Micro-state analysis of EEG

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A shared opinion on EEG/ERP: excellent temporal resolution (ms time-scale) but poor spatial resolution (scalp recording and inverse solution problem)
ERP = Event Related Potential

**Diagram Description:**
- **Stimulus:** The stimulus is applied to the individual.
- **Amplifier:** Amplifies the signal from the Electroencephalogram (EEG).
- **Signal Averager:** Averages the EEG signals over time.
- **EEG:** EEG traces with labeled time intervals: $S_1$, $S_2$, $S_3$, ..., $S_n$.
- **Mathematical Expression:** The averaged signal is calculated as $\frac{1}{n} \sum_{k=1}^{n} S_k$.
- **Visual ERP:** Graph showing visual event-related potential (ERP) with labeled peaks: NP80, N1, N2, P1, P2, and time axis from -100 to 300 ms.

*Source: Principles of Cognitive Neuroscience*
Visual event-related potential (ERP)

- Voltage (μV)
- Time (ms)

Key points:
- NP80
- N1
- P1
- P2
- N2
What is a peak?

“The simplest approach is to consider the ERP waveform as a set of waves, to pick the peaks (and troughs) of these waves, and to measure the amplitude and latency at these deflections.”

Picton et al., 2000, p.141
Caveat

......C1............P1/N1........N2..................P3.............

(Visual) stimulus onset

Response/Decision making

exogenous ERP components (sensory)
endogenous ERP components (cognitive)
10-20 EEG system (Jasper, 1958, 20 electrodes) up to 128 electrodes (high density ERP mapping)
When peaks hurt...

• What does an ERP (peak) actually mean? (synchronization, time and phase-locking but...)

• What about inter-peaks electric activity (meaningless)? Really true that only high amplitude (peak) is worth investigating?
• EEG is oscillatory in nature: maxima/peaks alone mean little.
• Worse: what about the landscape? (cf. tree and forest)
• Drawback/problem: reference! ERPs (amplitude) are strongly dependent on the reference!

• Wish: to analyze ERP data with less priors (and more power). Time (time-frames) and spatial (electrode positions) domains. + to get rid of the reference problem.
Topography enables a reference free measure!

Murray et al., 2008
Topography enables a reference free measure!

Murray et al., 2008
Topography matters!

Condition 1 ≠ Condition 2
Topography matters!

Read methods section (“acquisition: 32 or 64 channels; analyses: 1 or 2 channels”)
For this channel: same effect! At best a significant amplitude difference…
Tree hiding the forest…
Topography matters!

Condition 1

Condition 2

≠
Topography matters!

Condition 1

Condition 2

\( \neq \)
Topography matters!

Condition 1

Condition 2

≠
Key assumptions  
*(Lehmann & Skrandies, 1980)*

- If two topographic maps are different, one can be sure (demonstrated using maths) that the underlying configuration of intracranial generators is not the same (different brain networks involved!).

- However, the reverse assumption is not true. If the same topographic map is obtained in two conditions, it does not mean that the configuration of intracranial generators is the same (cf. 2 different networks leading to the same scalp map are feasible)!
Conventional analysis
Conventional analysis

(Statistical) Thresholding
“Pattern” analysis
“Pattern” analysis

peak

valley
“Pattern” analysis

Graph

Pattern analysis
How to define/identify a topographic map?
Spatial cluster analysis (Michel et al., 1999, 2001)
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**FUNCTIONAL MICROSTATES**

(obtained regardless of local amplitude changes)
Spatial cluster analysis *(Michel et al., 1999, 2001)*

Map series

62 channels

Temporal Segmentation (K-means)
Spatial correlation \( (C) \)

\[
C_{u,v} = \frac{\sum_{i=1}^{n} u_i \cdot v_i}{\|u\| \cdot \|v\|}
\]

\[
\|u\| = \sqrt{\sum_{i=1}^{n} u_i^2}, \quad \|v\| = \sqrt{\sum_{i=1}^{n} v_i^2}
\]

\( (C \) is equivalent to the Pearson coefficient) 

For each dominant map, one obtains then (after fitting) important indices not available with a peak analysis:

* Explained variance
* Duration
* Onset/Offset
* Strength (GFP)
* Best Correlation

Use these indices to perform brain-behavior correlations!

Perform the tracking of a topographic map into raw (EEG) or epoched (ERP) data
One of the advantages of topographic mapping over peak analysis:

Reduction of priors (time and space), and topographic maps can be used directly for Source Localization (inverse problem).
Easy solution: CARTOOL®
https://sites.google.com/site/fbmlab/cartool

Functional Brain Mapping Lab

Cartool Software

Important news about Cartool registration

- We have a new [Cartool Community](https://sites.google.com/site/fbmlab/cartool) website, which holds the FAQs, User’s Guide, Discussions etc... which replaces the old Cartool Google Group (still accessible, but only for the Discussions).

- Registering to Cartool is now a single step of registering to the Cartool Community, which ties together the agreement to use Cartool and the registration to the Cartool Community group.

- Due to this new scheme, we have to ask all the previously registered users of Cartool to go through the new registration process again. This way, we start with a clean setup for all of us, and I can also update the list of the registered users at the same time. Sorry for this little boring administrative work, that’s once in a many years task to do...

Cartool is our home-made EEG analysis software, a project started in 1996. This program has been fully programmed by Denis Brunet, and it evolves thanks to the valuable comments of numerous people (we can not cite all of them here!).

- What Is Cartool
- Cartool installation check-list
- Registration
- Download Cartool (once registered)
- Visit the Cartool Community group for more fun
One example/application
Go-NoGo task (color + orientation discrimination)

Go trial (2/3)

NoGo trial (1/3)

1000 ms

1000-2000 ms

Response (or 1000 ms)

1000 ms (correction)

1000 ms (FB)
Topographic pattern analysis

GFP (µV)

Time (ms)

HITS

ERRORS
Global Explained Variance (GEV)

Map x Condition interaction; $F(2,30) = 27.58, p<.001$
r(15) = -0.70
p = 0.004
Conclusions
Thank you for your attention!

Question?
=> Email me: gilles.pourtois@ugent.be