Seizure detection using scalp-EEG

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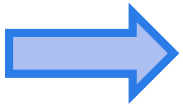
Scalp EEG based seizure detection - motivation

- seizure documentation and counting (‚recognizing the unobserved‘)
- epilepsy monitoring-unit
  - more efficient data analysis
  - automatic injection of isotopes for ictal SPECT scans
  - automatic neuropsychological testing
- outpatient setting
  - seizure alerts and warning $\Rightarrow$ improve patient safety

Scalp EEG based seizure detection - requirements

- high sensitivity
- high specificity = low false alarm rate
- on-line calculation  alarm devices
- short detection latency
- easy and ready to use in a clinical setting
  - no complicated parameter adjustments
  - no a-priori knowledge about individual seizure characteristics
  - no adjustment for individual patients - ‚patient specific detection‘

Scalp EEG based seizure detection - problems

- inter-individual differences in seizure patterns depending on seizure onset zone
- intra-individual differences in seizure patterns depending on conditions at seizure onset, speed and route of seizure propagation
- high sensitivity, but low specificity $\Rightarrow$ high false alarm rate
  - artifacts
  - recurrent rhythmic and high amplitude EEG data (e.g. FIRDA, TIRDA, sleep activity)
- highly selected EEG data for development and evaluation $\Rightarrow$ low percentage of non-ictal EEG data
- retrospective versus prospective application and evaluation

Scalp EEG based seizure detection - methods

- single versus multiple channels
- electrodes included
- artifact rejection
- detection of characteristic electrographic changes during seizures with respect to frequency, amplitude and/or rhythmicity
- frequency bands used
- linear and non-linear time-frequency signal analyses with numerous features
- on-line vs. off-line

Scalp EEG based seizure detection - selected studies

Reference	Patients (TLE:ETLE)/szs.	EEG duration	Sensitivity (%)	FpH (/h)
Pauri et al. (1992)	12/253	461	81.4	5.38
Gabor (1998)	65/181	4554	92.8	1.35
Wilson et al. (2004)	426/672	1049	76.0	0.11
Saab and Gotman (2005)	16/69	360	76.0	0.34
Meier et al. (2008)	57/91	1403	> 96.0	<0.5
Kelly et al. (2010)	55/146	1200	79.5	0.08
Hartmann et al. (2011)	48 (48:0)/186	4300	83.0	0.3
Zandi et al. (2012)	26 (22:4)/79	236	91.0	0.33
Hopfengärtner et al. (2014)	159 (117:35)/794	25278	87.3	0.22
Fürbass et al. (2015)	205(94)/526	15684	81.0	0.29

Scalp EEG based seizure detection - selected studies

- algorithm based on Short Time Fourier Transform, calculating the integrated power in the frequency band 2.5-12 Hz for a multi-channel seizure detection montage referenced against the average of Fz-Cz-Pz
- adaptive thresholding technique
- fixed set of parameters

- 159 patients (117 temporal-lobe epilepsies (TLE), 35 extra-temporal lobe epilepsies (ETLE), 7 other)
- total of 25,278 h of EEG data
- 794 seizures

- sensitivity: 87.3%
- number of false detections per hour (FpH): 0.22/h

- TLE patients: sensitivity 89.9%; FpH = 0.19/h
- ETLE patients: sensitivity 77.4%; FpH = 0.25/h

Hopfengärtner et al. Clin Neurophysiol 2014;125 :1346-1352

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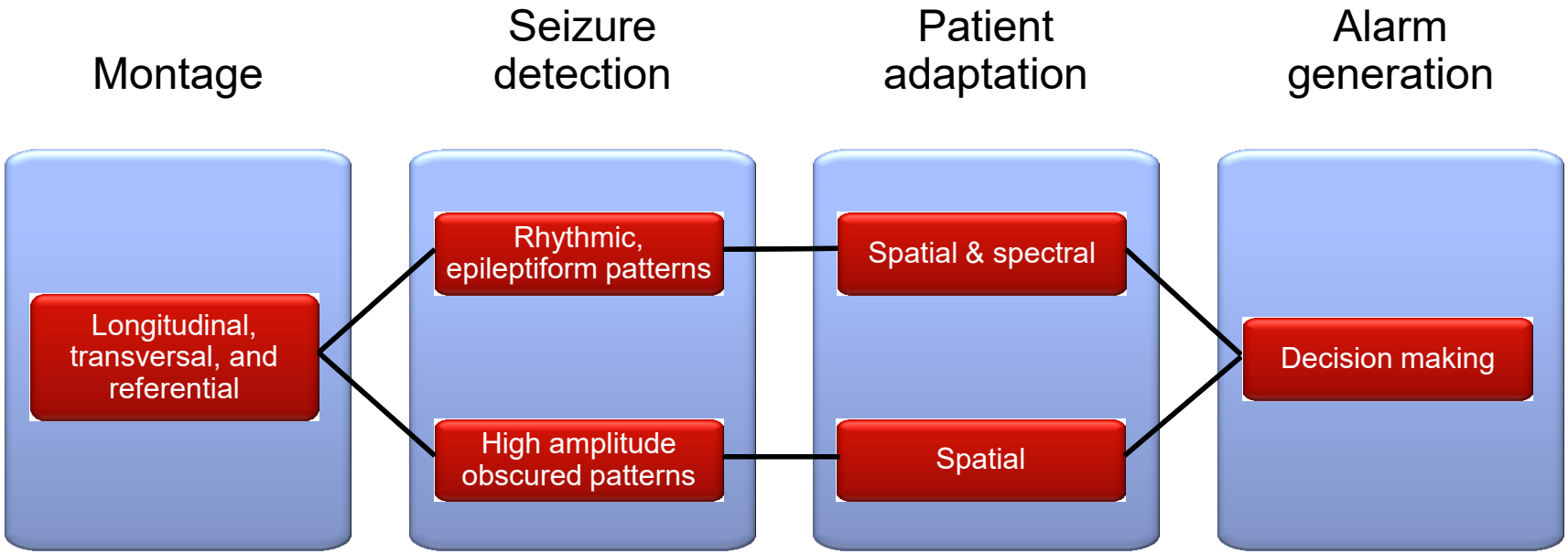
EpiScan

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY



Periodic waveform analysis

EpiScan: Online seizure detection for epilepsy monitoring units

Manfred M. Hartmann, Franz Fürbaß, Hannes Perko, Ana Skupch, Katharina Lackmayer, Christoph Baumgartner, and Tilmann Kluge

Hartmann et al. Conf Proc IEEE Eng Med Biol Soc 2011;2011:6096-9

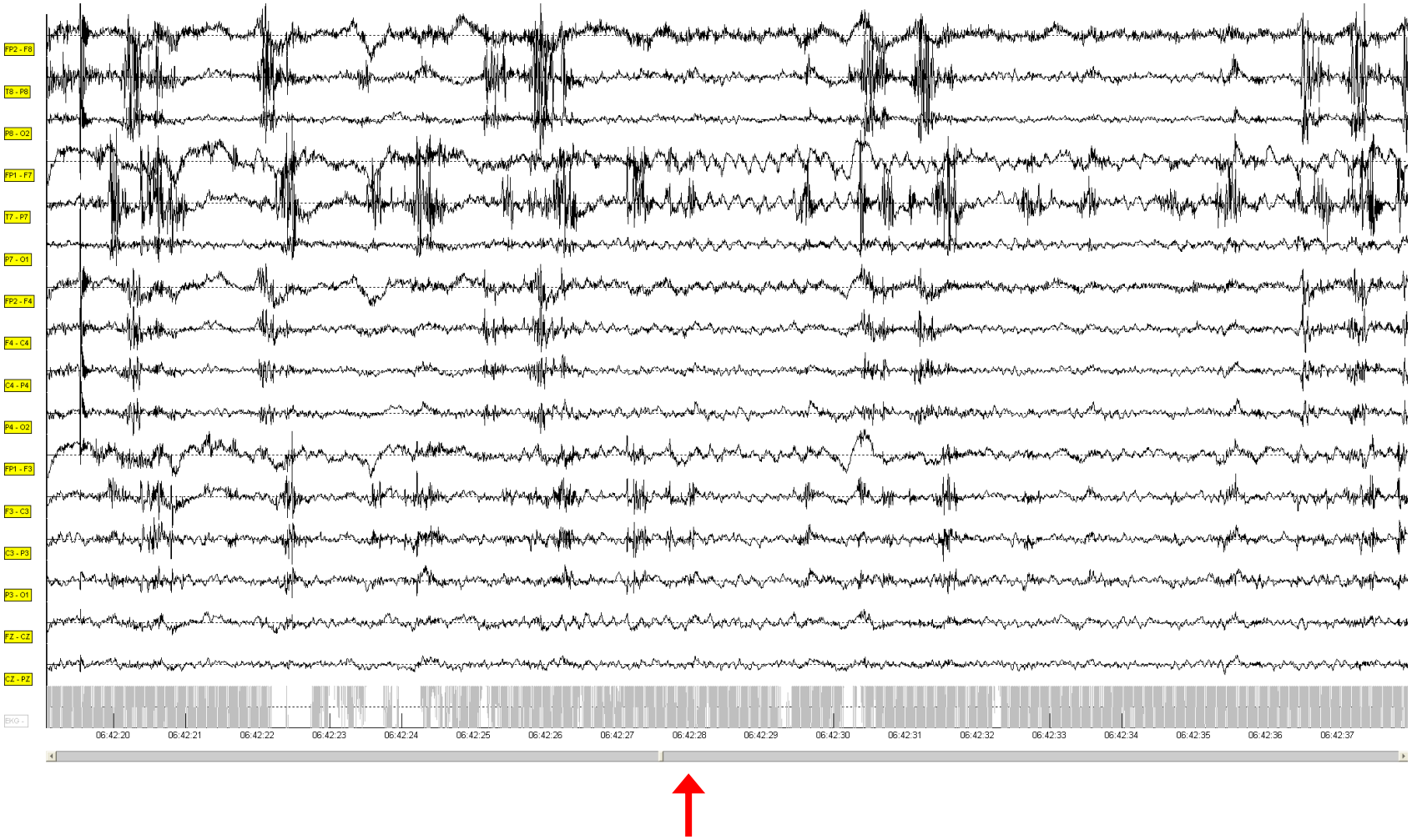
Epileptiform Wave Sequence (EWS) Analysis

Combining Time Series and Frequency Domain Analysis for a Automatic Seizure Detection

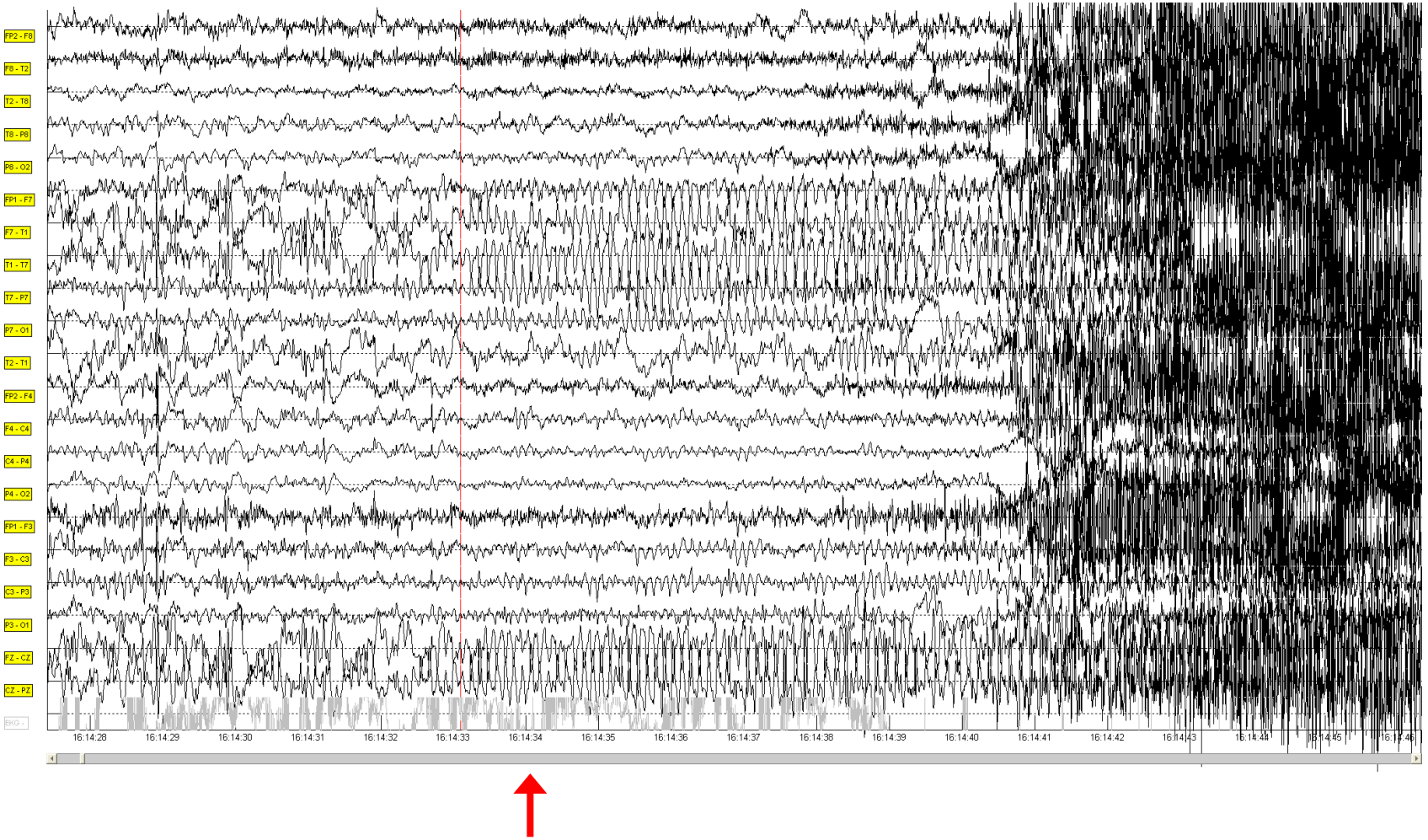
F. Fürbaß, M. Hartmann, H. Perko, A. Skupch, P. Dollfuß, G. Gritsch, C. Baumgartner, and T. Kluge

Fürbass et al. Conf Proc IEEE Eng Med Biol Soc 2012;2012:1020-3

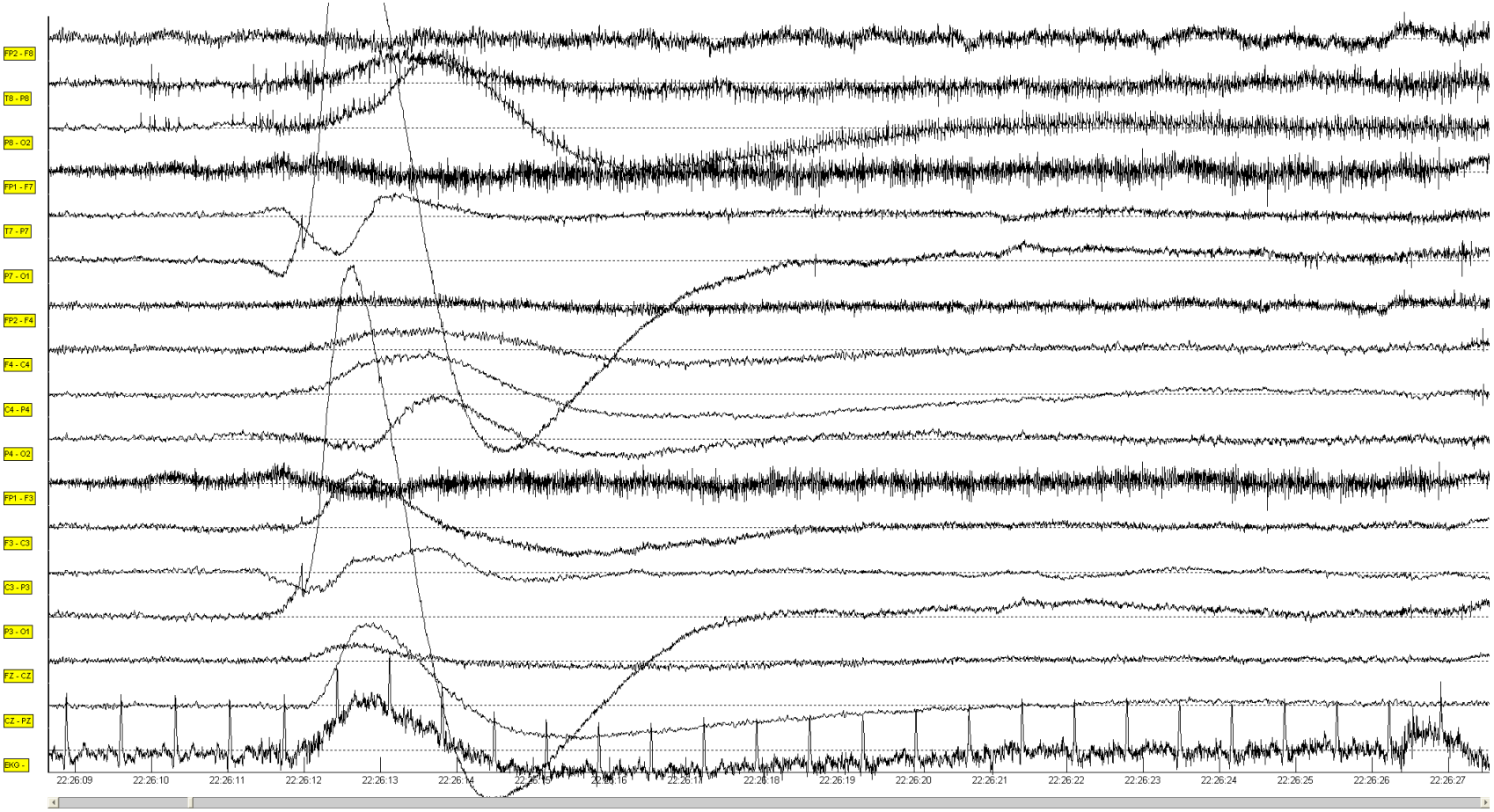
Seizure detected



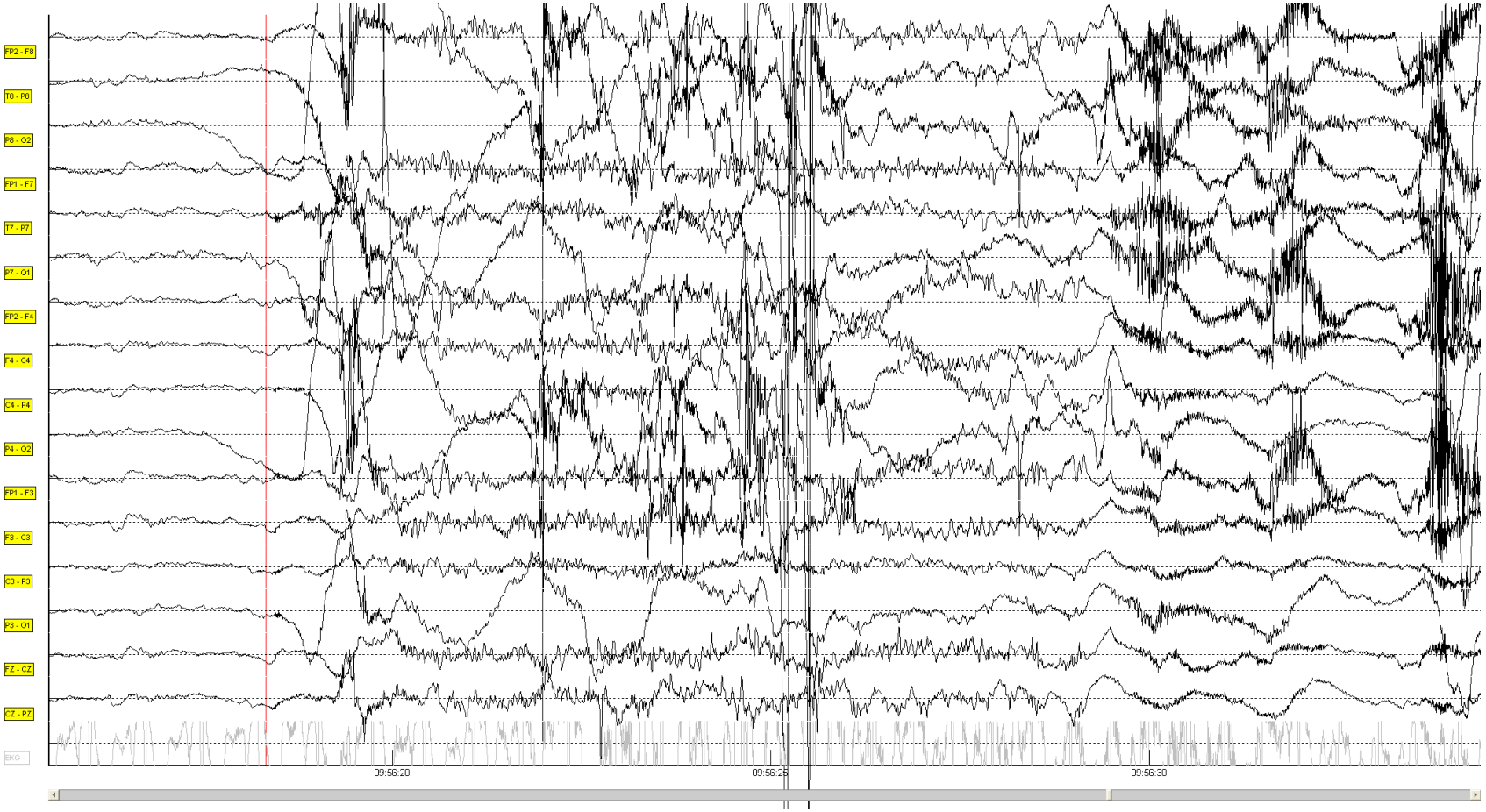
Seizure detected



Seizure not detected



Seizure not detected



Scalp EEG based seizure detection - methods

- 3 epilepsy monitoring units
  - Neurological Department, General Hospital Hietzing with Neurological Center Rosenhügel, Vienna, Austria (NCR)
  - Department of Neurology, Medical University of Vienna, Austria (MUV)
  - Epilepsy Center Kempenhaeghe, Heeze, The Netherlands (KEMP)

- prospective study
  - 15,684 hours of EEG
  - 205 patients including 94 patients with seizures
  - 526 seizures

- retrospective study
  - 25,567 hours of EEG
  - 310 patients including 124 patients with seizures
  - 1113 seizures

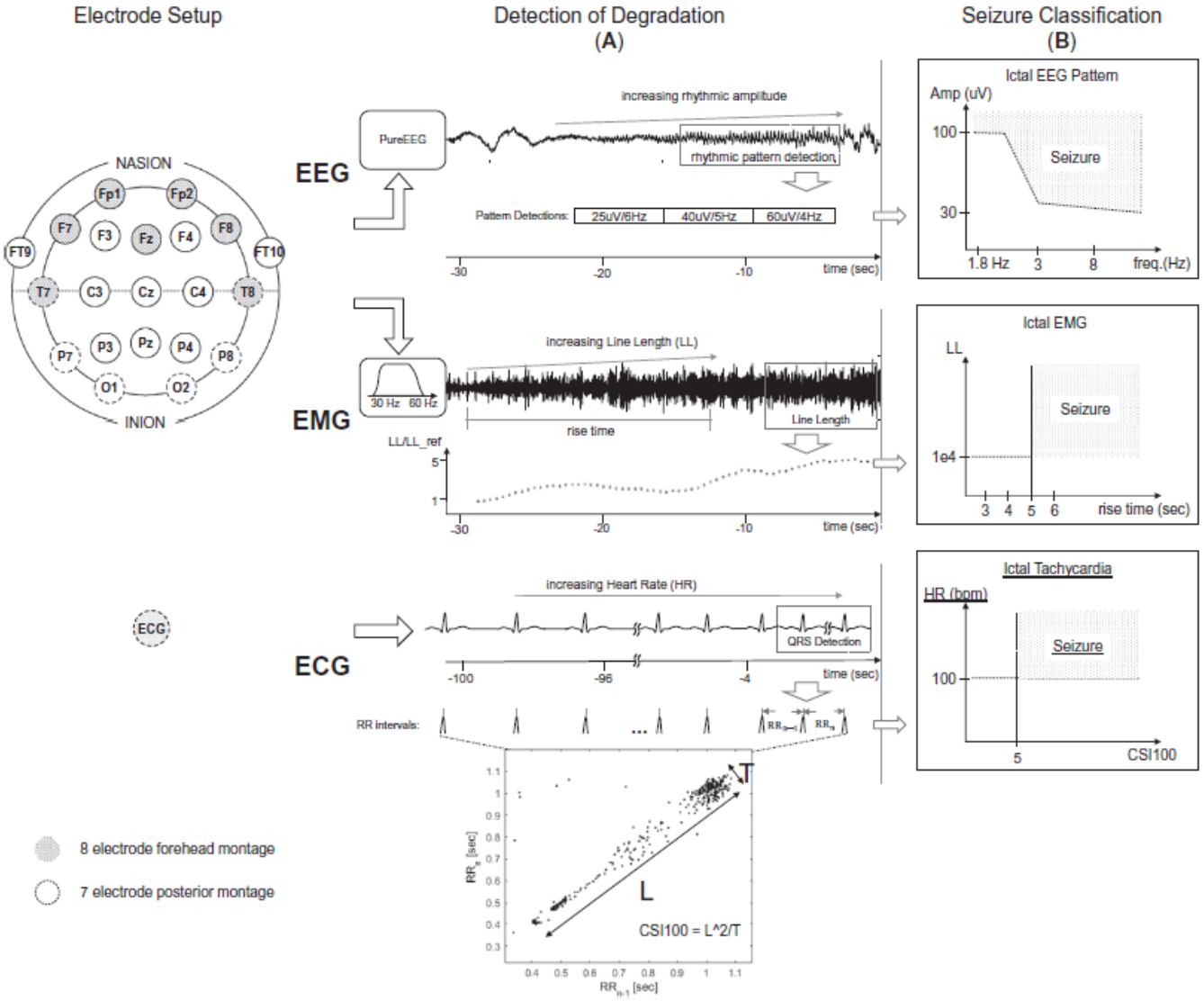
Fürbass et al. Clin Neurophysiol 2015;126:1124-1131

Scalp EEG based seizure detection - results

- prospective study
  - sensitivity: 81%
  - FA/24h: 7.1
  - EpiScan detected 16 previously undetected seizures (3% of all seizures)
  - all seizures were detected in more than 50% of patients
  - more than 80% of patients had less than 10 FA/24h
- retrospective study
  - sensitivity: 75%
  - FA/24h: 7.2
- performance depending on seizure onset zone
  - TLE: sensitivity: 83%; FA/24h: 6.7
  - ETLE: sensitivity: 64%; FA/24h: 7.3

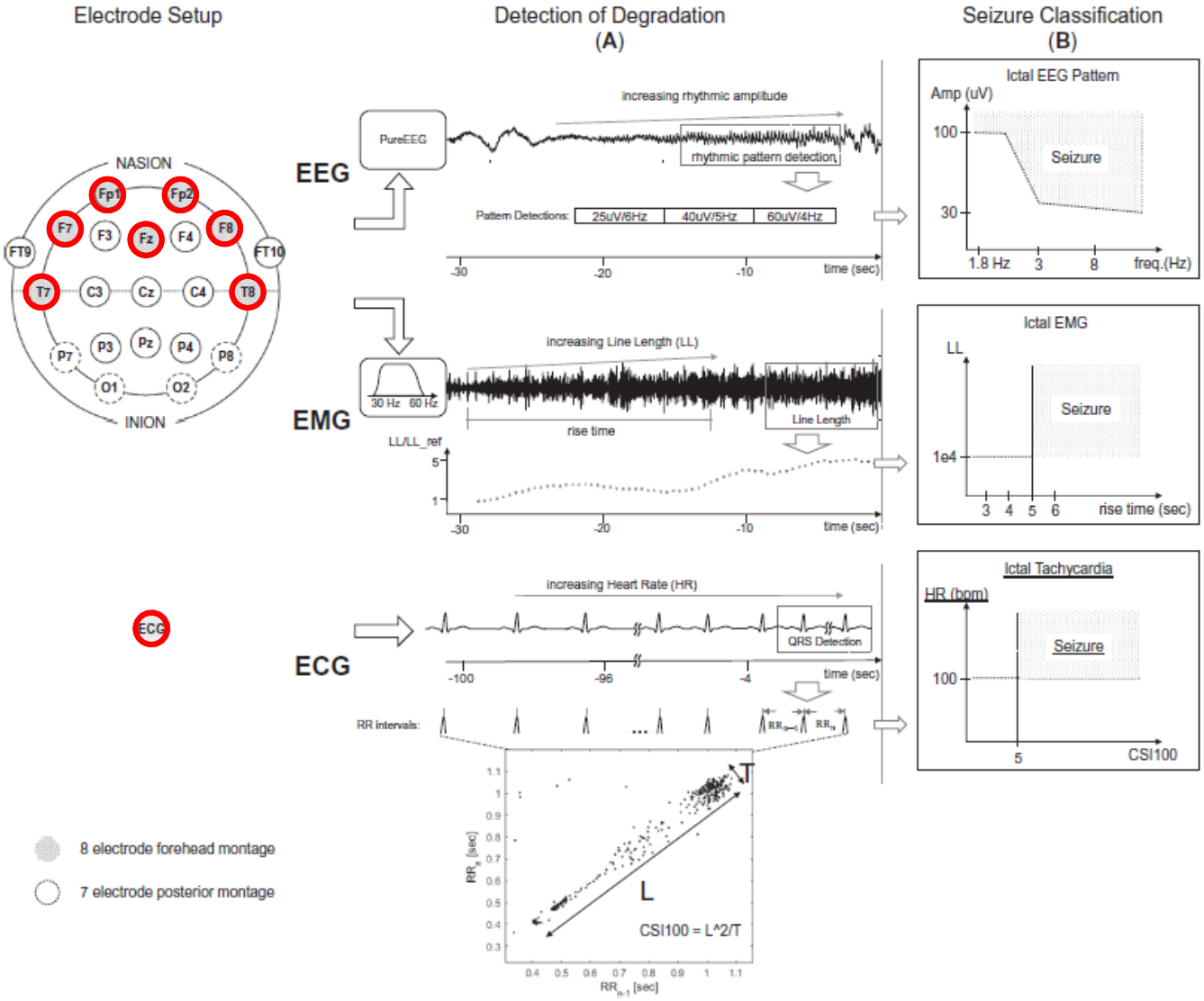
Fürbass et al. Clin Neurophysiol 2015;126:1124-1131

Multimodal seizure detection



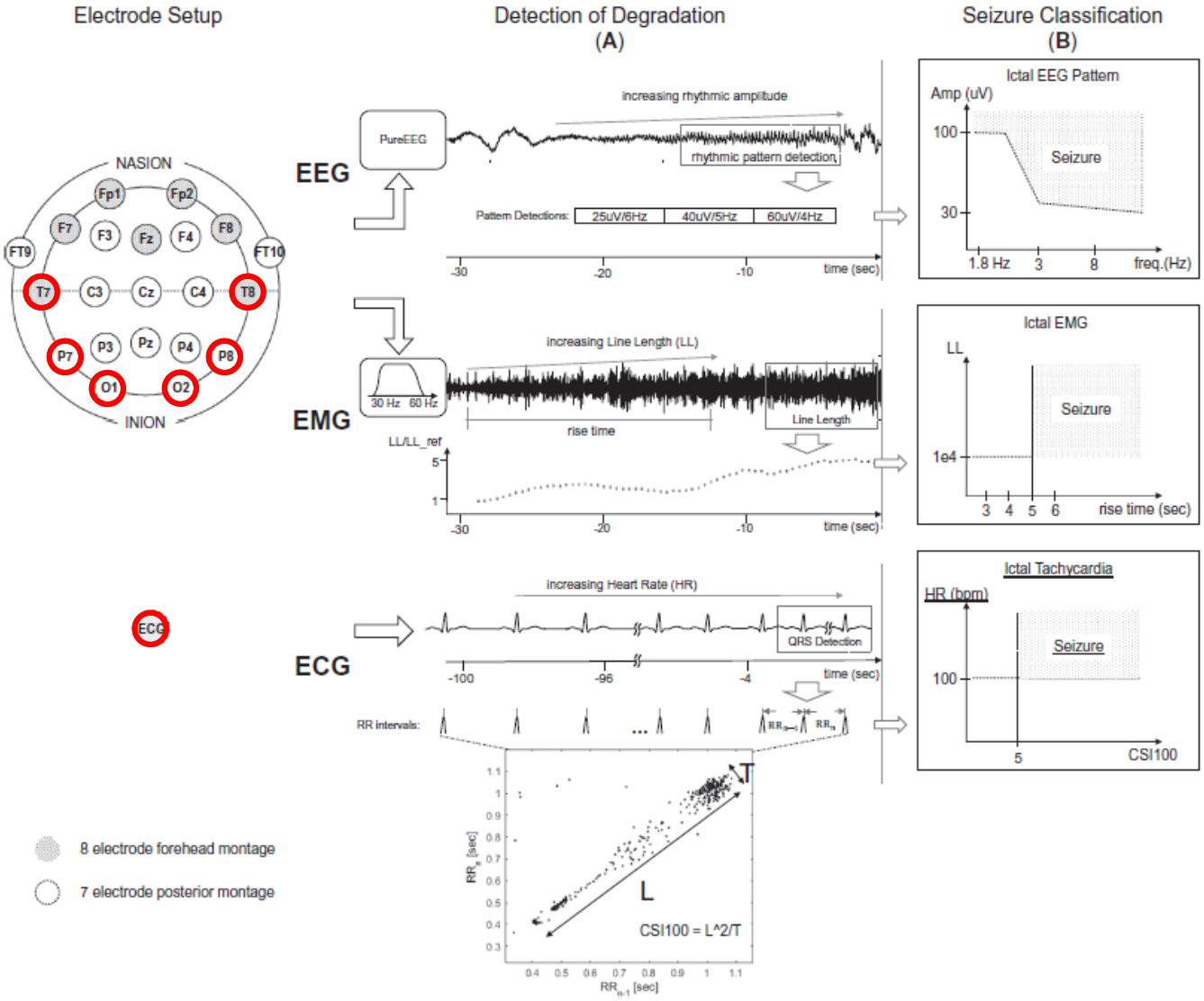
Fürbass et al. Clinical Neurophysiology 2017;128:1466-472

Multimodal seizure detection



Fürbass et al. Clinical Neurophysiology 2017;128:1466-472

Multimodal seizure detection



Fürbass et al. Clinical Neurophysiology 2017;128:1466-472

Multimodal seizure detection

Automatic seizure detection performance

	ALL $n = 92$ nSz = 494		TLE $n = 55$ nSz = 284		XTLE $n = 37$ nSz = 210		FS $n = 64$ nSz = 139		BTCS $n = 35$ nSz = 50	
	SE (%)	FD/24 h	SE (%)	FD/24 h	SE (%)	FD/24 h	SE (%)	FD/24 h	SE (%)	FD/24 h
22 electrode montage										
EEG	84	15.6	91	11.9	74	21.2	88	15.5	97	13.3
ECG	27	0.6	40	0.6	8	0.6	27	0.7	43	0.4
EMG	29	0.4	25	0.3	35	0.6	8	0.4	93	0.5
EEG + EMG	84	16.0	92	12.2	74	21.7	88	15.9	100	13.8
EEG + ECG + EMG (COMB)	86	16.5	94	12.8	74	22.2	89	16.4	100	14.1

sensitivity

- EEG alone: 84%
- EEG + ECG + EMG: 86%

Fürbass et al. Clinical Neurophysiology 2017;128:1466-472

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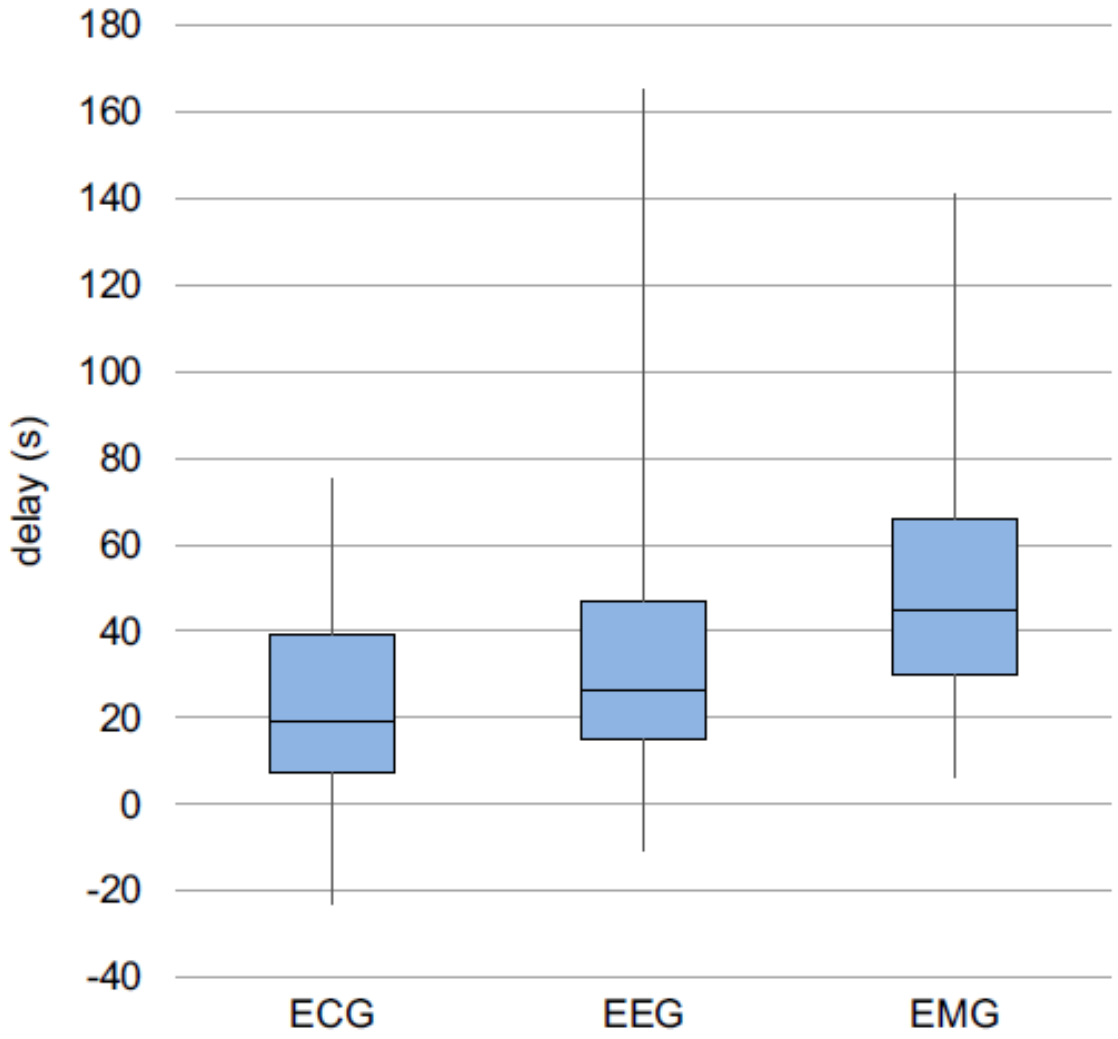
8 electrode forehead montage										
EEG	79	11.5								
ECG	27	0.6								
EMG	34	1.6								
EEG + EMG	81	12.1								
EEG + ECG + EMG (COMB)	81	13.5								
7 electrode posterior montage										
EEG	68	4.2								
ECG	27	1.2								
EMG	28	1.2								
EEG + EMG	69	5.4								
EEG + ECG + EMG (COMB)	74	6.0								

sensitivity

- 22 EEG electrodes: 84%
- 8 electrode forehead montage: 79%
- 7 electrode posterior montage: 68%

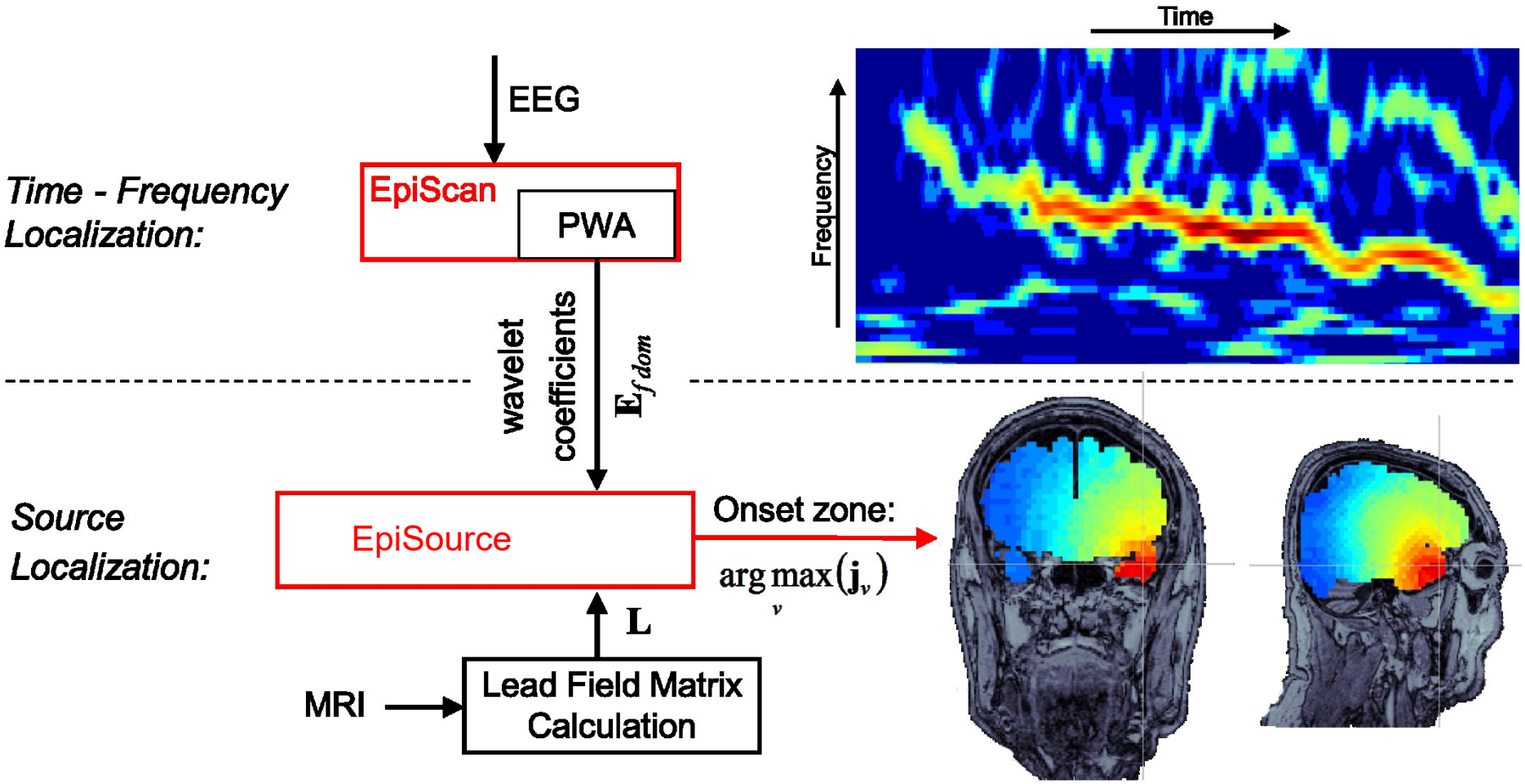
Fürbass et al. Clinical Neurophysiology 2017;128:1466-472

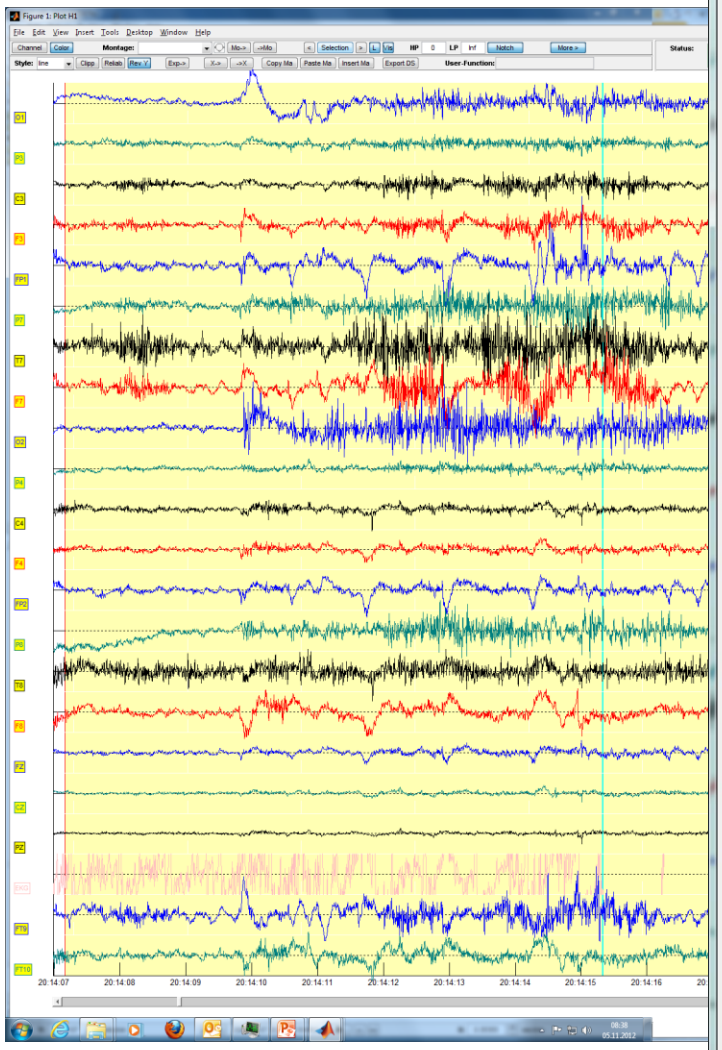
Multimodal seizure detection - detection latency



Fürbass et al. Clinical Neurophysiology 2017;128:1466-472

Automatic ictal source localization - EpiSource





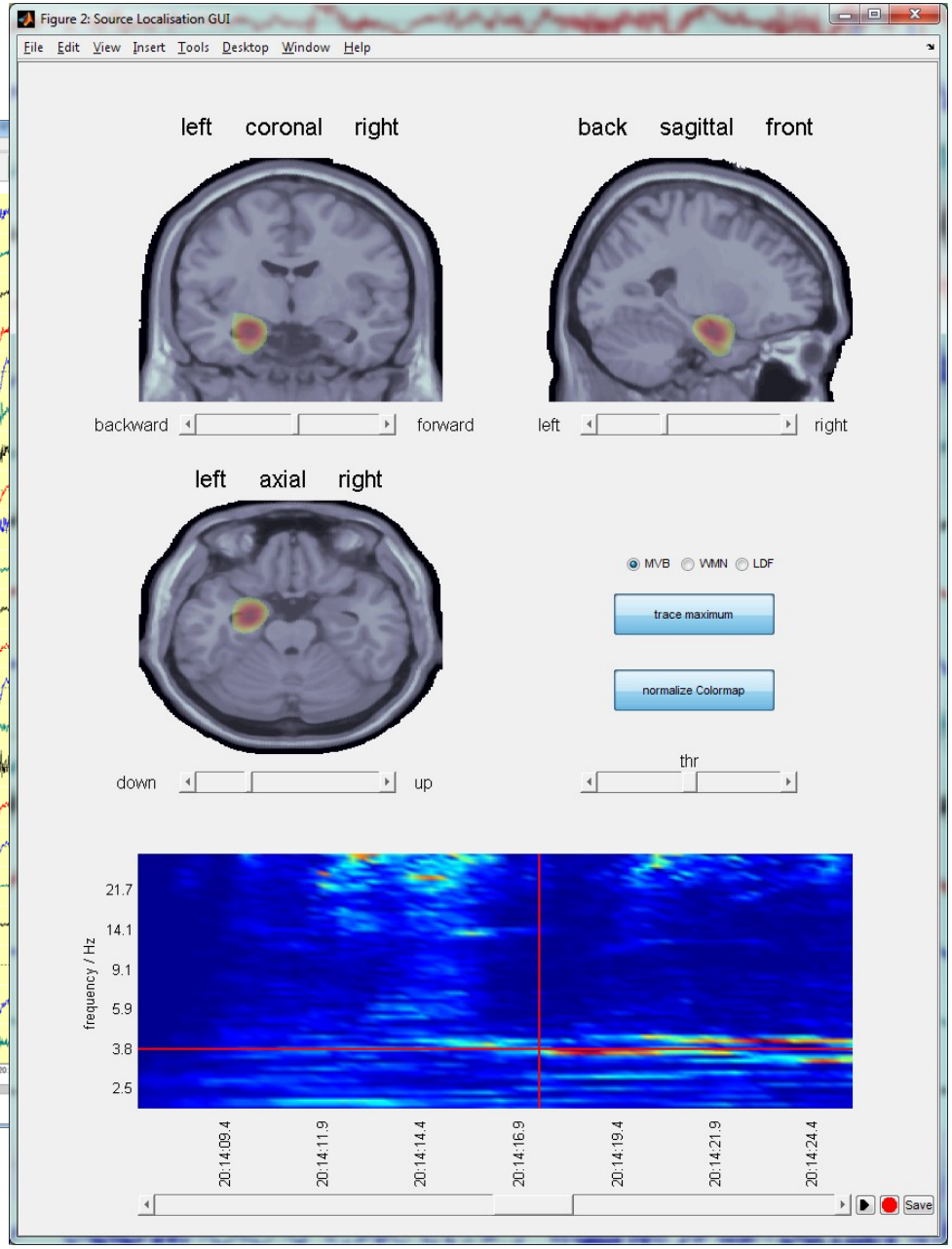


Figure 2: Source Localisation GUI
File Edit View Insert Tools Desktop Window Help
left coronal right
back sagittal front
backward
forward
left
right
left axial right
down
up
MVB
WMN
LDF
trace maximum
normalize Colormap
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frequency / Hz
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14.1
9.1
5.9
3.8
2.5
20:14:09.4
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20:14:14.4
20:14:16.9
20:14:19.4
20:14:21.9
20:14:24.4
Save

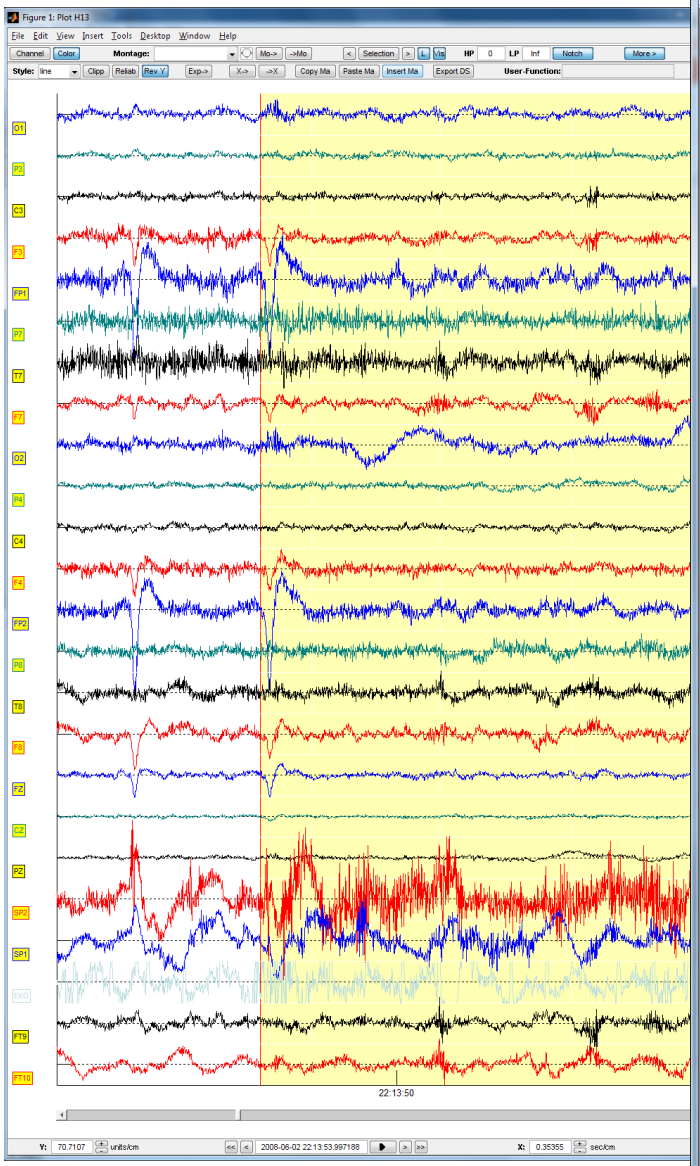
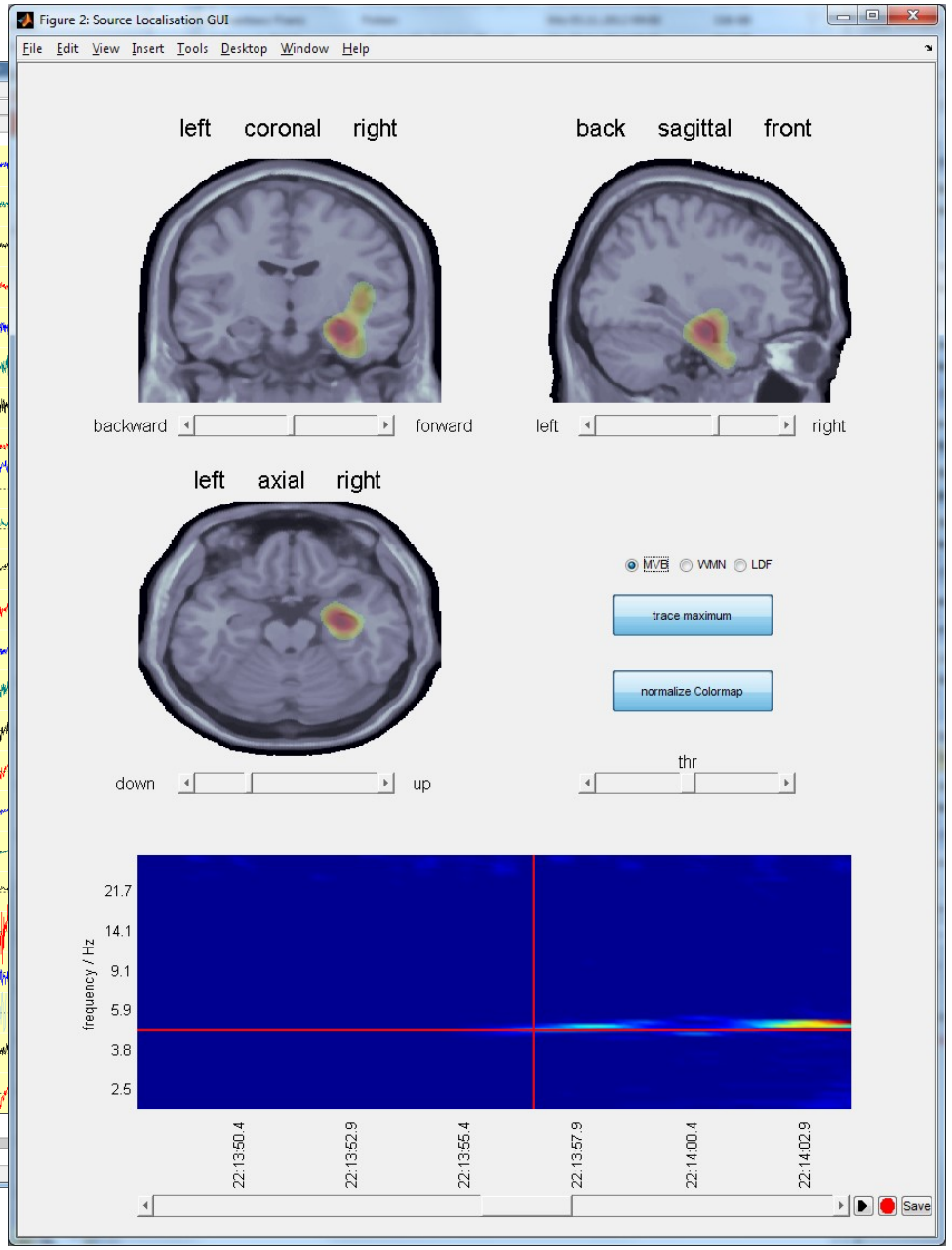


Figure 1: Plot H13
File Edit View Insert Tools Desktop Window Help
Channel Color Montage: Selection HP LP Notch More >
Style: line Clipp Reliab Rev.Y Exp-> X-> ->X Copy Ma Paste Ma Insert Ma Export DS User-Function:
O1
P3
C3
F3
FP1
P7
T7
F7
O2
P4
C4
F4
FP2
P8
T8
F8
FZ
CZ
PZ
SP2
SP1
EKG
FT9
FT10
22:13:50
Y: 70.7107 units/cm
2008-06-02 22:13:53.997188
X: 0.35355 sec/cm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File Edit View Insert Tools Desktop Window Help
left coronal right
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MVB WMN LDF
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22:13:52.9
22:13:55.4
22:13:57.9
22:14:00.4
22:14:02.9
Save

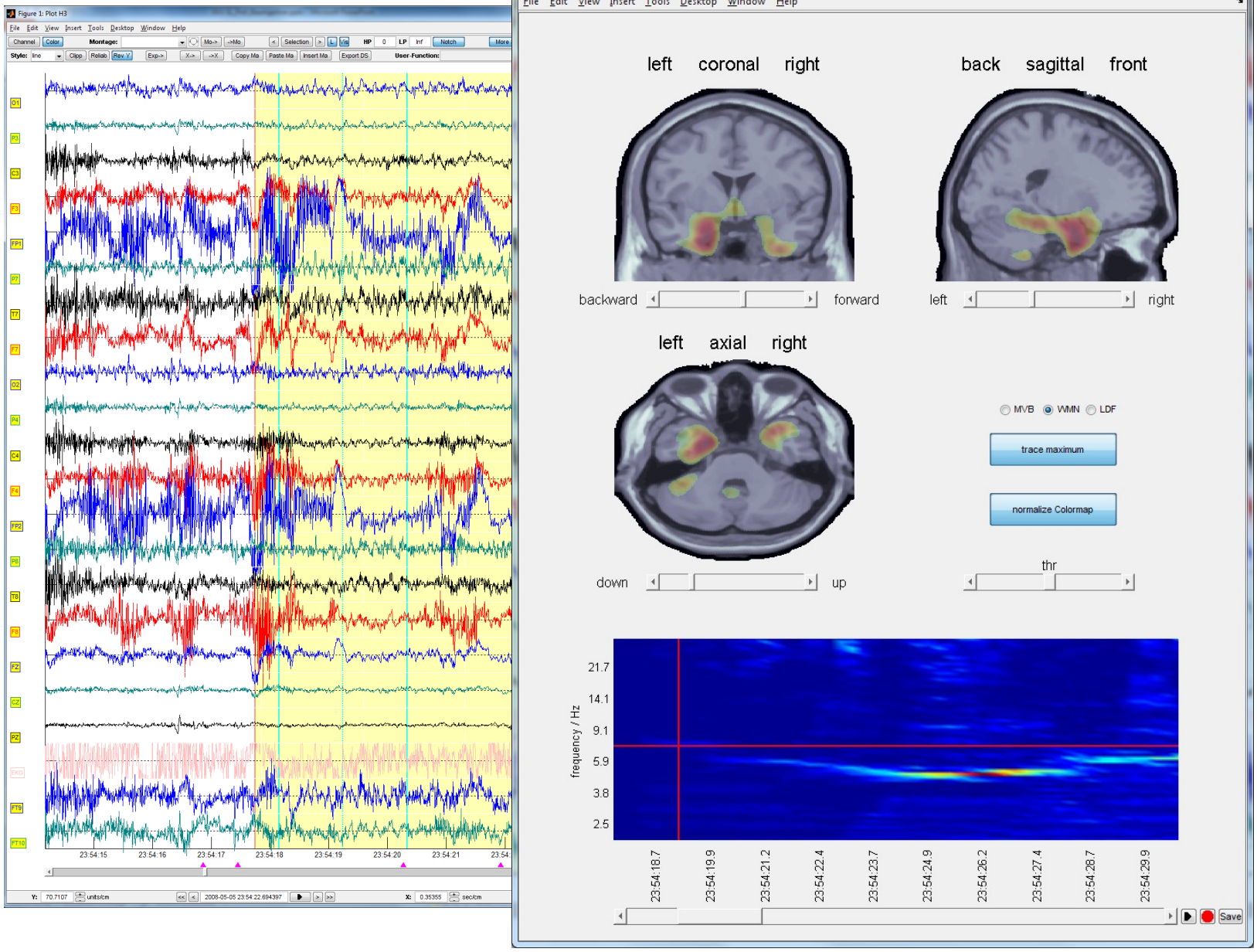
Figure 1: Plot H3
File Edit View Insert Tools Desktop Window Help
Figure 2: Source Localisation GUI
File Edit View Insert Tools Desktop Window Help
left coronal right
back sagittal front
backward
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left
right
left axial right
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MVB
VMN
LDF
trace maximum
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21.7
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5.9
3.8
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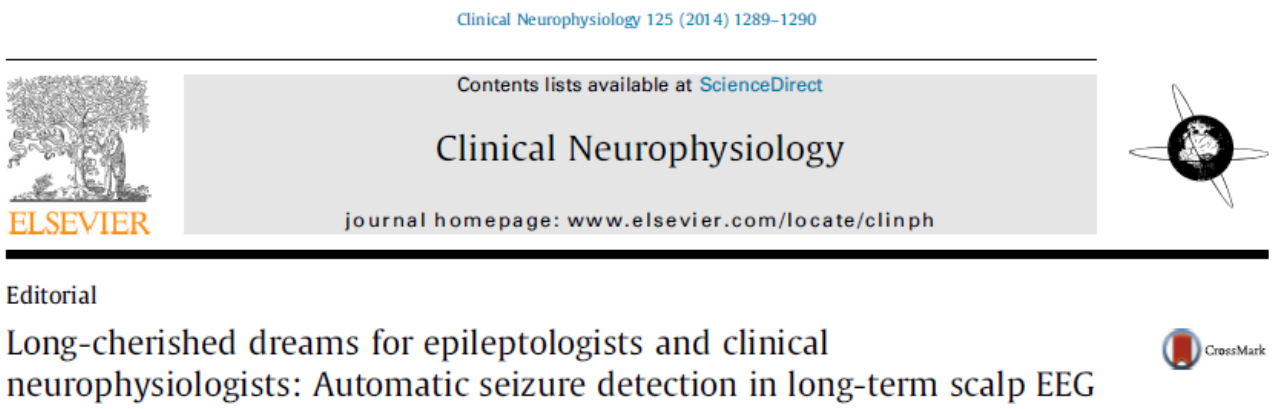
Save

Conclusions



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Editorial

Long-cherished dreams for epileptologists and clinical neurophysiologists: Automatic seizure detection in long-term scalp EEG

Pin and Nakasoto. Clin Neurophysiol 2014;125 :1289-1290

- scalp EEG based seizure detection is feasible
  - seizure documentation and counting (‚recognizing the unobserved‘)
  - more efficient data analysis
  - automatic injection of isotopes for ictal SPECT scans
  - automatic neuropsychological testing
  - seizure alerts and warning $\Rightarrow$ improve patient safety
- still limitations in everyday clinical practice – can help, but cannot replace the epilepsy monitoring team

Thank you for your attention!

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Medizinische Fakultät
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TOMORROW TODAY

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