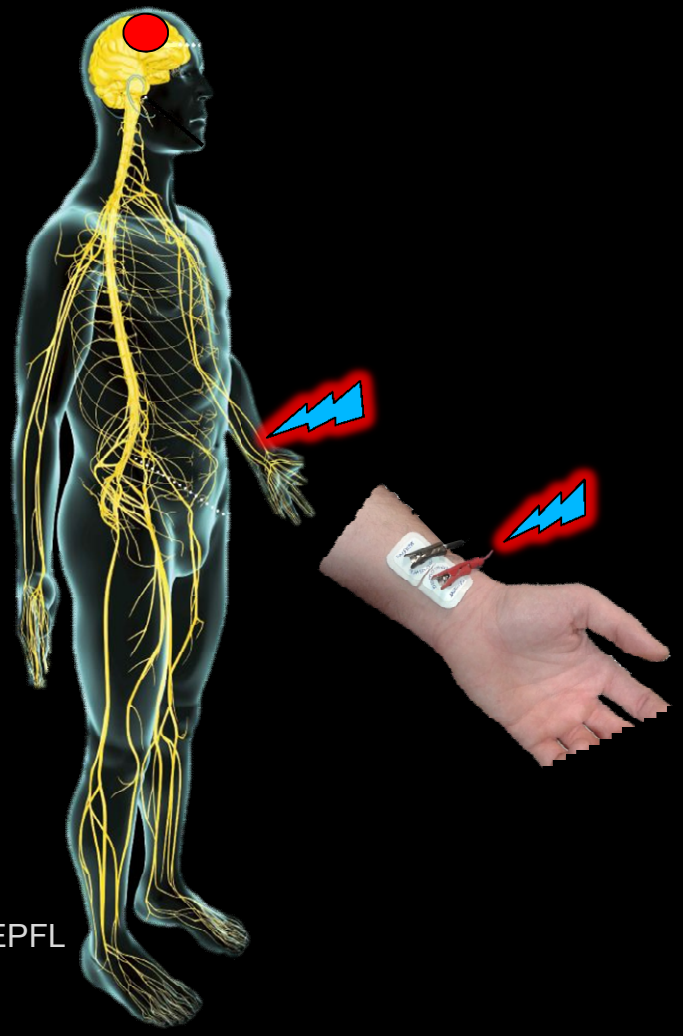
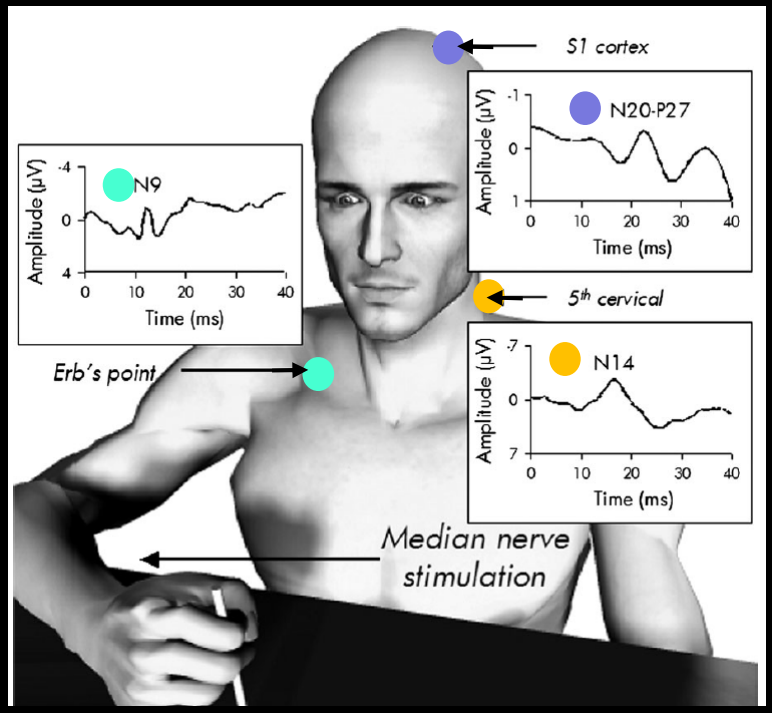


Image: EPFL

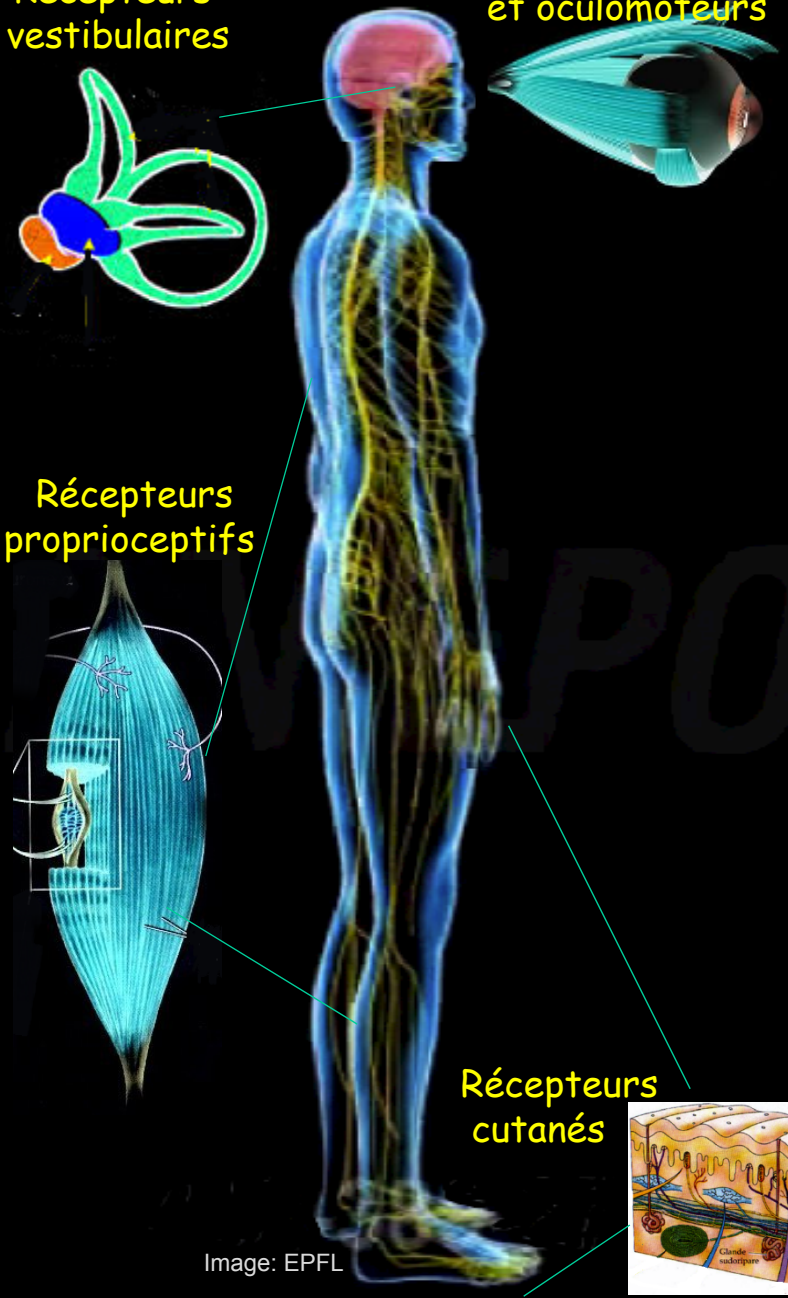


Exemple: Potentiels évoqués périphériques et corticaux résultants d'une stimulation du nerf median (cutané) (Bernier et al. 2009)

The brain builds up expectations to future events based on the patterns of past events

Récepteurs vestibulaires

Récepteurs visuels et oculomoteurs

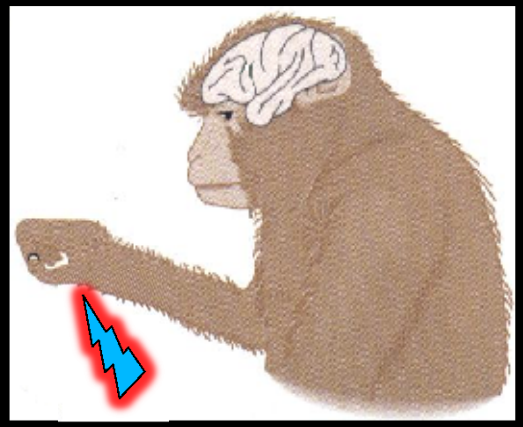


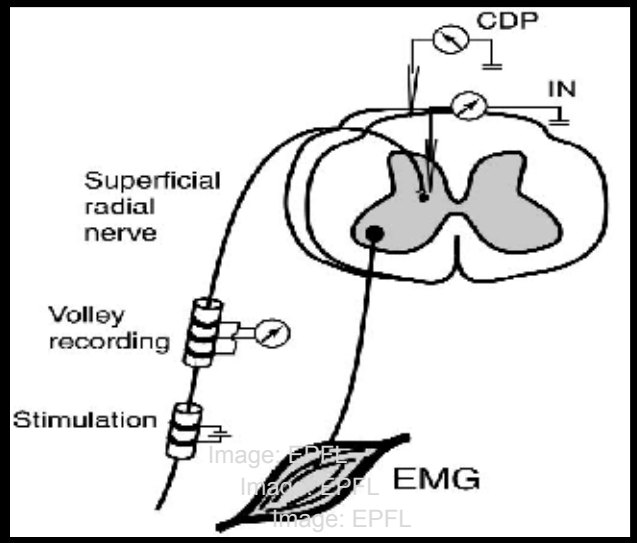
Récepteurs proprioceptifs

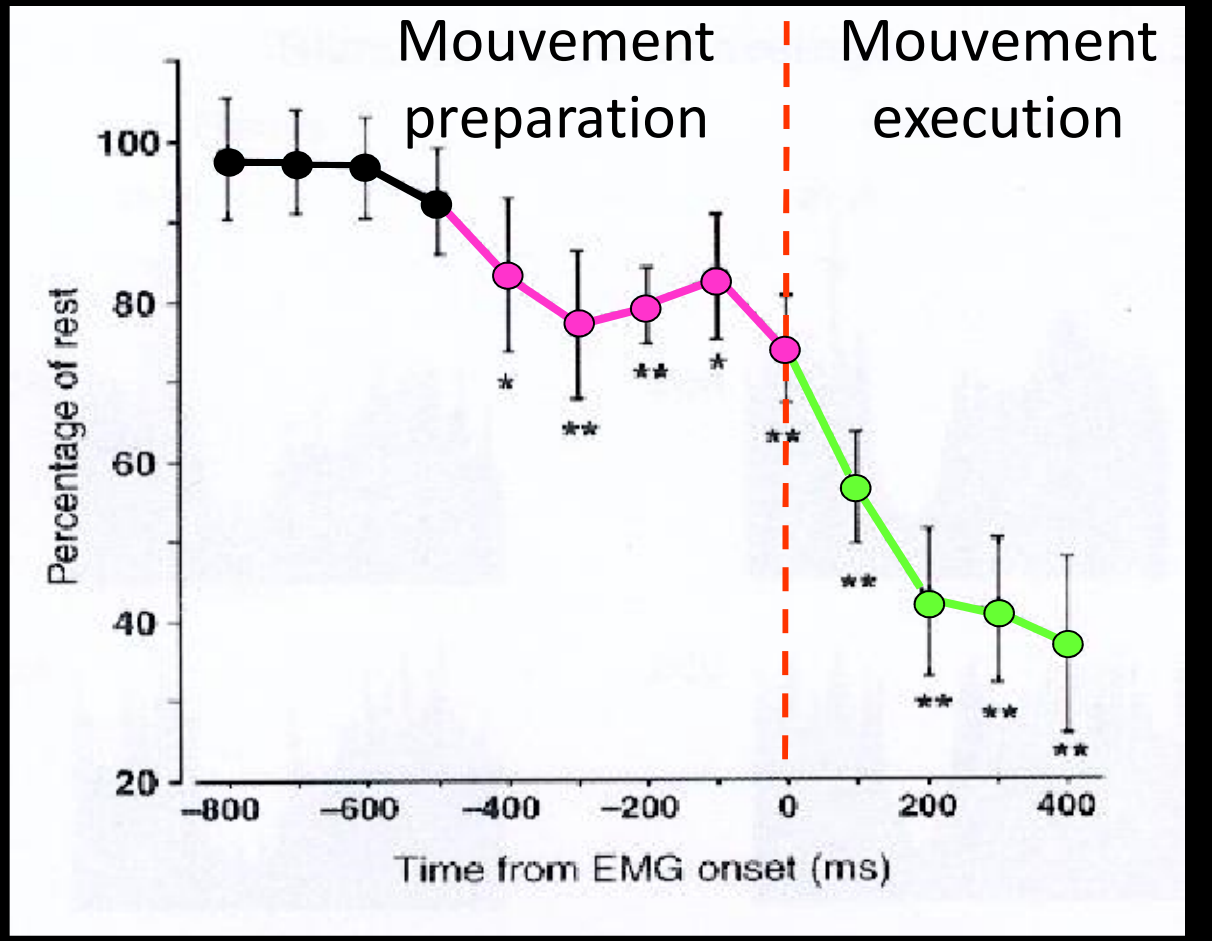
Récepteurs cutanés

Image: EPFL

Sensory attenuation (Gating)

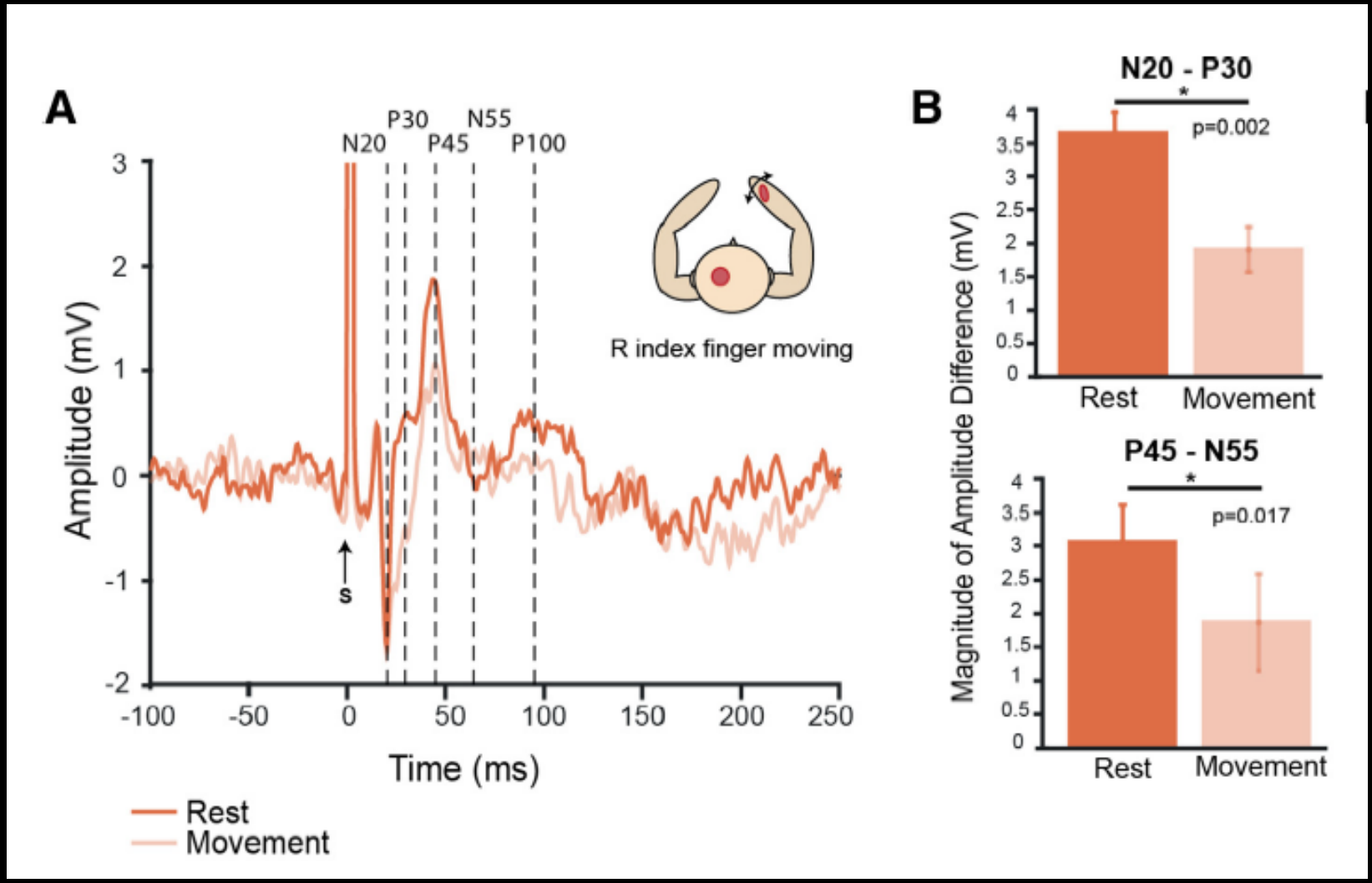






Adapted from Seki et al. Nature Neuroscience, 2003

Physiological sensory attenuation is represented as a decrease in the amplitude of the primary and secondary components of the somatosensory evoked potential (SEP) before and during movement



Palmer et al, Journal of Neuroscience 2016

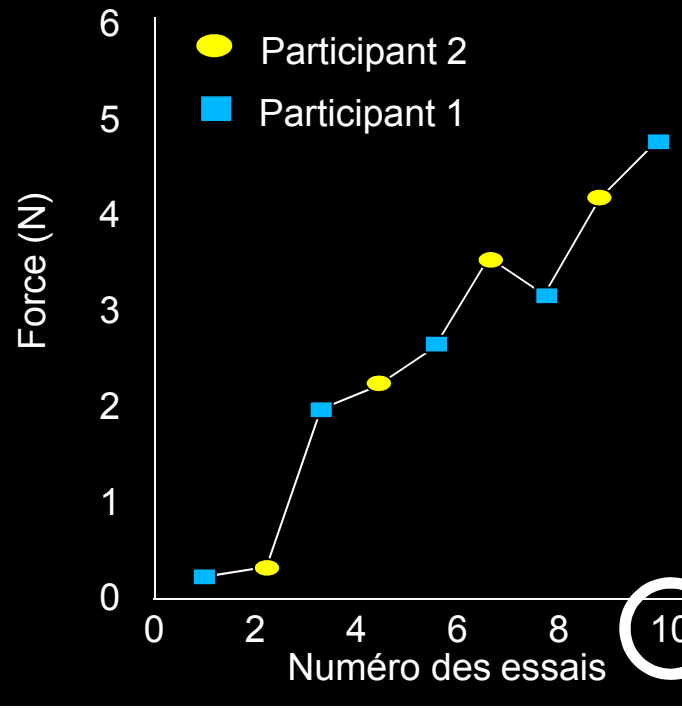
Physiological sensory attenuation is represented as a decrease in the amplitude of the primary and secondary components of the somatosensory evoked potential (SEP) before and during movement

Perceptual sensory attenuation, is a reduction in the perception of the afferent input of a self-produced tactile sensation due to the central cancellation of the reafferent signal by the efference copy of the motor command to produce the action.

Est-ce que l'atténuation des retours sensoriels auto-générés peut expliquer l'intensification des conflits?
OUI, preuve expérimentale:

Instructions données séparemment aux participants:

La personne devant vous va exercer une force sur votre doigt. Vous devrez par la suite exercer la même force sur son doigt. Puis cette personne reproduira la même force que vous avez exercée sur son doigt, ainsi de suite...



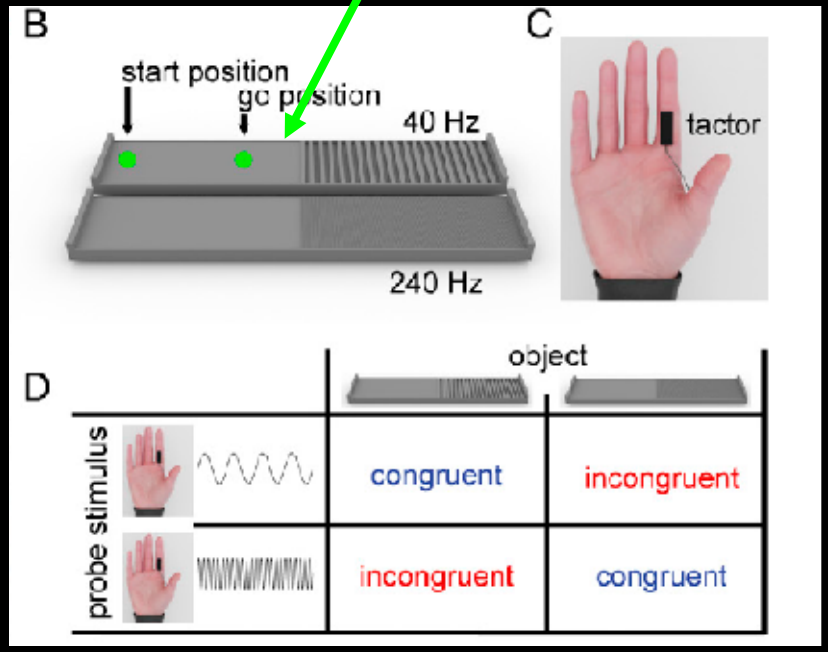
Chaque participant a cru que l'instruction reçue par l'autre participant était de doubler la force ressentie !

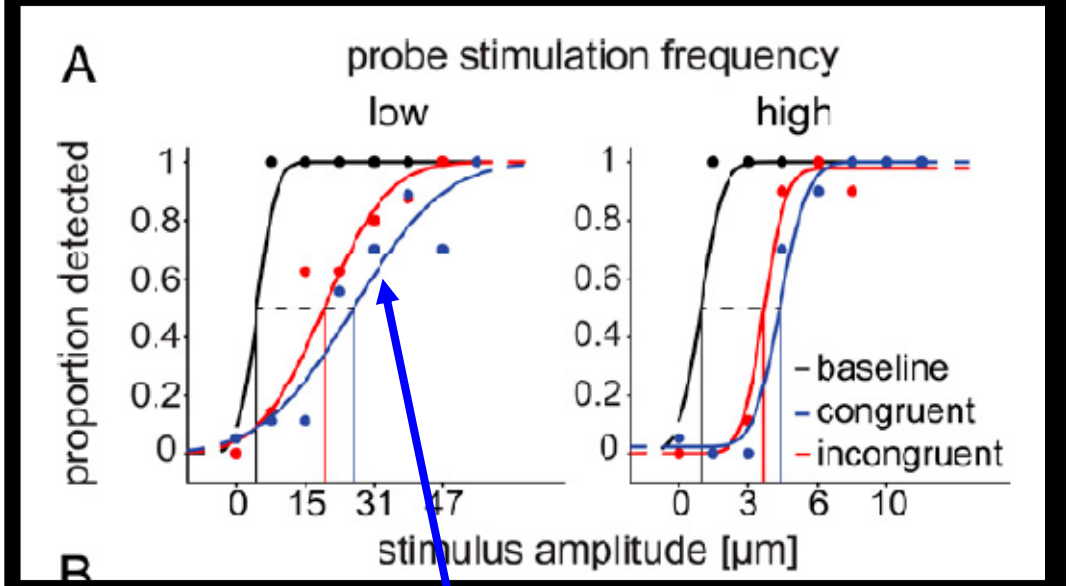
Les expérimenteurs arrêtent l'expérience après 10 essais!

Shergill, Bays, Frith & Wolpert (2003) Science

Specific tactile suppression due to **precise** sensorimotor predictions

brief vibrotactile stimulus





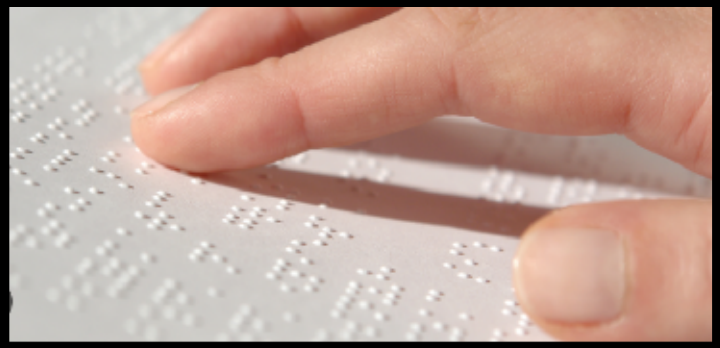
Poorer sensitivity due to stronger tactile suppression

40 Hz to mainly stimulate the Meissner corpuscles that are most sensitive to vibrations of 40–60 Hz

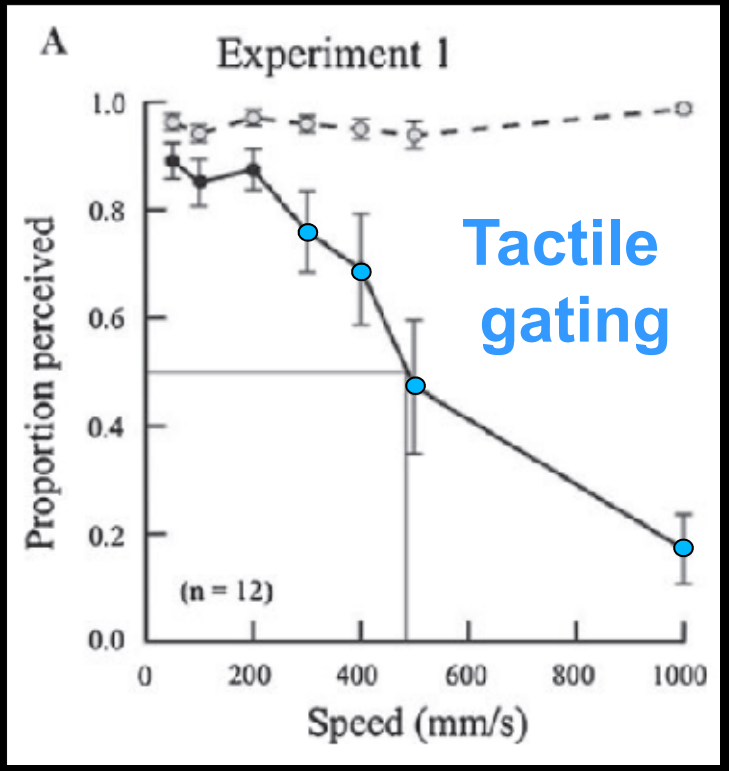
240 Hz range of the Pacinian corpuscles with their maximal sensitivity being between 200–300 Hz

Fuehrer, Voudouris, Lezkana, Drewing & Fiehler, PNAS 2022

Performance starts to decline at 300 mm/s



Braille readers use a median speed of 7.5 characters/s or **64 mm/s**
Excellent Braille readers use speeds up to 22 characters/s or **188 mm/s** (Grunwald 1966).



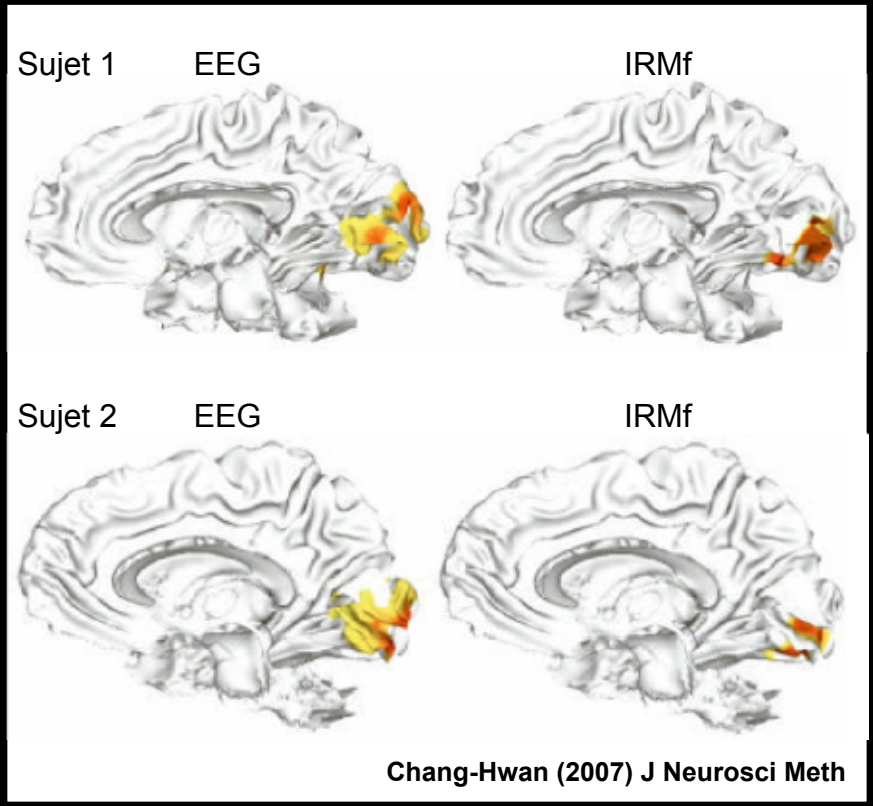
Cybulska-Klosowicz et al., Exp Brain Res 2011

4. Les sources d'activité cérébrale

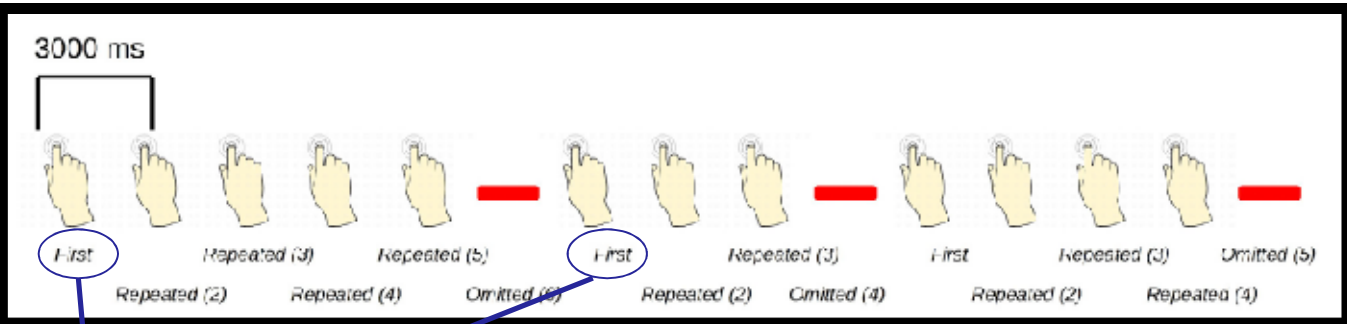
Cette analyse nous permet de connaitre les zones cérébrales impliquées dans le traitement des informations tactiles et à quel moment

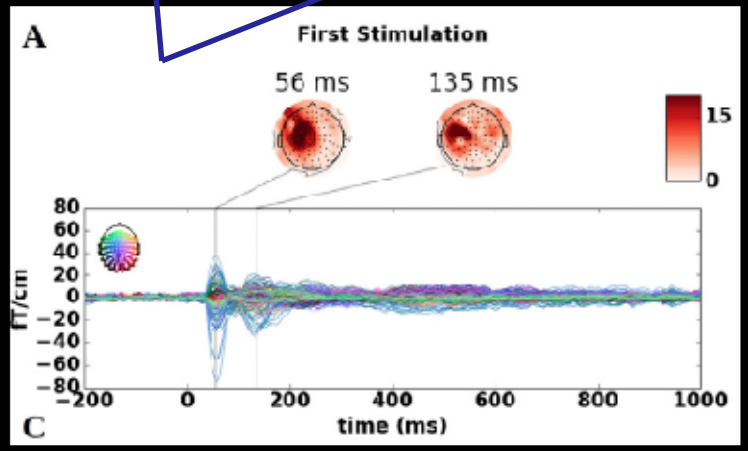
L'EEG a une excellente résolution temporelle: 1 ms (IRMf: ~1 s)

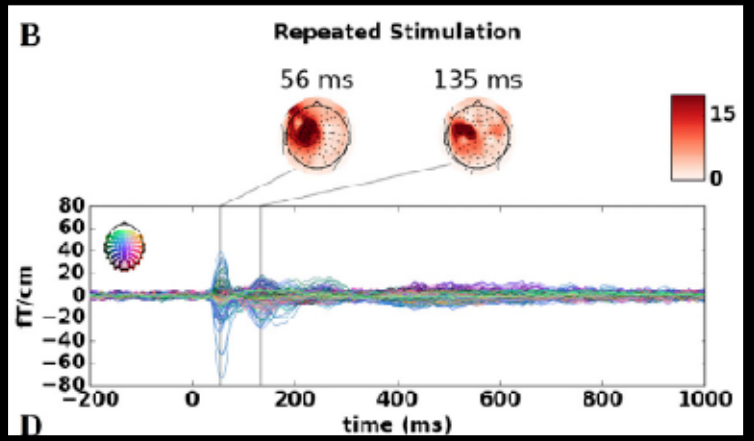
La résolution spatiale de l'EEG est ~7 mm (LORETA) (IRMf: ~1 mm)

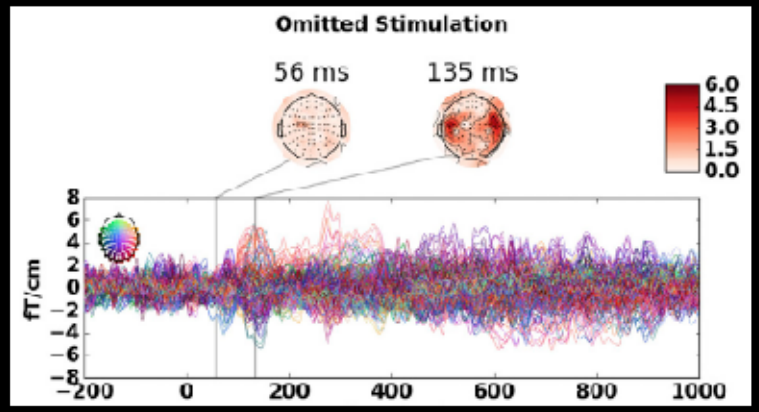


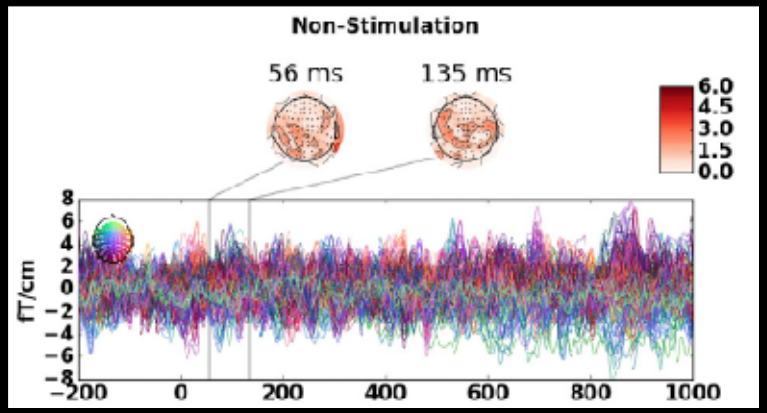
Chang-Hwan (2007) J Neurosci Meth









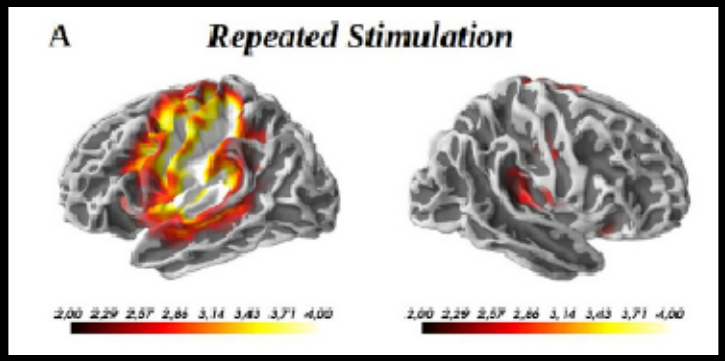


Andersen & Lundqvist, NeuroImage 2019

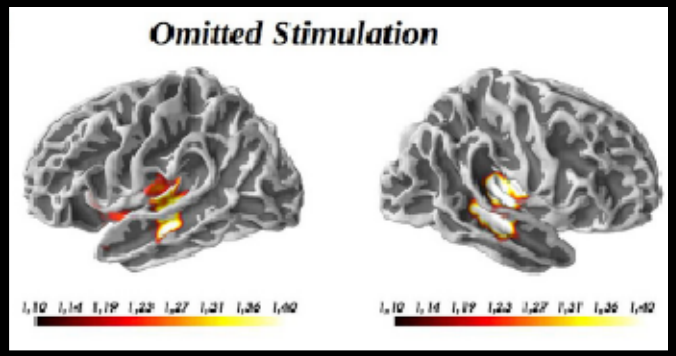
56 ms SI response (primary somatosensory cortex)

135 ms SII response (secondary

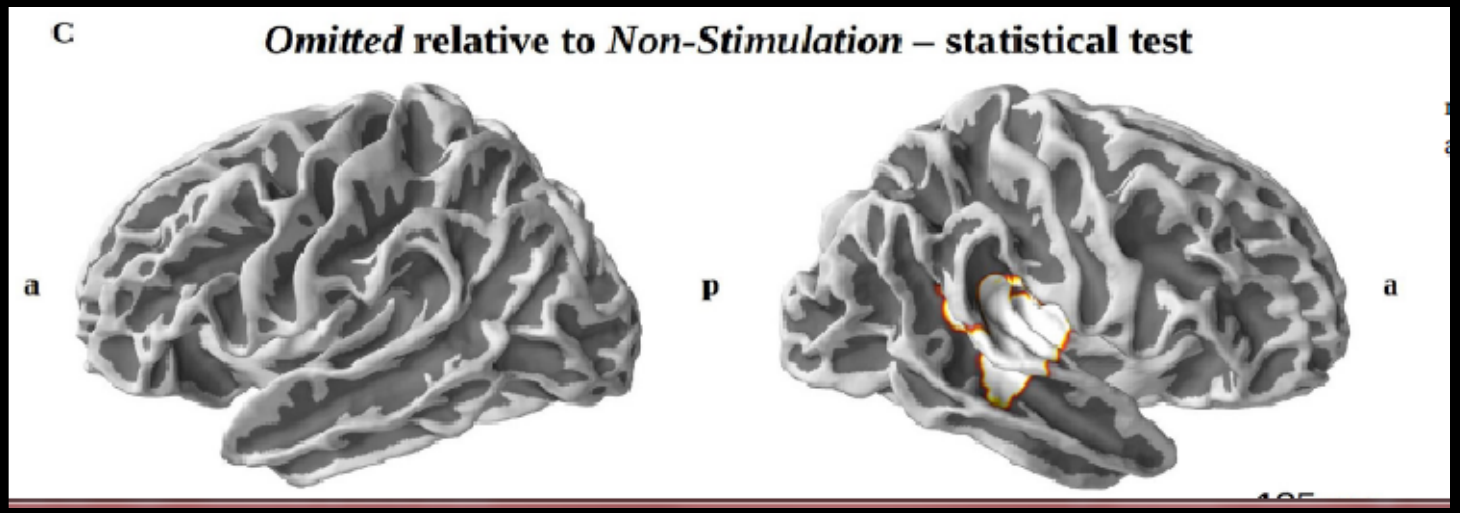
Statistical Source maps at 135 ms



Bilateral activation of the SII and contralateral activation of SI.



Bilateral activation of SII.



The difference response is localized to the right superior temporal gyrus, posterior insula and SII.

5. Les fréquences d'oscillation

Cette analyse nous permet de connaitre les processus associés au traitement des afférences tactiles

Analyse spectrale des oscillations neuronales: Autre méthode pour investiguer le traitement des informations sensorielles

Les signaux enregistrés en EEG sont composés de plusieurs bandes de fréquence

Basses fréquences

Basses + hautes fréquences

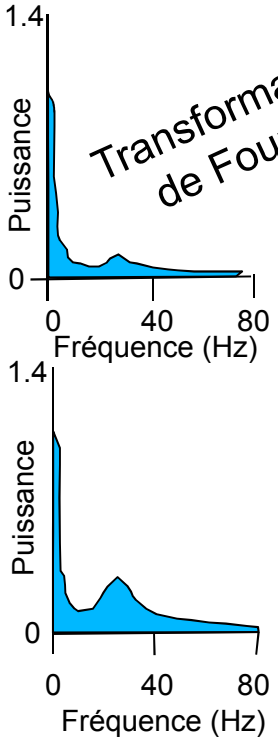
Adapté de Collins et al. (2001) J. Neurophysiol

Analyse spectrale des oscillations neuronales: Autre méthode pour investiguer le traitement des informations sensorielles

Les signaux enregistrés en EEG sont composés de plusieurs bandes de fréquence

Essentiellement basses fréquences

Basses + hautes fréquences

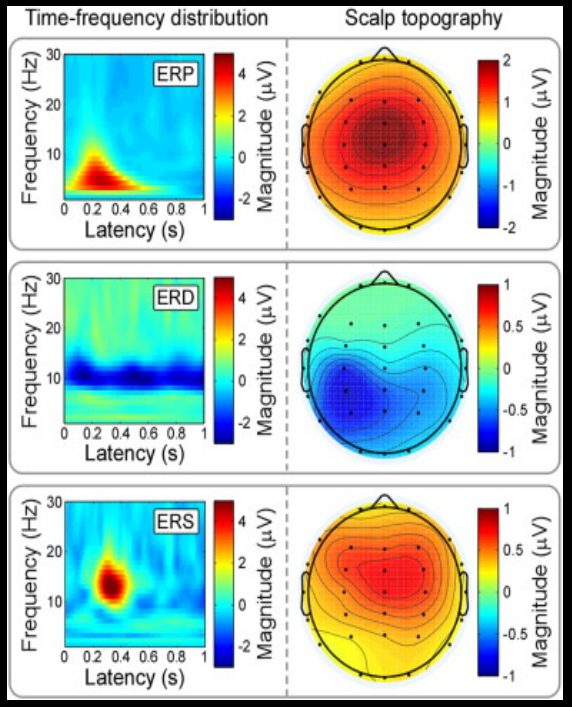


Adapté de Collins et al. (2001) J. Neurophysiol

Joseph Fourier

1768-1830

Analyse spectrale des oscillations neuronales: Autre méthode pour investiguer le traitement des informations sensorielles



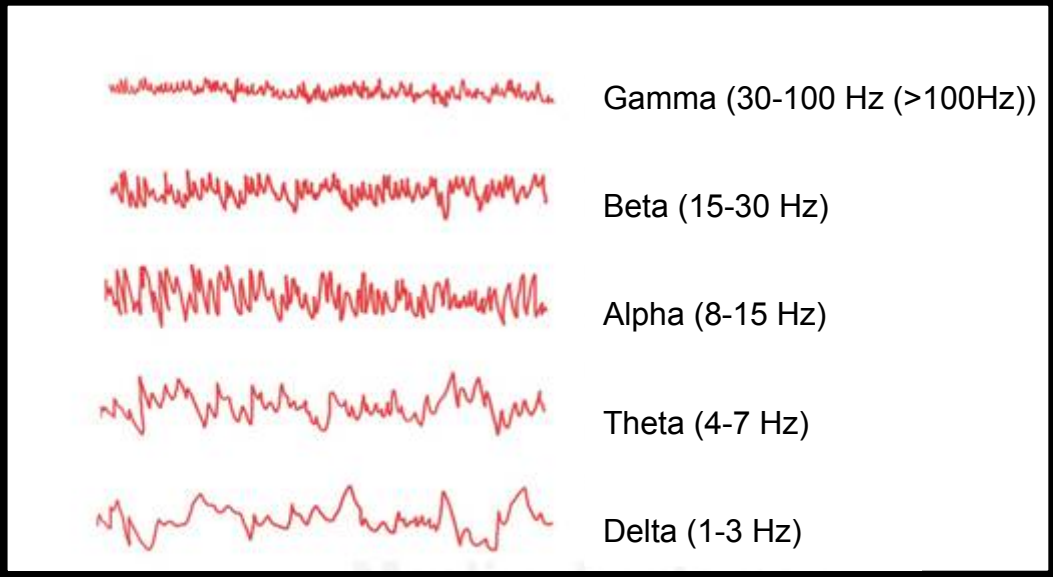


Image: http://www.medicalook.com

Analyse spectrale des oscillations neuronales: Autre méthode pour investiguer le traitement des informations sensorielles

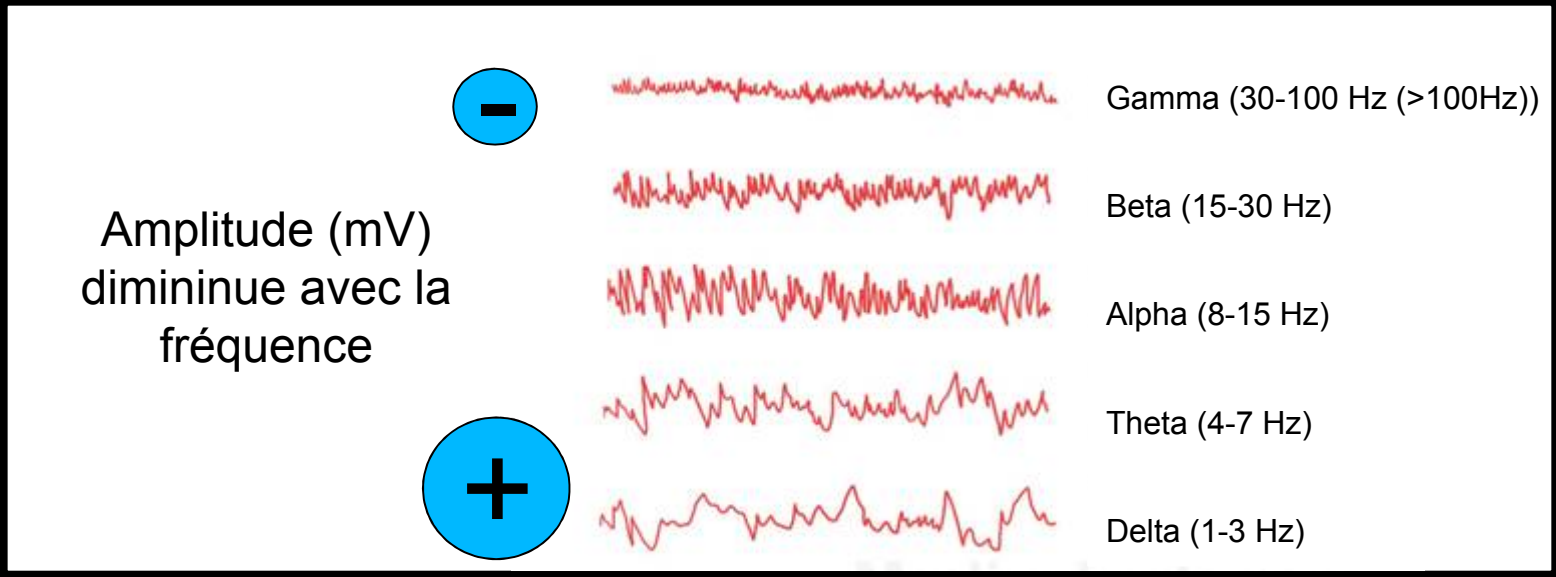


Image: http://www.medicalook.com

Analyse spectrale des oscillations neuronales: Autre méthode pour investiguer le traitement des informations sensorielles

Difficulté pour les étudier les bandes de fréquences

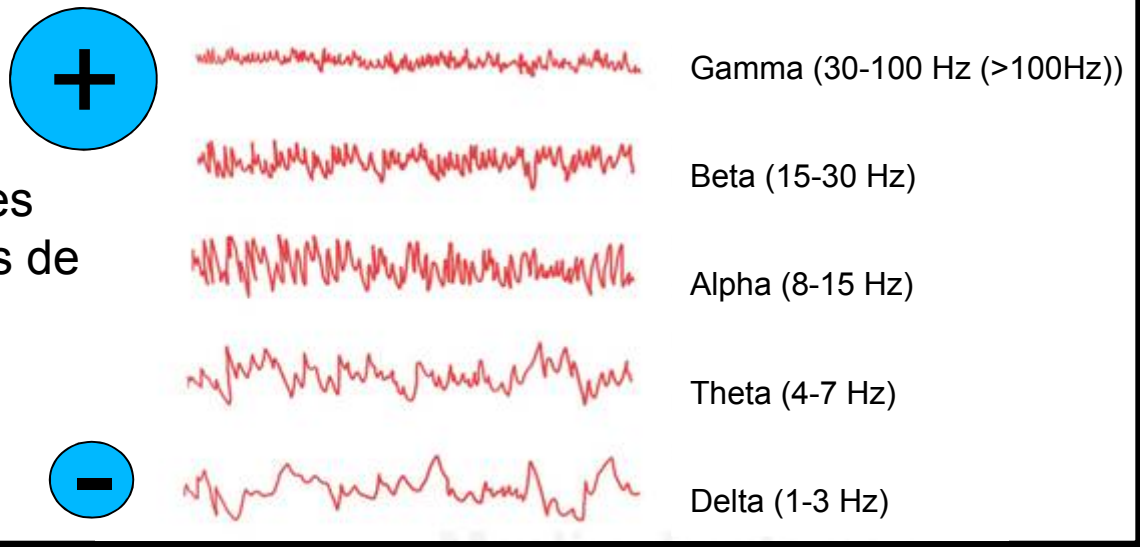


Image: http://www.medicalook.com

Analyse spectrale des oscillations neuronales: Autre méthode pour investiguer le traitement des informations sensorielles

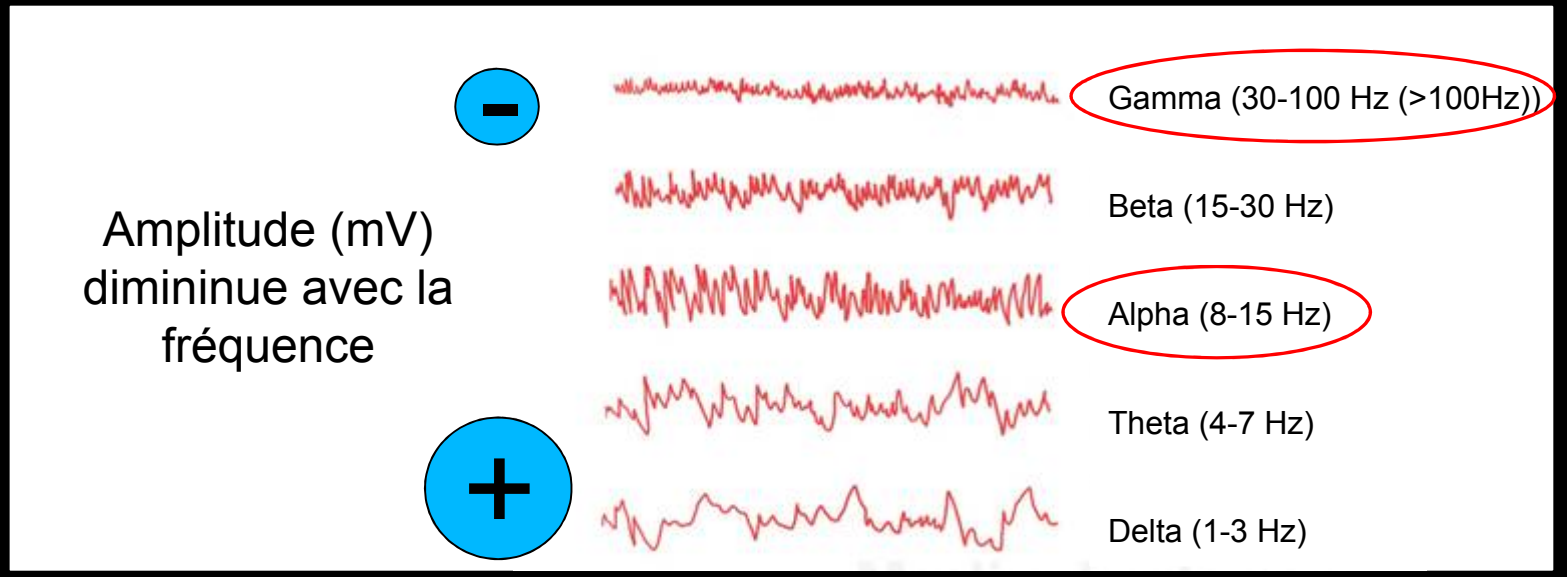
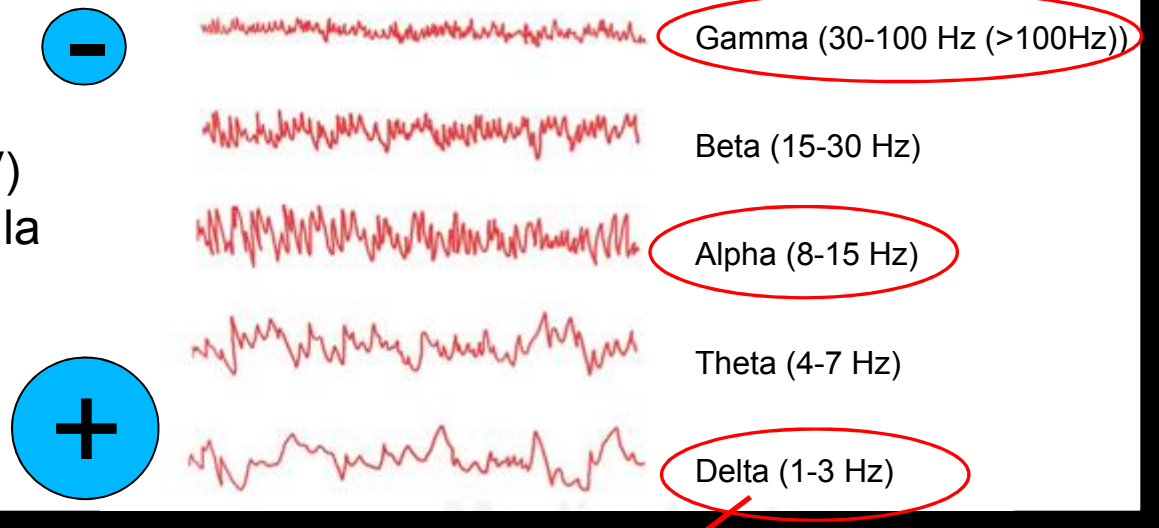


Image: http://www.medicalook.com

Analyse spectrale des oscillations neuronales: Autre méthode pour investiguer le traitement des informations sensorielles

Amplitude (mV) dimininue avec la fréquence



Diminution puissance **ALPHA** (~8-12 Hz)

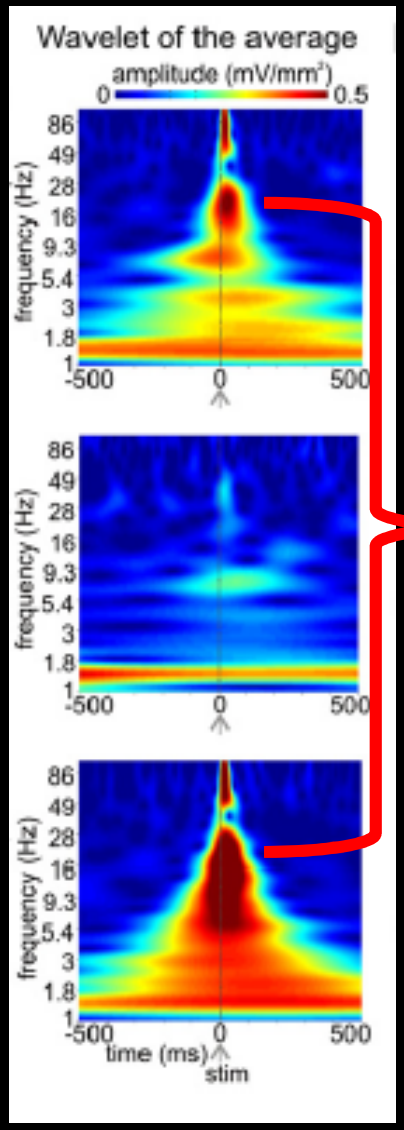
Marqueur local d'excitabilité corticale

Oscillatory components of **unimodal** and **bimodal** responses within the **Primary Auditory cortex**

Auditory stimulus (clic)
unimodal

Tactile stimulus (e stim median nerve)
unimodal

Audio-tactile stimuli
biimodal

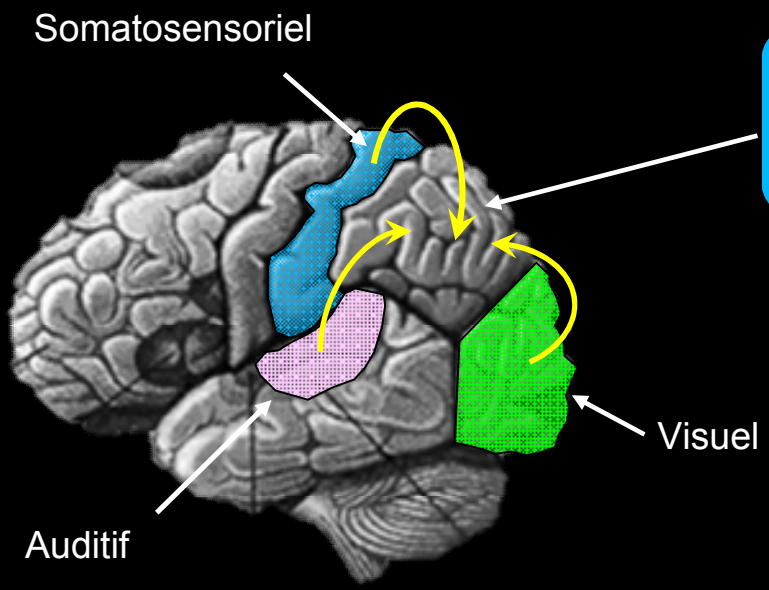


Increase power in the gamma frequency (35 Hz) band

Hearing hand effects.
The somatosensory stimulation produces perceptual amplification of auditory input

Lakatos et al, Neuron 2007

Communication neuronale entre plusieurs aires notamment avec le couplage (binding) theta



Ex: Cortex pariétal postérieur associatif

1. **EEG: historique – les avantages et inconvénients**
2. ***Principes (activité des cellules pyramidales)***
3. ***Les potentiels évoqués moteurs et sensoriels***
4. ***Les sources d'activité cérébrale***
5. ***Les fréquences d'oscillation et les processus associés***