Neurophysiology of Human Primary Consciousness

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Primary (phenomenal) consciousness vs. nonconscious stimulus processing

In the figure, primary consciousness sub-serves reading of the newspaper article, while nonconscious processes elaborate walking people stimulus.
Dominant resting (eyes-closed) alpha rhythms are coherent over wide cortical areas and corresponding thalamic nuclei.

Pyramidal neurons oscillating at synchronized alpha frequencies.

Reticular neurons

Relay neurons

REST

THALAMUS

BRAIN STEM
Pyramidal neurons oscillating at several peculiar high frequencies substitute alpha rhythms during activity. ERPs may be formed by re-phasing of EEG oscillations.
Primary consciousness of visuo-spatial functions can be experimentally studied giving visual stimuli at threshold time (passive view).

50% of the cue stimuli are consciously detected ("seen")

50% of the cue stimuli are consciously missed ("not seen")

(unpredictable) go at right, movement at right button

self-report ("seen" or "not seen")
Occipital and posterior parietal sources of **pre-stimulus alpha rhythms** are related to **consciousness of visuo-spatial stimuli**.

Occipital and posterior parietal sources of alpha ERD are related to consciousness of visuo-spatial stimuli.

Cue stimulus onset

LORETA sources

Occipital and posterior parietal sources of P3 are related to consciousness of visuo-spatial stimuli

P3 peak (about +400 ms post-stimulus)

LORETA sources

C. Babiloni, F. Vecchio, M. Miriello, GL Romani and PM Rossini. Visual-spatial consciousness and parieto-occipital areas: a high-resolution EEG study. Cerebral Cortex 2005
Are parietal alpha ERD epiphenomena for visuo-spatial consciousness?

Visuo-spatial attention and consciousness are impaired by rTMS in parietal areas showing maximum alpha ERD

**EFFECT OF rTMS ON INFERIOR PARietAL CORTEX**

**CONSCIOUSNESS**

**ATTENTIONAL**

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Primary consciousness of frontal executive functions can be experimentally studied (paradigm of “inverted response”)

50% of the cue stimuli are consciously detected ("seen")

50% of the cue stimuli are consciously missed ("not seen")

(self-report ("seen" or "not seen")

(unpredictable) go at right, movement at left button
Frontal and parieto-occipital sources of P3 are related to consciousness of visuo-spatial stimuli during executive functions.

Primary consciousness of emotional faces can be experimentally studied (passive view)

50% of the cue stimuli (just one face for each event) are consciously detected ("seen")

50% of the cue stimuli are consciously missed ("not seen")

happy (sad) icon, movement at left (right) button

self-report ("seen" or "not seen")
Frontal and posterior parietal sources of N170 are related to consciousness of emotional sad faces

Primary consciousness of words can be experimentally studied (passive view)

50% of the cue stimuli are consciously detected ("seen")

50% of the cue stimuli are consciously missed ("not seen")

Cue and go stimuli: muro (wall), mulo (mule), cane (dog), pane (bread)

left or right mouse button if the go stimulus was a living or nonliving being

self-report ("seen" or "not seen")
ERPs to cue stimuli (words) are higher in amplitude at N1 and P3 peaks during primary consciousness.

Occipito-temporal N1 sources are related to primary consciousness of words.
Reduced cortical EEG activation during focused attention in elite pistol shooters. Restriction of conscious experience?

Hum Brain Mapp. 2009

VIDEO
Postural freezing of elite shooters is related to selectivity/neural efficiency as revealed by widespread cortical EEG deactivation: a “disconnection” from irrelevant stimuli of the external world?

More efficiency

Compared to non-athletes, pistol shooters show stronger parieto-temporal and parieto-occipital alpha coherence.

STATISTICAL ANALYSES
INTRA-HEMISPHERIC EVENT RELATED COHERENCE
Low-frequency alpha

High-frequency alpha

Gamma

Understanding of the sporting performance by other athletes is related to selectivity/neural efficiency of parietal cortical activation (mirror systems) as revealed by EEG mapping. More efficiency?

**sLORETA SOLUTIONS**

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<thead>
<tr>
<th>LOW-FREQUENCY ALPHA</th>
<th>HIGH-FREQUENCY ALPHA</th>
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<tbody>
<tr>
<td>NON-GYMNASTS</td>
<td>GYMNASTS</td>
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*More efficiency?*

Low- (about 8–10 Hz) and high-frequency (about 10–12 Hz) alpha rhythms were lower in amplitude in the elite karate athletes compared to the non-gymnasts in occipital and temporal areas (ventral pathway) and in dorsal pathway.

Judgment of actions in elite amateur katate athletes: a high-resolution EEG study. Behavioral Brain Research. 2010
EEG provides the high temporal resolution necessary for the study of secondary ("extended") consciousness including autobiographical and moral consciousness.
Resting state alpha sources are especially depressed in persistent vegetative state (PVS) subjects (awake but not conscious) who will not recover consciousness at 3-months follow up.

Resting EEG data:

Resting EEG data:
30 normal controls
12 PVS recovered
32 PVS not recovered

In PVS subjects, permanent deterioration of \textit{secondary consciousness} may be related to abnormality of resting state \textit{alpha} rhythms.

Resting EEG data:
30 normal controls
32 PVS recovered
12 PVS not recovered

Resting state alpha sources are depressed in locked in syndrome (LIS) subjects (they are conscious but with some abnormalities in emotional experiences).
In LIS subjects, some abnormal **conscious experience** may be related to abnormality of resting state **alpha** rhythms.
Conclusions: mapping alpha rhythms or ERPs unveils cortical processes related to primary and secondary consciousness

Cortical alpha rhythms before and during the stimulus are related to primary consciousness ("neuromodulatory context of cortical neural synchronization/desynchronization")

ERPs disclose the spatio-temporal evolution (100-400 ms post-stimulus) of cortical responses related to primary consciousness ("re-phasing and synchronization of cortical neurons")

Cortical resting state alpha rhythms are abnormal in subjects with persistent abnormal consciousness and in subjects with locked in syndrome

Cortical resting state alpha rhythms reflect efficiency of attention processes in elite athletes
Thanks for your consciousness

The father of EEG: H. Berger