AARHUS UNIVERSITY

Danish Epilepsy Centre FILADELFIA

When is something spikish an epileptiform spike ?

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@SBeniczky

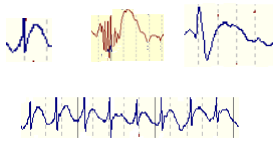
Disclosures

- Scientific consultant: Epihunter
- Speaker: Natus Neuro

Learning Objectives

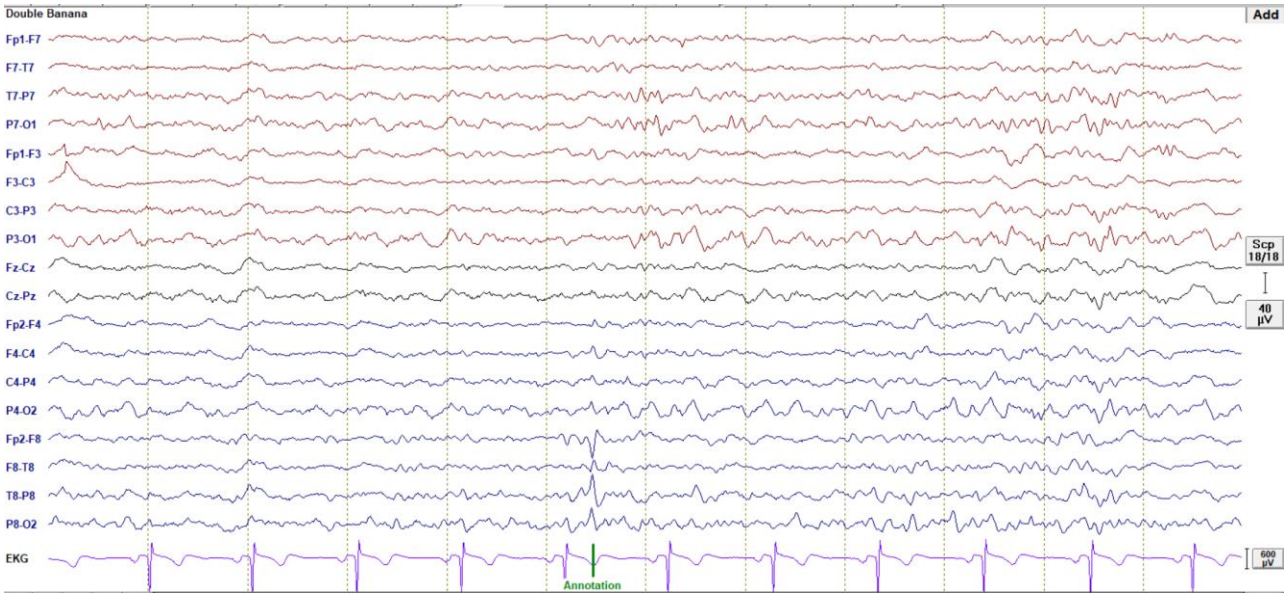
- To recognize the IFCN criteria for identifying IEDs.
- To distinguish between IEDs and non-epileptiform sharp transients applying the IFCN criteria.
- To explain the trade-off between sensitivity and specificity in clinical EEG reading

Interictal Epileptiform Discharges

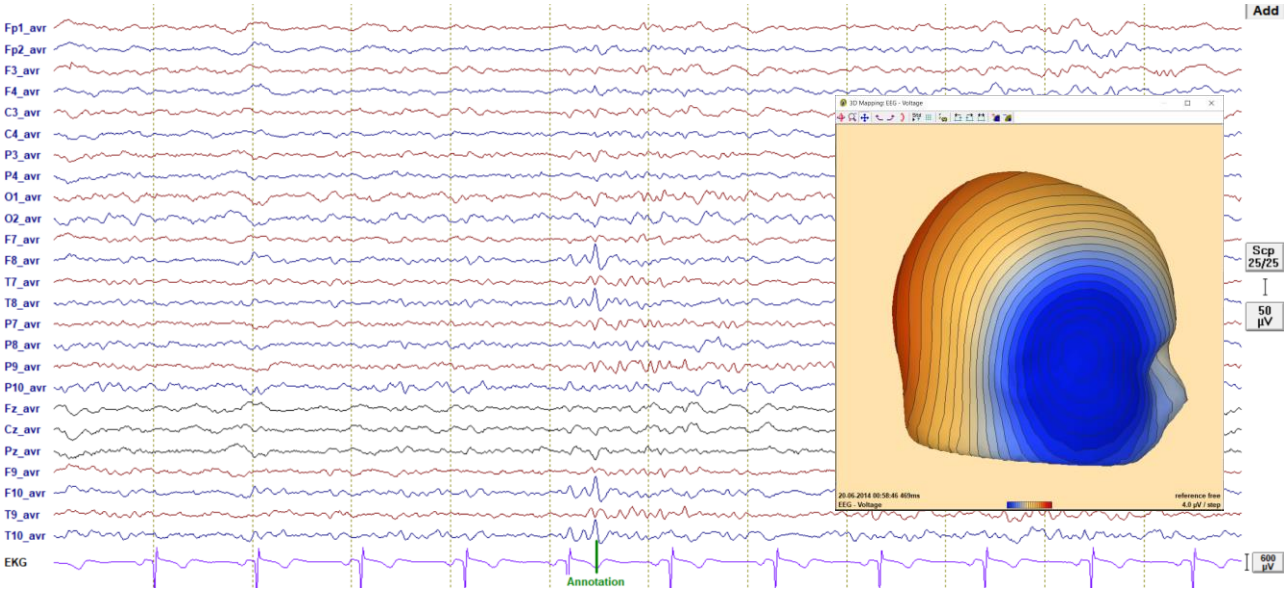


- The most well-documented EEG biomarker of epilepsy
- In skilled hands: diagnosis & classification of epilepsy
- However: it is also the most abused item in EEG

Is this an IED?



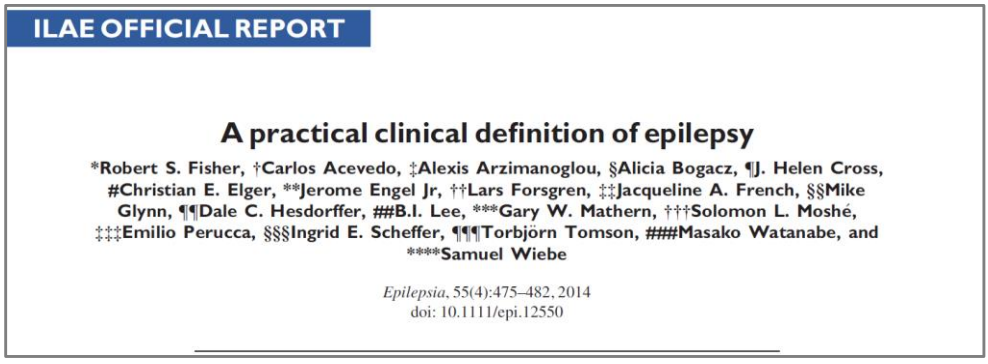
Is this an IED?



When is a spike a spike and who / what finds it?

- **IEDs` role in epilepsy diagnosis**
- **IFCN´s operational criteria for IEDs**
- **Spotting IEDs in source space**
- **AI & hybrid systems**

Epilepsy - diagnosis



ILAE OFFICIAL REPORT

A practical clinical definition of epilepsy

*Robert S. Fisher, †Carlos Acevedo, ‡Alexis Arzimanoglou, §Alicia Bogacz, ¶J. Helen Cross, #Christian E. Elger, **Jerome Engel Jr, ††Lars Forsgren, ‡‡Jacqueline A. French, §§Mike Glynn, ¶¶Dale C. Hesdorffer, ##B.I. Lee, ***Gary W. Mathern, †††Solomon L. Moshé, ‡‡‡Emilio Perucca, §§§Ingrid E. Scheffer, ¶¶¶Torbjörn Tomson, ###Masako Watanabe, and ****Samuel Wiebe

Epilepsia, 55(4):475–482, 2014
doi: 10.1111/epi.12550

- (1) At least two unprovoked (or reflex) seizures occurring >24 h apart
- (2) One unprovoked (or reflex) seizure and a probability of further seizures ≥ 60%
- (3) Diagnosis of an epilepsy syndrome.

Probability of further seizures after the first unprovoked seizure:

Children		Adults	
• Normal EEG:	? %	• Normal EEG:	? %
• EEG=IED:	? %	• EEG=IED:	? %

Camfield et al, 1985; Shinnar et al, 1996; Stroink et al, 1998; Ramos Lizana et al, 2000
Donselaar et al 1992; Berg et al 2008; Wirrell et al, 2010; Su et al, 2013

Probability of further seizures after the first unprovoked seizure:

Children		Adults	
• Normal EEG:	38%	• Normal EEG:	12%
• EEG=IED:	? %	• EEG=IED:	? %

Camfield et al, 1985; Shinnar et al, 1996; Stroink et al, 1998; Ramos Lizana et al, 2000
Donselaar et al 1992; Berg et al 2008; Wirrell et al, 2010; Su et al, 2013

Probability of further seizures after the first unprovoked seizure:

Children		Adults	
• Normal EEG:	38%	• Normal EEG:	12%
• EEG=IED:	65%	• EEG=IED:	83%

Camfield et al, 1985; Shinnar et al, 1996; Stroink et al, 1998; Ramos Lizana et al, 2000
Donselaar et al 1992; Berg et al 2008; Wirrell et al, 2010; Su et al, 2013

Abusing spikes & EEG

- Over-reading EEG /IEDs: the most common source of misdiagnosing epilepsy
- 25%–30% of patients seen at epilepsy centers for drug-resistant seizures do not have epilepsy
- Detrimental consequences:
  - restrictions on driving
  - restrictions on career choices
  - unnecessary exposure to side effects of antiepileptic drugs
  - not treating the real condition of the patient.

WARNING:

The false-positive EEG report (over-reading) is potentially more harmful to the patient than the false negative report (under-reading)!

Causes of over-reading

- Lack of proper training
- ”Trying too hard syndrome” *(Tatum & Benbadis)*
- Fetishizing phase reversal / big & spikey waveforms
- Too vague definition / lack of widely accepted operational criteria.

Operational definition of IEDs
(spikes / polyspikes, sharp-waves)

Clinical Neurophysiology Practice 2 (2017) 170–185

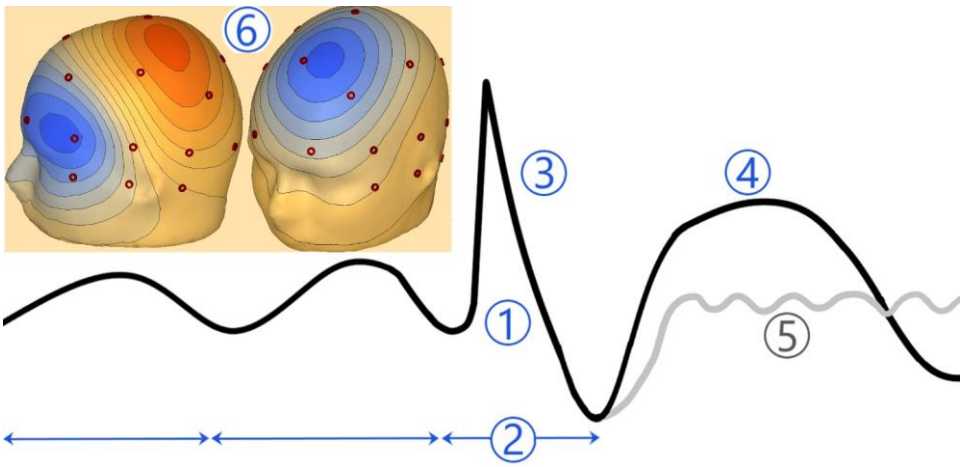
Contents lists available at ScienceDirect

Clinical Neurophysiology Practice

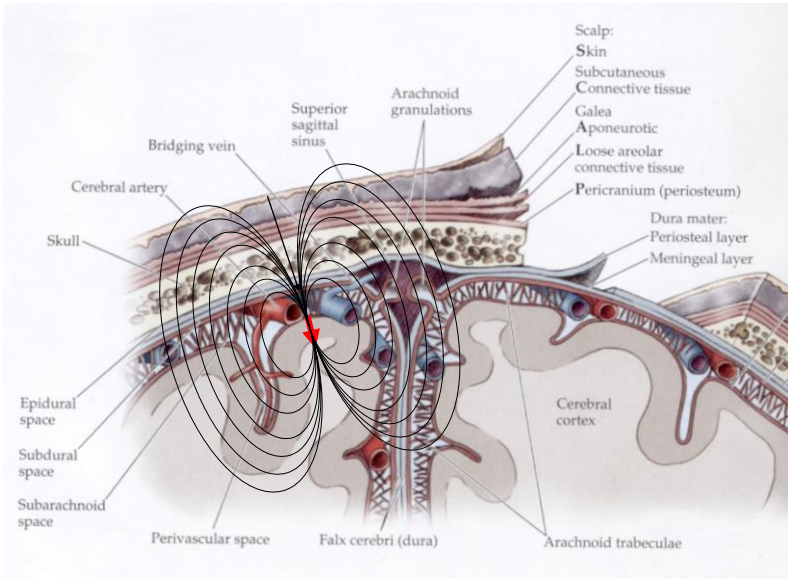
journal homepage: www.elsevier.com/locate/cnp

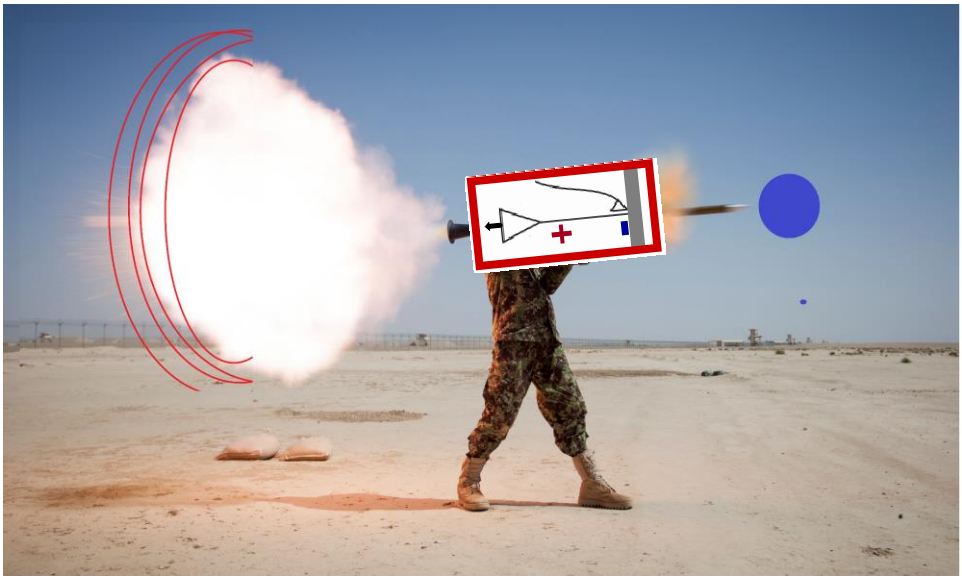
A revised glossary of terms most commonly used by clinical electroencephalographers and updated proposal for the report format of the EEG findings. Revision 2017

Nick Kane [a,*], Jayant Acharya [b], Sandor Beniczky [c], Luis Caboclo [d], Simon Finnigan [e], Peter W. Kaplan [b], Hiroshi Shibasaki [f], Ronit Pressler [a], Michel J.A.M. van Putten [g]



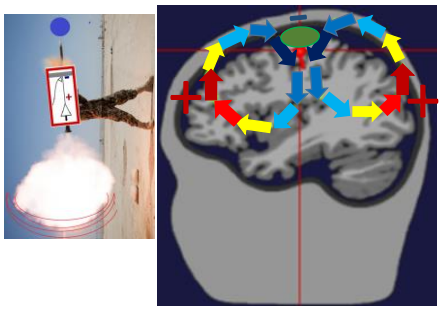
1. Di / tri-phasic waves with sharp / spiky morphology (pointed peak).
2. Different wave-duration than the ongoing background activity.
3. Asymmetry of the waveform.
4. The transient is followed by an associated slow after-wave.
5. The background activity surrounding EDs is disrupted by the presence of the EDs.
6. Distribution of the negative and positive potentials on the scalp suggests a source of the signal in the brain, corresponding to a radial, oblique or tangential orientation of the source. This is best assessed by inspecting voltage maps constructed using common-average reference.

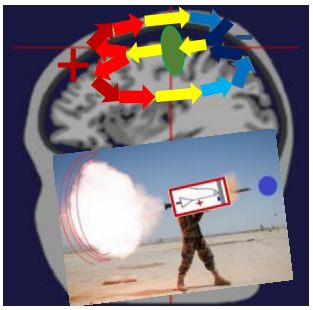

Scalp:
Skin
Subcutaneous
Connective tissue
Galea
Aponeurotic
Loose areolar
connective tissue
Pericranium (periosteum)
Dura mater:
Periosteal layer
Meningeal layer
Arachnoid
granulations
Superior
sagittal
sinus
Bridging vein
Cerebral artery
Skull
Epidural
space
Subdural
space
Subarachnoid
space
Perivascular space
Falx cerebri (dura)
Arachnoid trabeculae
Cerebral
cortex

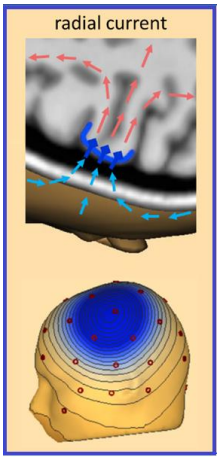


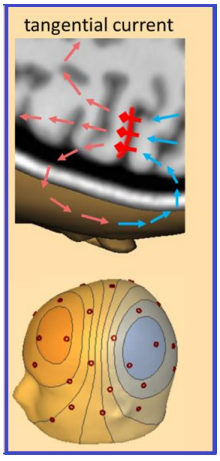
Signal generation:

Both negative and positive potentials on the scalp

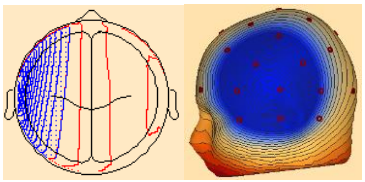


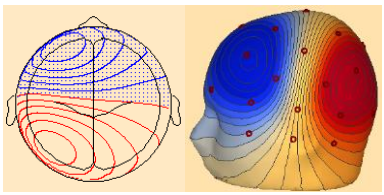




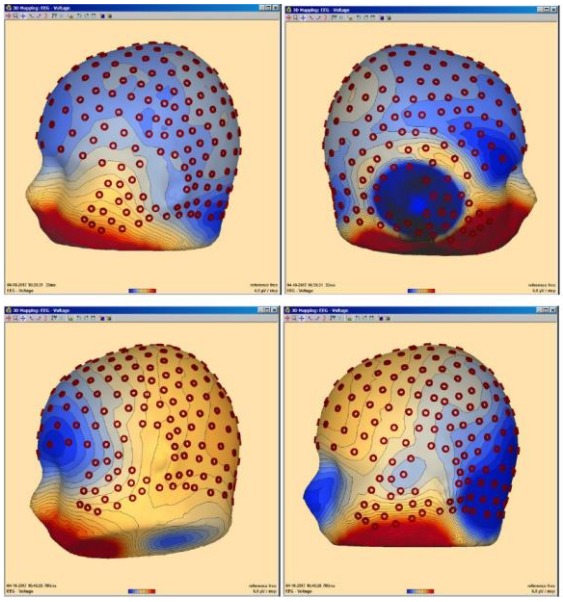


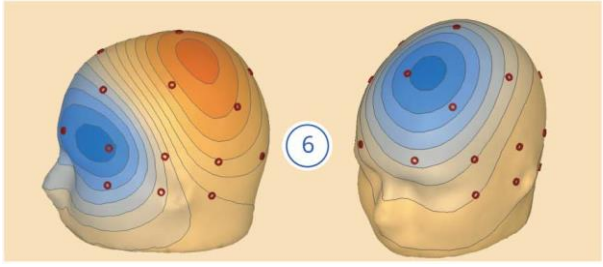
From the brain

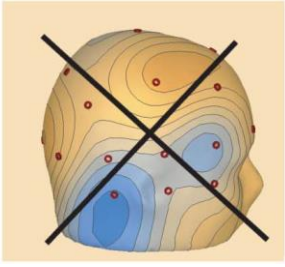


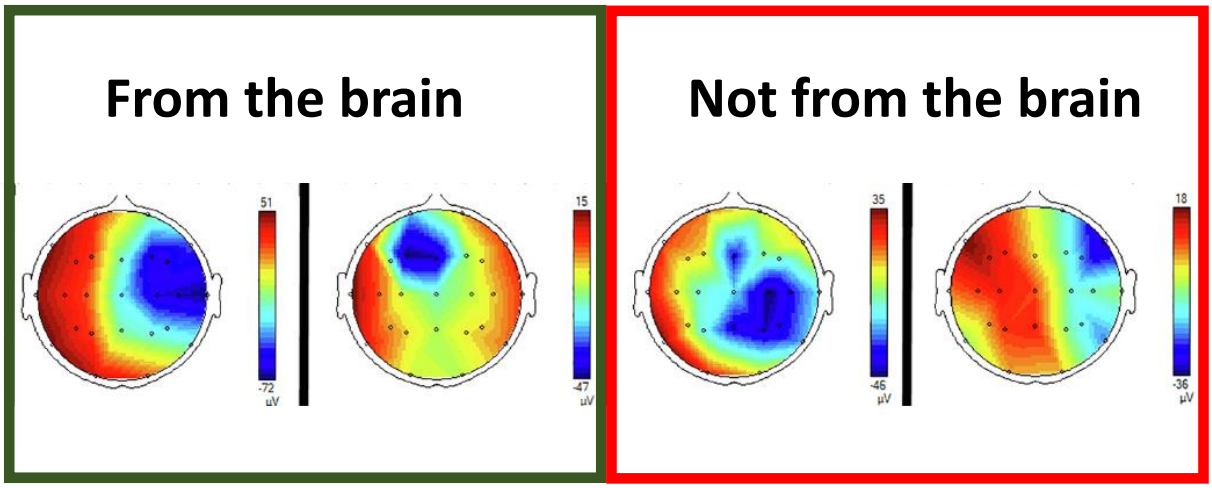


Not from the brain









Does this work?

How many criteria need to be there?

ARTICLE OPEN ACCESS CLASS OF EVIDENCE

Criteria for defining interictal epileptiform discharges in EEG

A clinical validation study

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Mustafa Aykut Kural, MD, Lene Duez, MD, PhD, Vibeke Sejer Hansen, MD, PhD, Pål G. Larsson, MD, DMSc, Stefan Rampp, MD, PhD, Reinhard Schulz, MD, Hatice Tankisi, MD, PhD, Richard Wennberg, MD, PhD, Bo M. Bibby, PhD, Michael Scherg, PhD, and Sándor Beniczky, MD, PhD

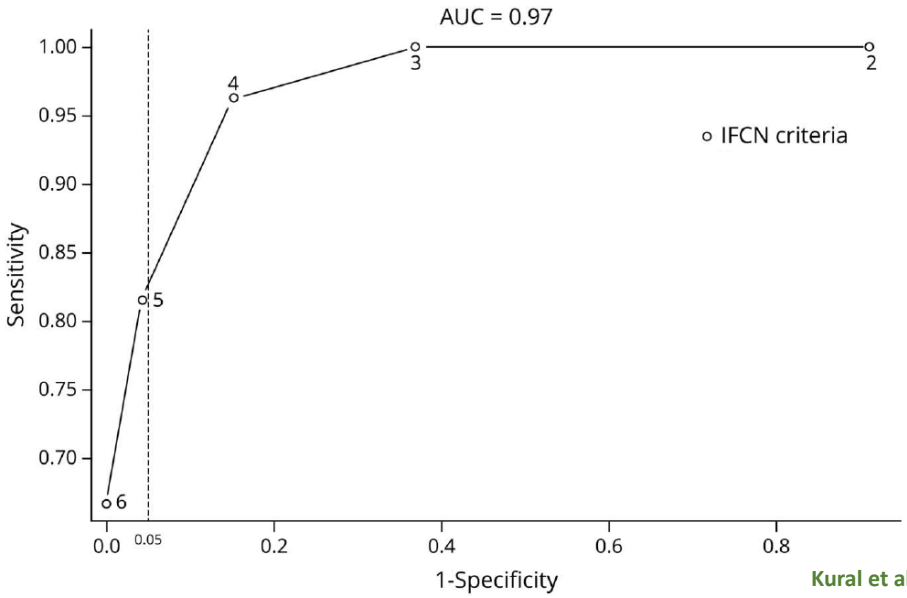
Neurology® 2020;94:e2139-e2147. doi:10.1212/WNL.0000000000009439

RELATED ARTICLE

Editorial
Epileptiform discharges: Are we still defining them?
Page 862

Unequivocal gold standard: Video-EEG recordings of the habitual clinical episodes

Figure 3 Receiver operating characteristic (ROC) curve



Kural et al., Neurology 2020

Table 1 Sensitivity, specificity, accuracy, and IRA of the methods for identifying IEDs in sensor space and source space compared with expert scorings

Method	Sensitivity % (95% CI)	Specificity % (95% CI)	Accuracy % (95% CI)	AC1 (95% CI)
IFCN criteria in sensor space				
Cutoff (no. of fulfilled criteria)				
≥2	100 (93.40–100)	8.70 (2.42–20.79)	58 (47.71–67.80)	0.83 (0.76–0.88)
≥3	100 (93.40–100)	63.04 (47.55–76.79)	83 (74.18–89.77)	0.64 (0.53–0.74)
≥4	96.30 (87.25–99.55)	84.78 (71.13–93.66)	91 (83.60–95.80)	0.60 (0.53–0.69)
≥5	81.48 (68.57–90.75)	95.65 (85.16–99.47)	88 (79.98–93.64)	0.49 (0.38–0.60)
=6	66.67 (52.53–78.91)	100 (92.29–100)	82 (73.05–88.97)	0.60 (0.50–0.70)
Source space	85.19 (72.88–93.38)	95.65 (85.16–99.47)	90 (82.38–95.10)	0.59 (0.51–0.68)

Abbreviations: AC1 = Gwet agreement coefficient; CI = confidence interval; IED = interictal epileptiform discharge; IFCN = International Federation of Clinical Neurophysiology; IRA = interrater agreement.

Is it just the number of criteria that matters?

Are all criteria equal?

or

Is there a specific combination of a few criteria that accurately identifies IEDs?

Clinical Neurophysiology 131 (2020) 2250–2254

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Optimized set of criteria for defining interictal epileptiform EEG discharges

Mustafa Aykut Kural [a], Hatice Tankisi [a], Lene Duez [a], Vibeke Sejer Hansen [a], Aparna Udupi [b], Richard Wennberg [c], Stefan Rampp [d], Pål G. Larsson [e], Reinhard Schulz [f], Sándor Beniczky [a,g,h,*]

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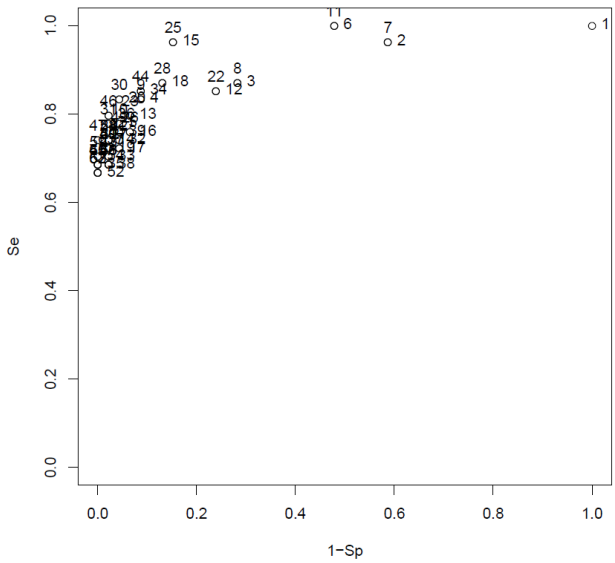
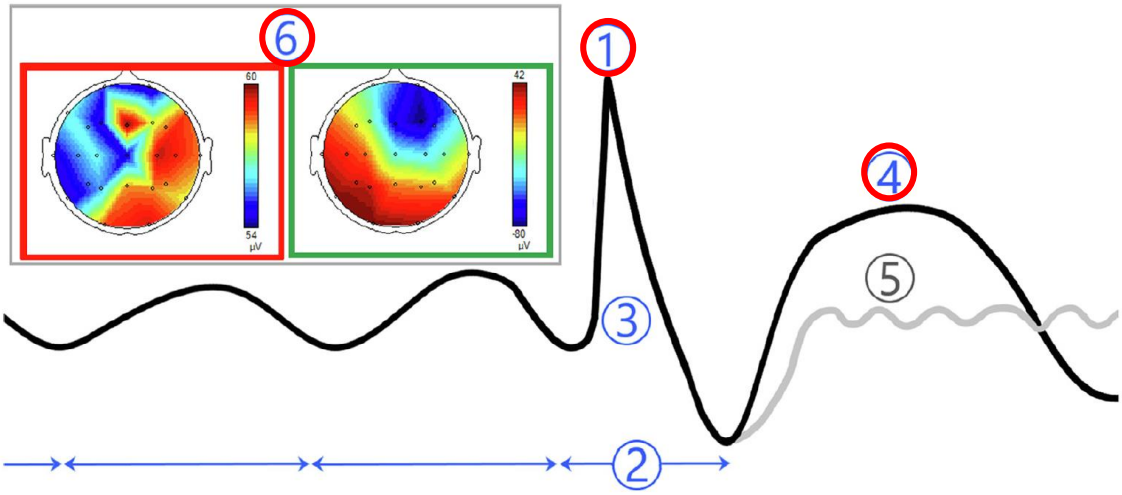
[e] Department of Neurosurgery, Rikshospitalet, Oslo University Hospital, Oslo, Norway
[f] Epilepsy Center Bethel, Mara Hospital, Bielefeld, Germany
[g] Department of Clinical Neurophysiology, Danish Epilepsy Centre, Dianalund, Denmark
[h] Department of Clinical Medicine, Aarhus University, Denmark

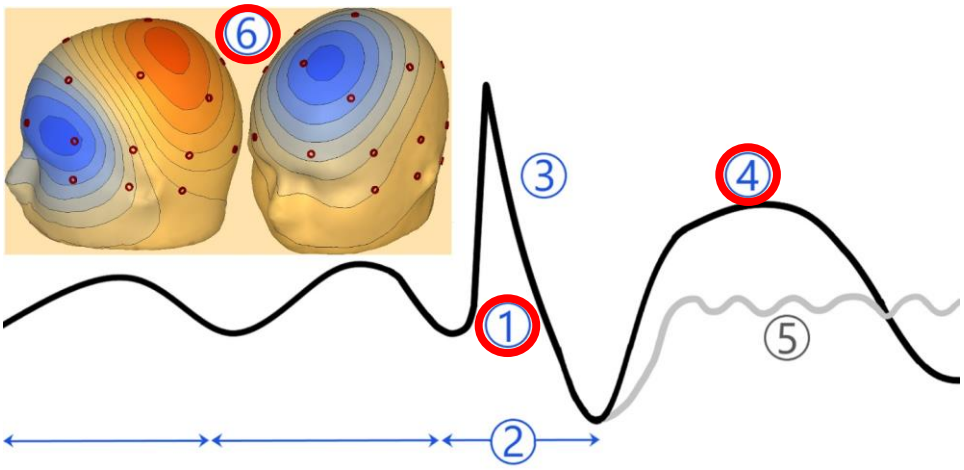
63 different combinations of the 6 criteria



		Sensitivity (95%CI)	Specificity (95%CI)	Accuracy (95%CI)	Agreement coefficient
Subjective expert scoring					
Combinations of IFCN criteria	1–2–4–6				
	1–2–4				
	1–4–6				



1+4+6
or:
at least 5 of any criteria-combination



How many times do you need to spot a spike in a recording?

ELSEVIER

Clinical Neurophysiology

Available online 5 May 2021

The influence of the abundance and morphology of epileptiform discharges on diagnostic accuracy: How many spikes you need to spot in an EEG

Mustafa Aykut Kural [a], Erisela Qerama [a], Birger Johnsen [a], Steffen Fuchs [a], Sándor Beniczky [a, b]

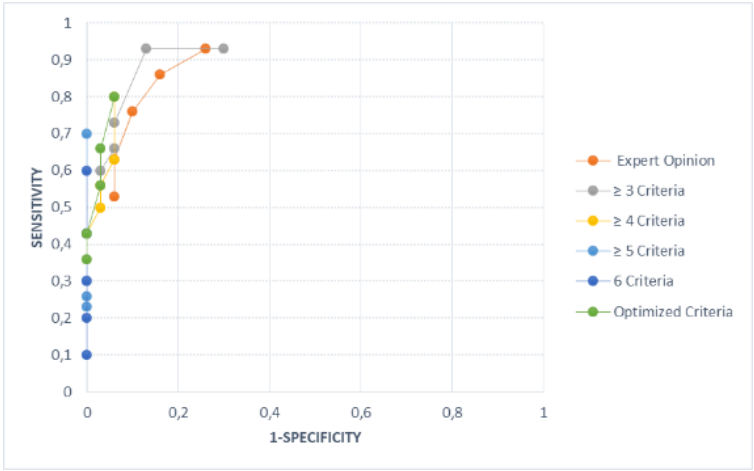
https://doi.org/10.1016/j.clinph.2021.03.045

How many times do you need to spot a spike in a recording?

- IFCN criteria: a single discharge
- That is NOT the clinical scenario (20-30 minutes EEG recording)

- Less clear-cut spikes? Are they good enough if they occur many times?
  → Only few criteria present, but many discharges in the recording?

- 60 EEGs of 20 minutes: 30 epilepsy + 30 non-epileptic paroxysmal episodes
- 3 neurologists; majority consensus
- Gold standard = EMU



Sets of criteria	AUC
Expert Opinion (non-restricted)	0.897
≥ 3 IFCN Criteria	0.909
≥ 4 IFCN Criteria	0.869
≥ 5 IFCN Criteria	0.850
= 6 IFCN Criteria	0.715
Optimizing Criteria (#1-4-6)	0.883

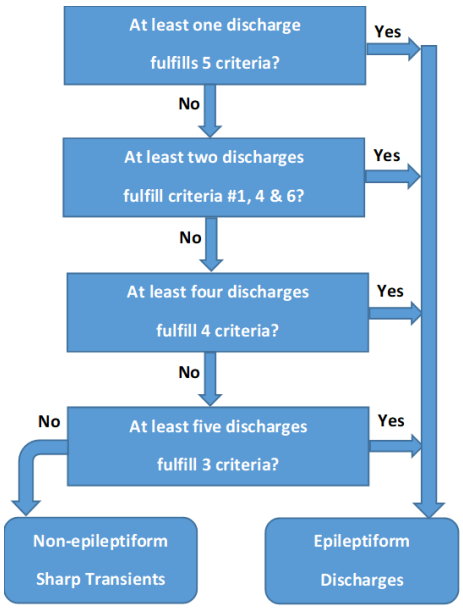
CRITERIA	Number of discharges	SENSITIVITY	SPECIFICITY	ACCURACY
Expert Opinion (non-restricted)	**≥1**	93.33%	73.33%	83.33%
	≥2	86.67%	83.33%	85.00%
	≥3	76.67%	90.00%	83.33%
	≥4	63.30%	93.33%	78.33%
	≥5	53.33%	93.33%	73.33%
≥3 IFCN criteria	**≥1**	93.33%	70.00%	81.67%
	≥2	93.33%	86.67%	90.00%
	≥3	73.33%	93.33%	83.33%
	≥4	66.67%	93.33%	80.00%
	≥5	**60.00%**	**96.67%**	78.33%
≥4 IFCN criteria	**≥1**	80.00%	93.33%	86.67%
	≥2	63.3%	93.33%	78.33%
	≥3	56.6%	93.33%	75.00%
	≥4	**50.00%**	**96.67%**	73.33%
	≥5	43.33%	96.67%	70.00%
≥5 IFCN criteria	**≥1**	**70.00%**	**100.00%**	85.00%
	≥2	43.33%	100.00%	71.67%
	≥3	30.00%	100.00%	65.00%
	≥4	26.67%	100.00%	63.33%
	≥5	23.33%	100.00%	61.67%
6 IFCN criteria	**≥1**	**43.33%**	**100.00%**	71.67%
	≥2	20.00%	100.00%	60.00%
	≥3	10.00%	100.00%	55.00%
	≥4	6.67%	100.00%	53.33%
	≥5	3.33%	100.00%	51.67%
Set of 3 Optimized Criteria	**≥1**	80.00%	93.33%	86.67%
	≥2	**66.67%**	**96.67%**	81.67%
	≥3	56.67%	96.67%	76.67%
	≥4	43.33%	100.00%	71.67%
	≥5	36.67%	100.00%	68.33%

Combination of Criteria-sets	Sensitivity	Specificity	Accuracy
1 IED fulfilling 5-criteria OR 2 IEDs fulfilling the Optimized Criteria	73.33%	96.67%	85.00%
1 IED fulfilling 5-criteria OR 4 IEDs fulfilling 4 criteria	70.00%	96.67%	83.33%
1 IED fulfilling 5-criteria OR 5 IEDs fulfilling 3-criteria	76.67%	96.67%	86.67%
1 IED fulfilling 5-criteria OR 2 IEDs fulfilling Optimized Criteria OR 4 IEDs fulfilling 4-criteria OR 5 IEDs 3-criteria	80.00%	96.67%	88.33%

How many criteria need to be there in a routine EEG?

To achieve a specificity >95% (avoid over-reading)

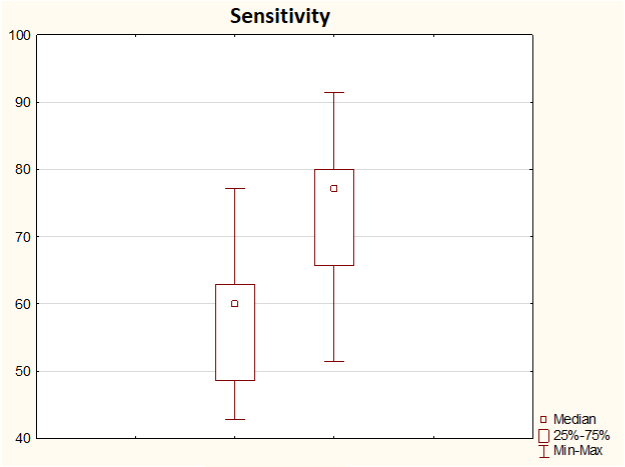
- ≥ 5 criteria: one is enough
- Criteria 1-4-6: ≥ twice
- 4 criteria (any): ≥ 4 times
- 3 criteria (any): ≥ 5 times

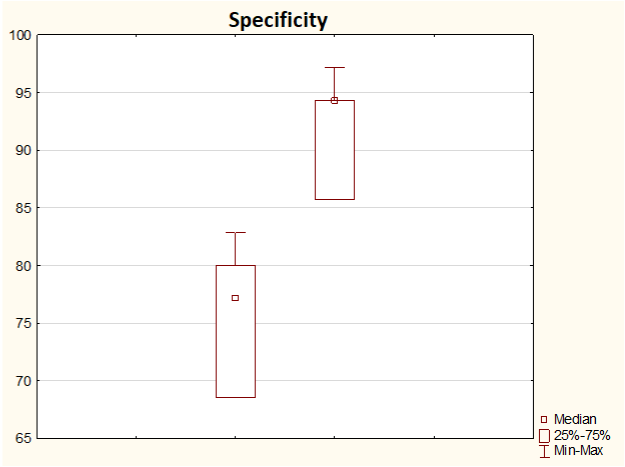


Kural et al., Clinical Neurophysiology 2020

You can learn it!

Seven trainees: before / after this teaching session

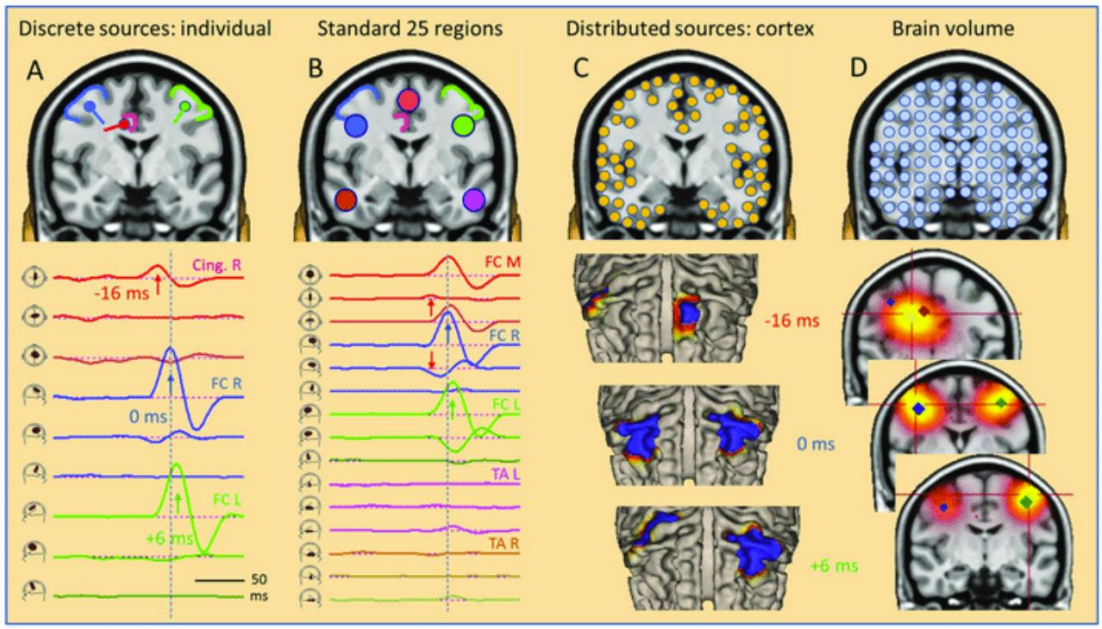




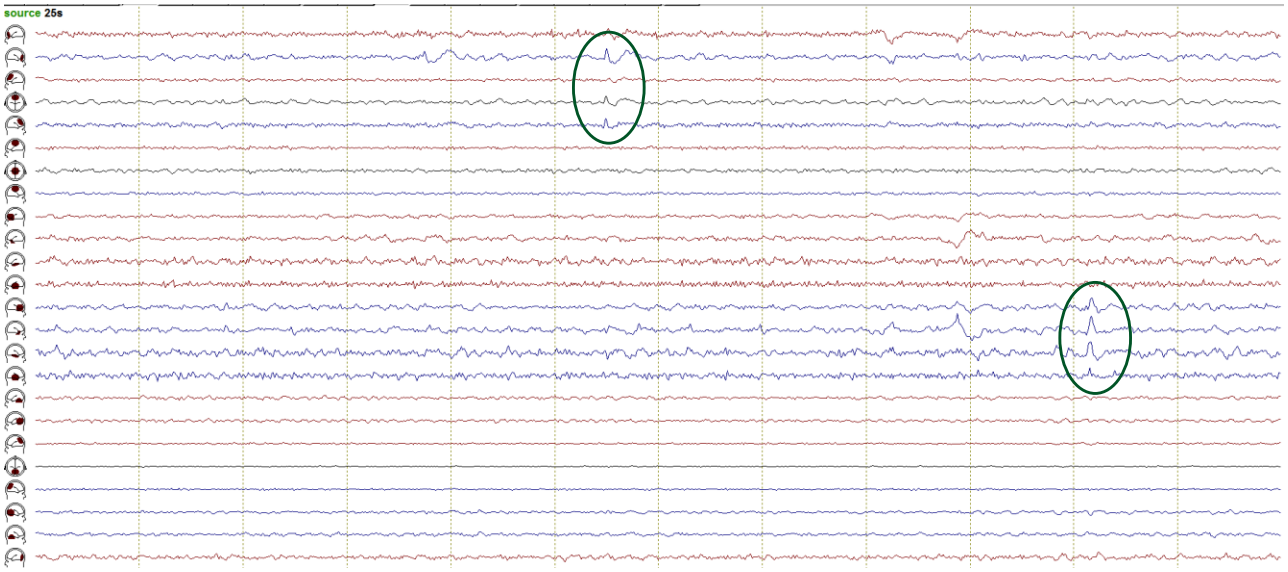
IRA: fair (k=0.31) → high-moderate (k=0.56)

Kural et al., Epileptic Disorders 2021

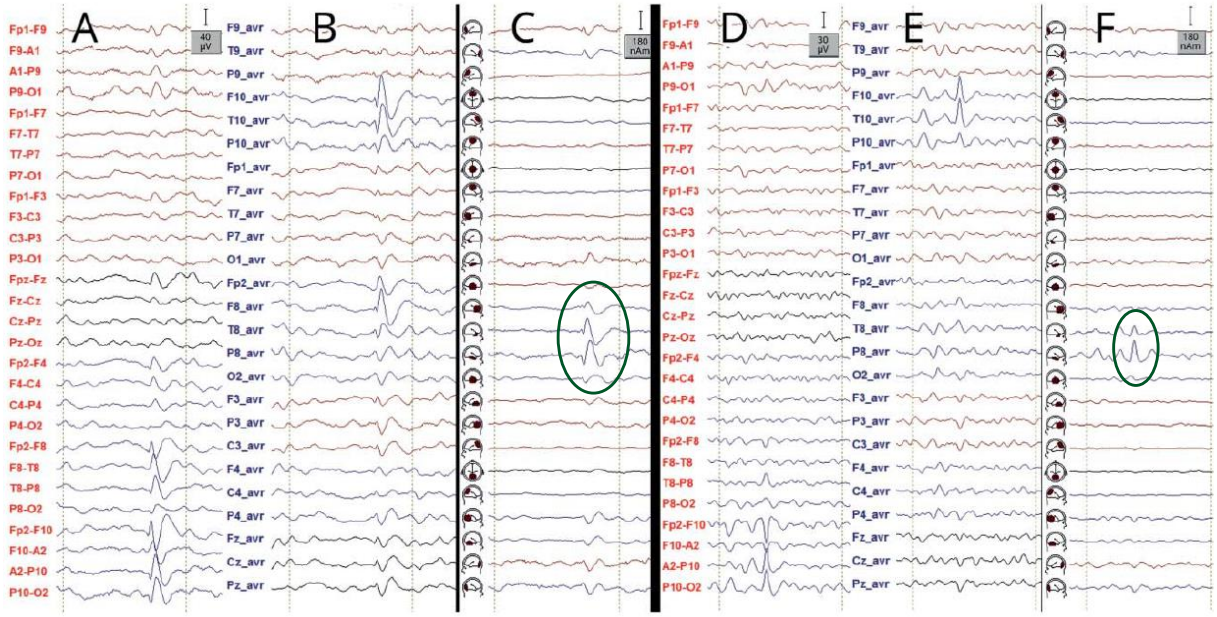
Reading EEG in source space



EDs – in source space



EDs – in source space



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=6	66.67 (52.53–78.91)	100 (92.29–100)	82 (73.05–88.97)	0.60 (0.50–0.70)
Source space	85.19 (72.88–93.38)	95.65 (85.16–99.47)	90 (82.38–95.10)	0.59 (0.51–0.68)

Abbreviations: AC1 = Gwet agreement coefficient; CI = confidence interval; IED = interictal epileptiform discharge; IFCN = International Federation of Clinical Neurophysiology; IRA = interrater agreement.

Who / what finds the spikes?

- Algorithms & artificial intelligence

  vs.

- Human experts

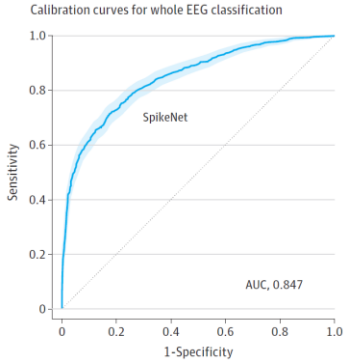
Research

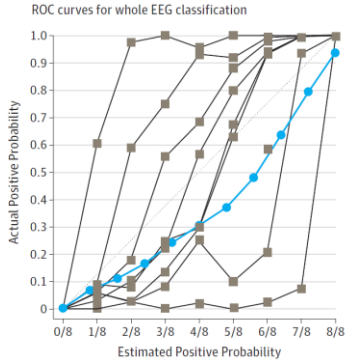
JAMA Neurol. doi:10.1001/jamaneurol.2019.3485
Published online October 21, 2019.

JAMA Neurology | Brief Report

Development of Expert-Level Automated Detection of Epileptiform Discharges During Electroencephalogram Interpretation

Jin Jing, PhD; Haoqi Sun, PhD; Jennifer A. Kim, MD, PhD; Aline Herlopian, MD; Ioannis Karakis, MD, PhD; Marcus Ng, MD; Jonathan J. Halford, MD; Douglas Maus, MD, PhD; Fonda Chan, MD; Marjan Dolatshahi, MD; Carlos Muniz, MD; Catherine Chu, MD; Valeria Sacca, PhD; Jay Pathmanathan, MD; Wendong Ge, PhD; Justin Dauwels, PhD; Alice Lam, MD, PhD; Andrew J. Cole, MD; Sydney S. Cash, MD, PhD; M. Brandon Westover, MD, PhD





Clinical Neurophysiology 131 (2020) 1174–1179

Contents lists available at ScienceDirect

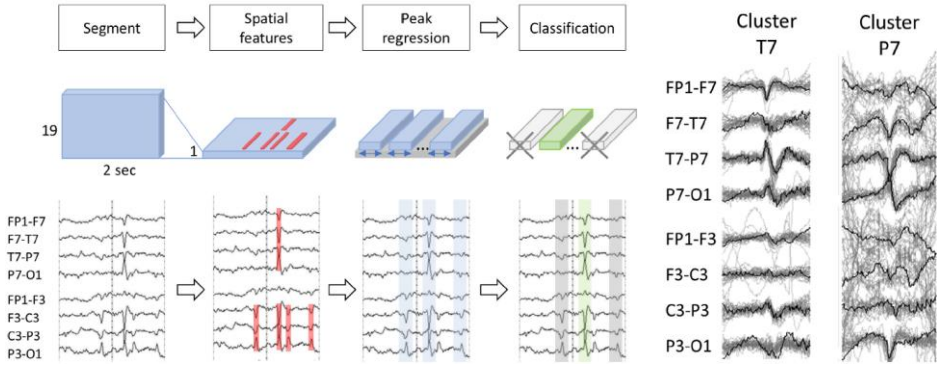
Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

An artificial intelligence-based EEG algorithm for detection of epileptiform EEG discharges: Validation against the diagnostic gold standard

Franz Fürbass [a], Mustafa Aykut Kural [b], Gerhard Gritsch [a], Manfred Hartmann [a], Tilmann Kluge [a], Sándor Beniczky [b,c,*]

[a] Center for Health & Bioresources, AIT Austrian Institute of Technology GmbH, Vienna, Austria
[b] Department of Clinical Neurophysiology, Aarhus University Hospital and Department of Clinical Medicine, Aarhus University, Aarhus, Denmark
[c] Department of Clinical Neurophysiology, Danish Epilepsy Centre, Dianalund, Denmark



Challenges & possible solutions

- Algorithms: at high sensitivity – too low specificity.

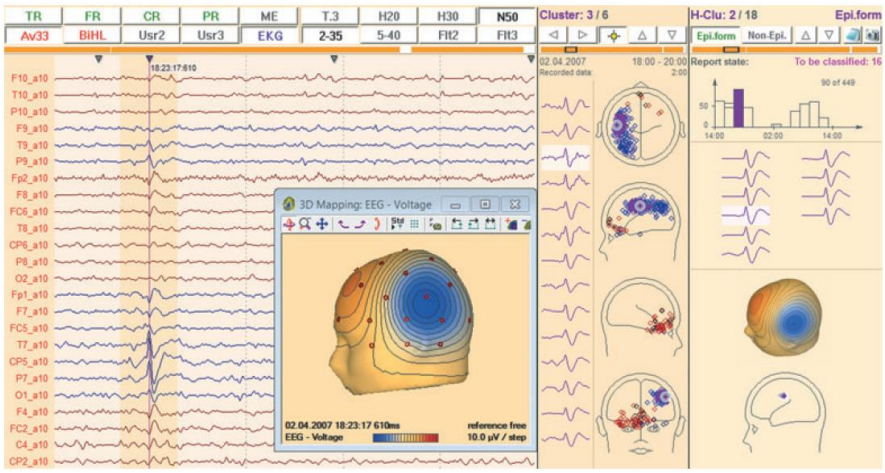
- Hybrid systems
  - Algorithms: scans the whole EEG → high sensitivity
  - Algorithm: groups detections into clusters → save time for evaluation
  - Human expert: reviews the clusters → high specificity

Epilepsia, 53(7):1196–1204, 2012
doi: 10.1111/j.1528-1167.2012.03503.x

FULL-LENGTH ORIGINAL RESEARCH

Fast evaluation of interictal spikes in long-term EEG by hyper-clustering

*Michael Scherg, *Nicole Ille, *Dieter Weckesser, *Arndt Ebert, *†Andrea Ostendorf, ‡§Tobias Boppel, ‡Susanne Schubert, ¶#Pål G. Larsson, #Oliver Henning, and ‡**Thomas Bast



91% of the visually identified spikes

Received: 10 January 2022 | Revised: 17 February 2022 | Accepted: 17 February 2022

DOI: 10.1111/epi.17206

Epilepsia®

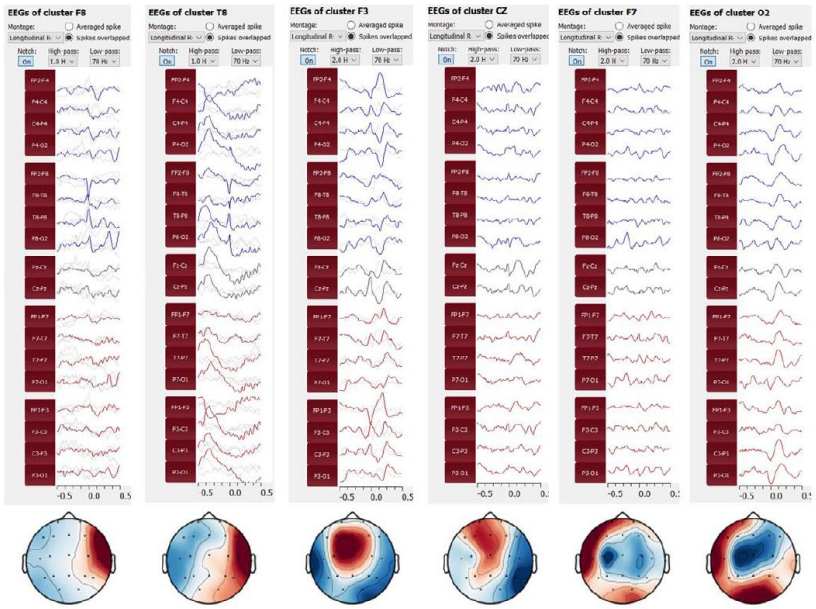
RESEARCH ARTICLE

Accurate identification of EEG recordings with interictal epileptiform discharges using a hybrid approach: Artificial intelligence supervised by human experts

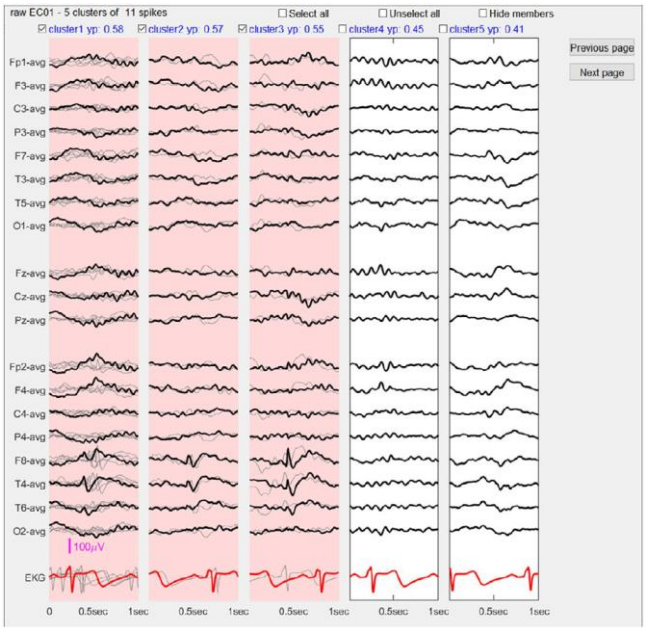
Mustafa Aykut Kural[1,2,3] | Jin Jing[4] | Franz Fürbass[5] | Hannes Perko[5] | Erisela Qerama[2,3] | Birger Johnsen[2,3] | Steffen Fuchs[2] | M. Brandon Westover[4] | Sándor Beniczky[1,2,3]

- Head-to-head comparison of 3 AI spike-detectors: 20 min. routine-EEG
- Diagnostic gold standard: habitual seizures recorded in LTM
- Fully automated
- Hybrid: evaluation of the clustered spikes , by exerts using IFCN criteria

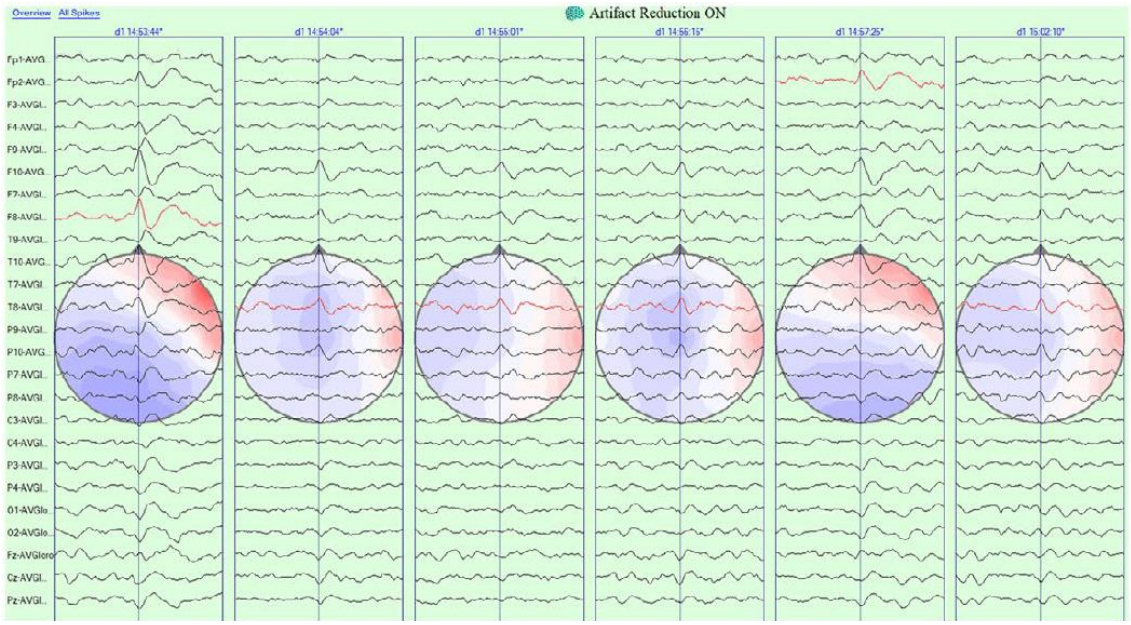
Encevis

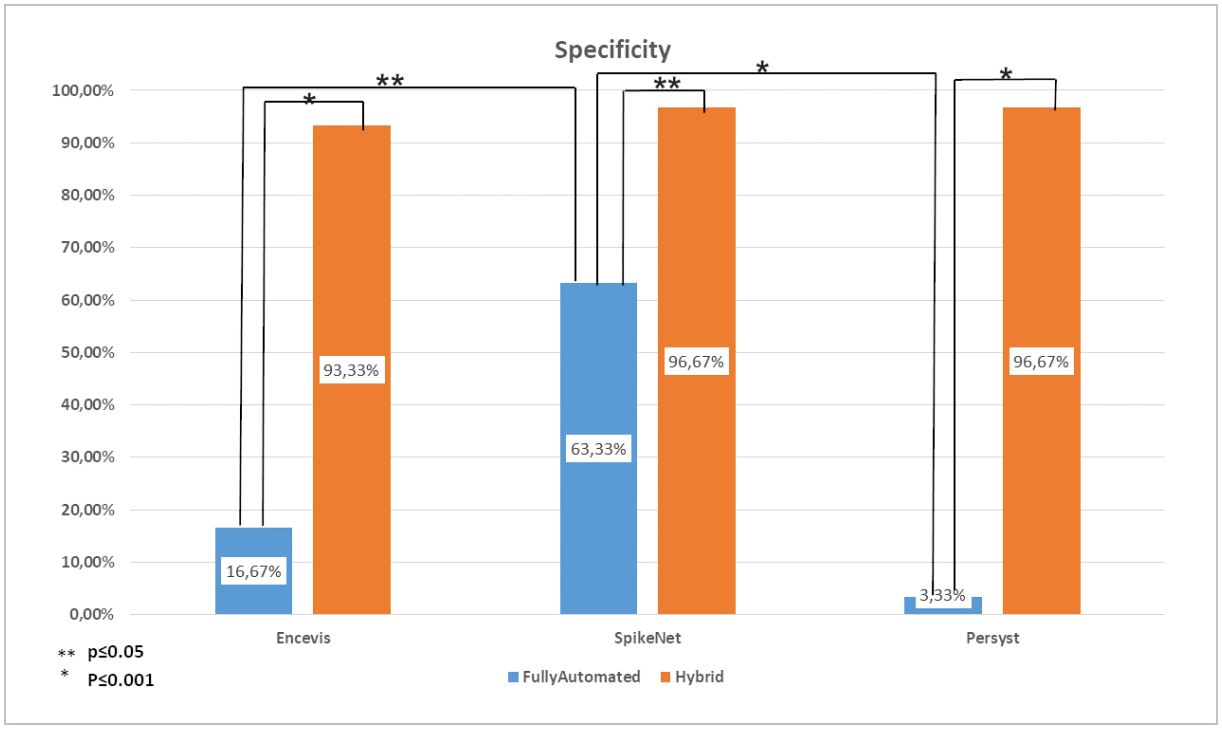


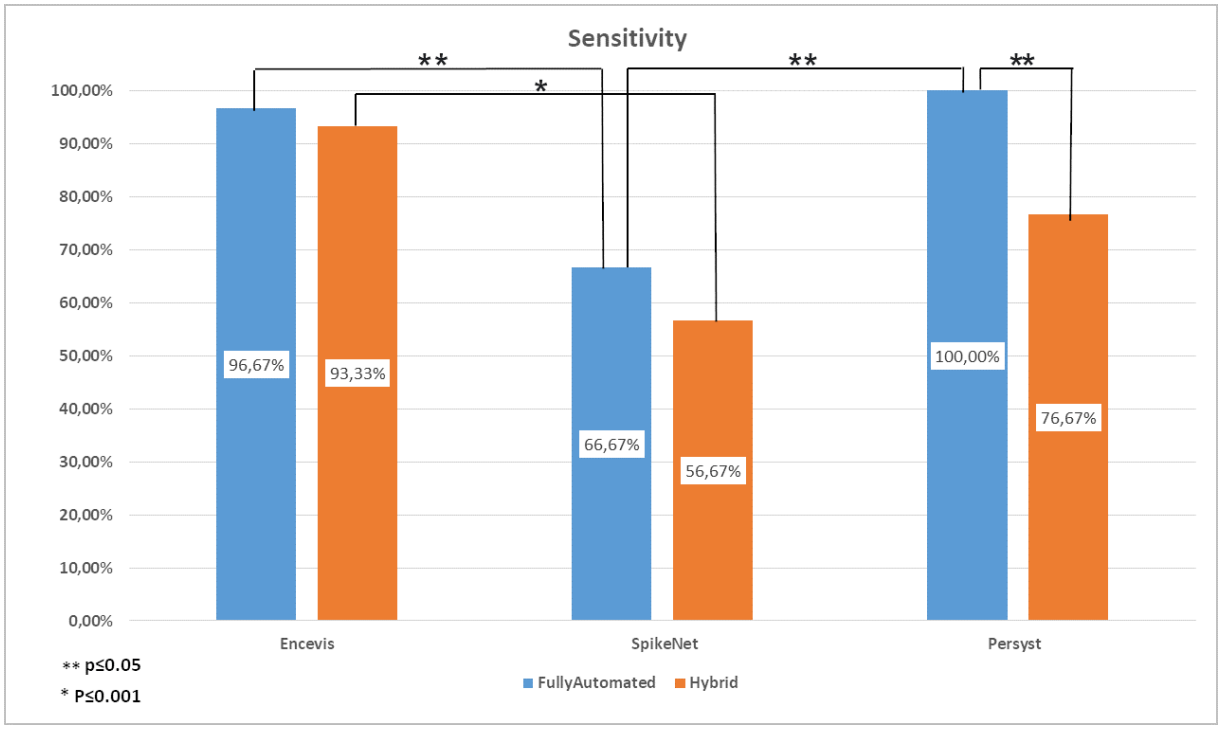
Spikenet



Persyst




Specificity
100,00%
90,00%
80,00%
70,00%
60,00%
50,00%
40,00%
30,00%
20,00%
10,00%
0,00%
**
*
**
*
*
16,67%
93,33%
63,33%
96,67%
3,33%
96,67%
Encevis
SpikeNet
Persyst
** p≤0.05
* P≤0.001
FullyAutomated
Hybrid

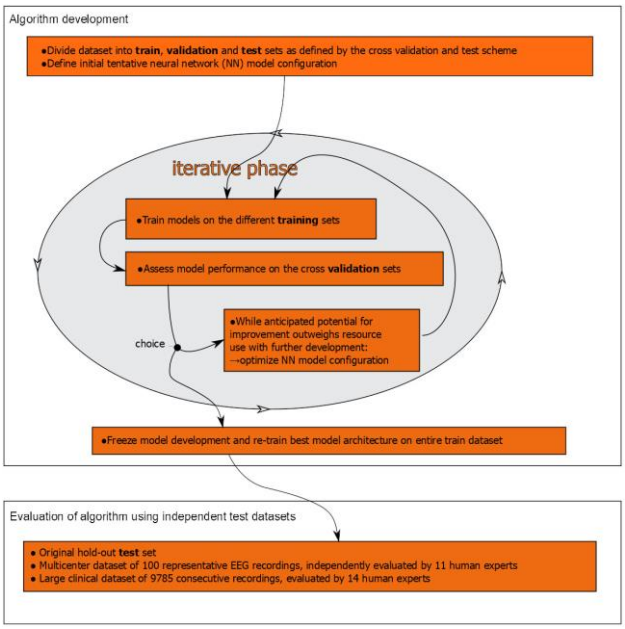

Sensitivity
100,00%
90,00%
80,00%
70,00%
60,00%
50,00%
40,00%
30,00%
20,00%
10,00%
0,00%
**
*
**
**
96,67%
93,33%
66,67%
56,67%
100,00%
76,67%
Encevis
SpikeNet
Persyst
** p≤0.05
* P≤0.001
FullyAutomated
Hybrid

Reduced time-consumption!

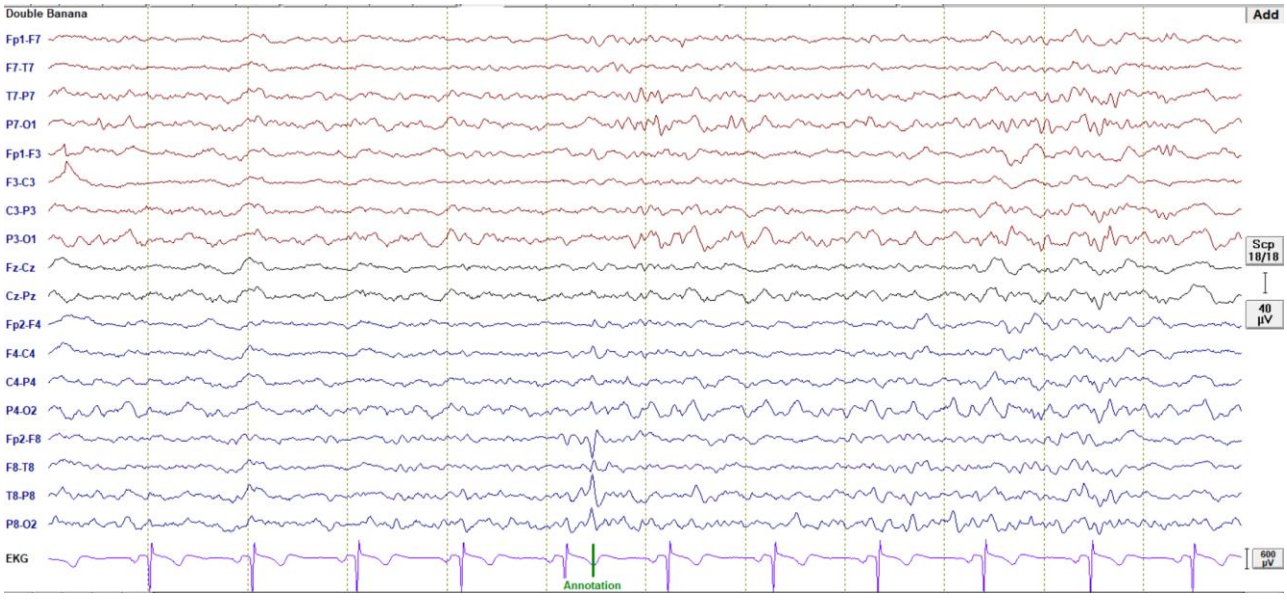
- by 26% – 91% using the hybrid approach
- $p < 0.001$

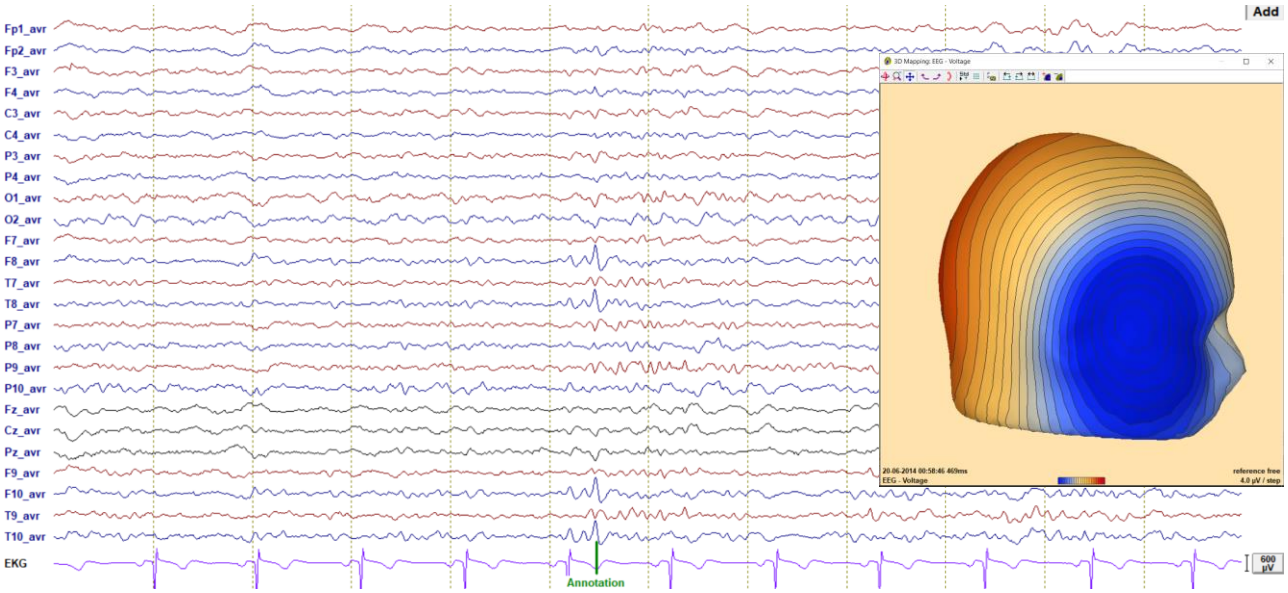
Fully automated EEG reading: routine clinical EEGs

- AI (CNN) – autoSCORE
- Development:
  - 30k EEGs – highly annotated in SCORE
- Clinical Validation
  - Independent dataset: 10k EEGs
- Output:
  - Normal
  - Abnormal:
    - Epileptiform-Focal
    - Epileptiform-Generalized
    - Slowing-Diffuse
    - Slowing-Focal

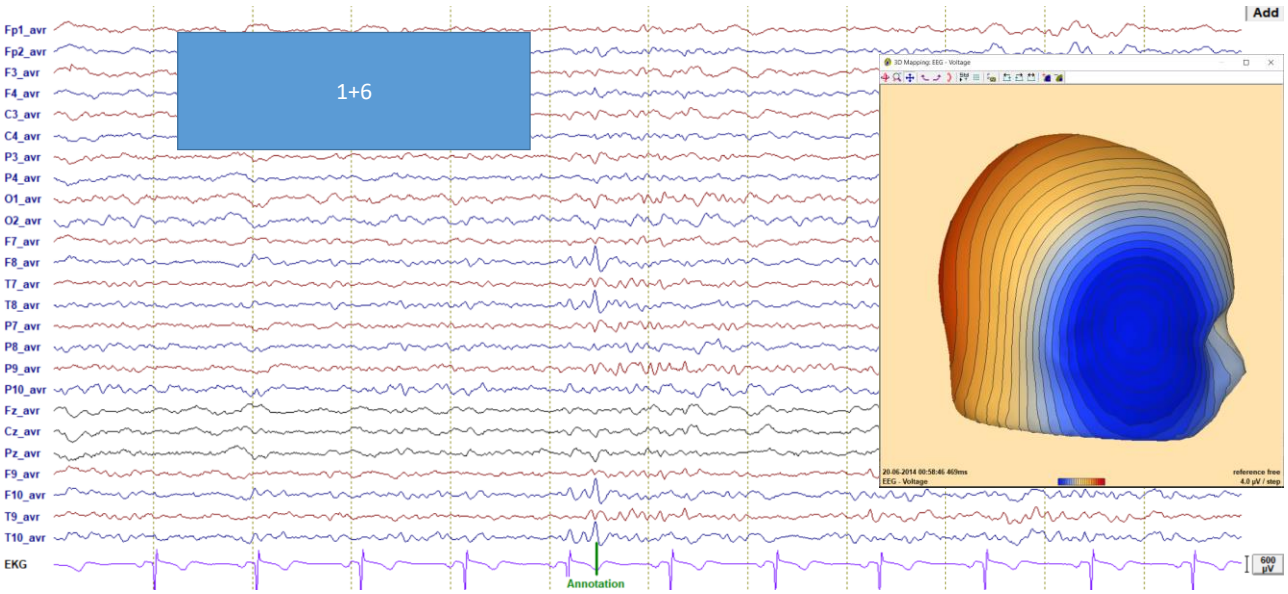


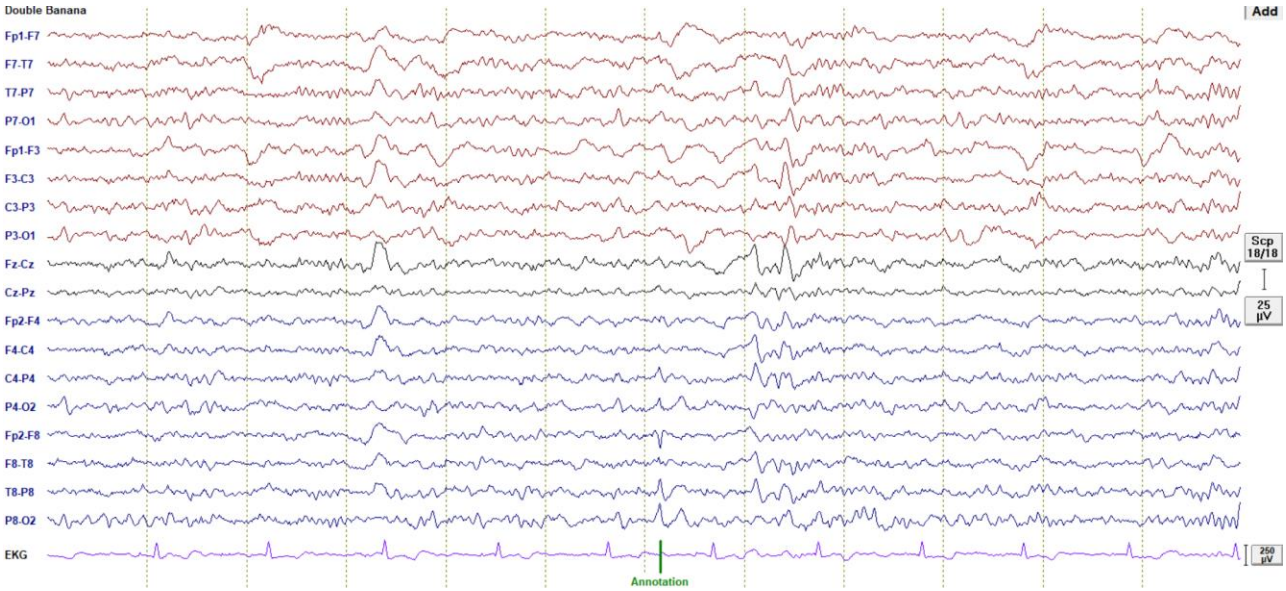

READY FOR A
QUIZ?

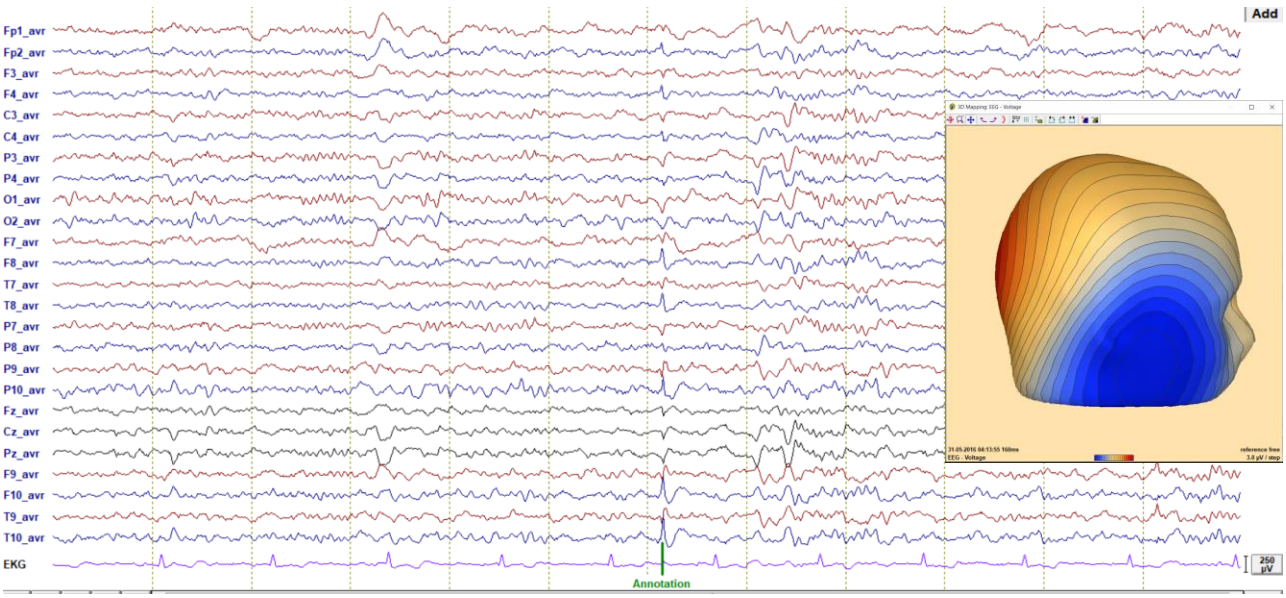

Double Banana
Add
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
Fz-Cz
Cz-Pz
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2
EKG
Annotation
Scp 18/18
40 µV
600 µV



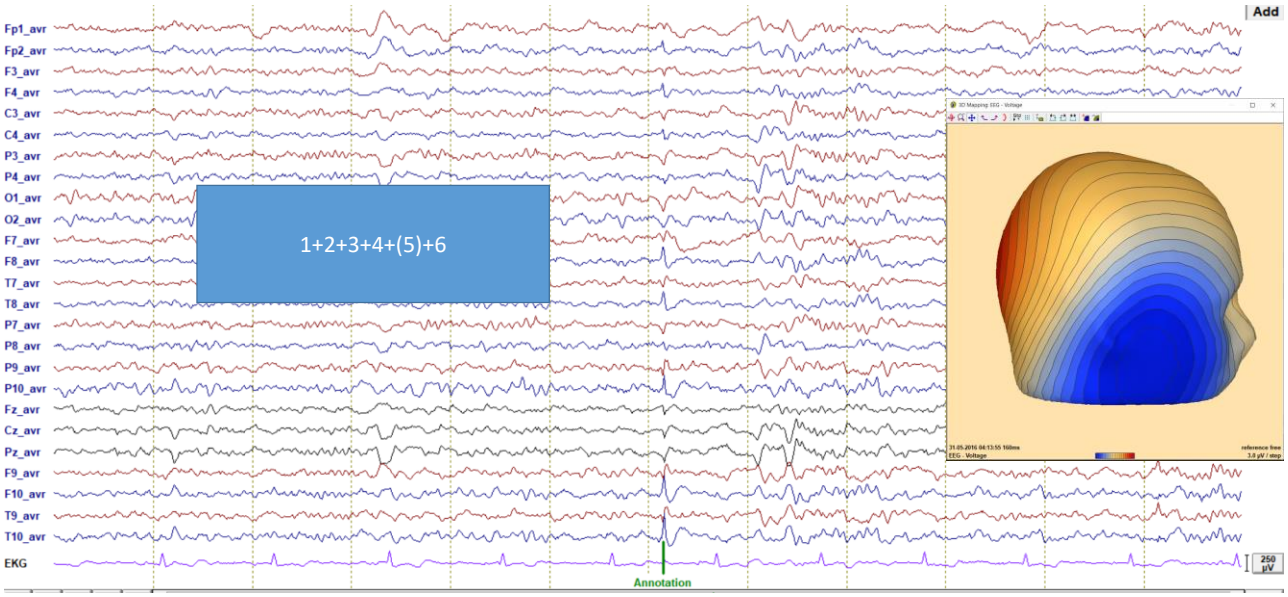
Normal sharp transient!

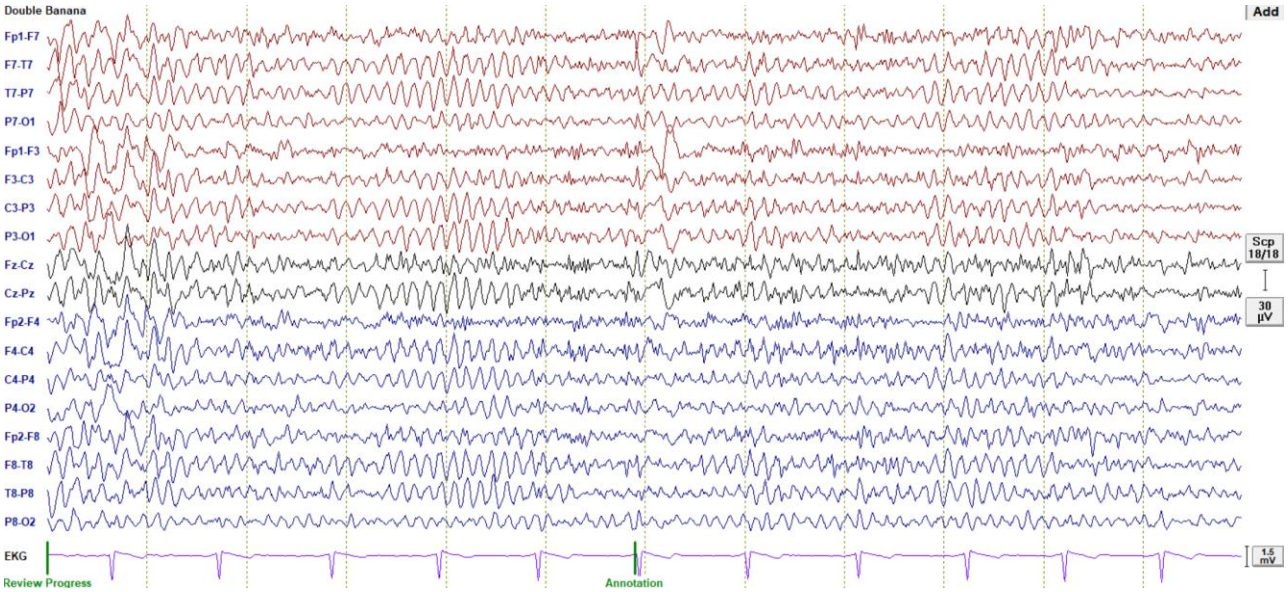


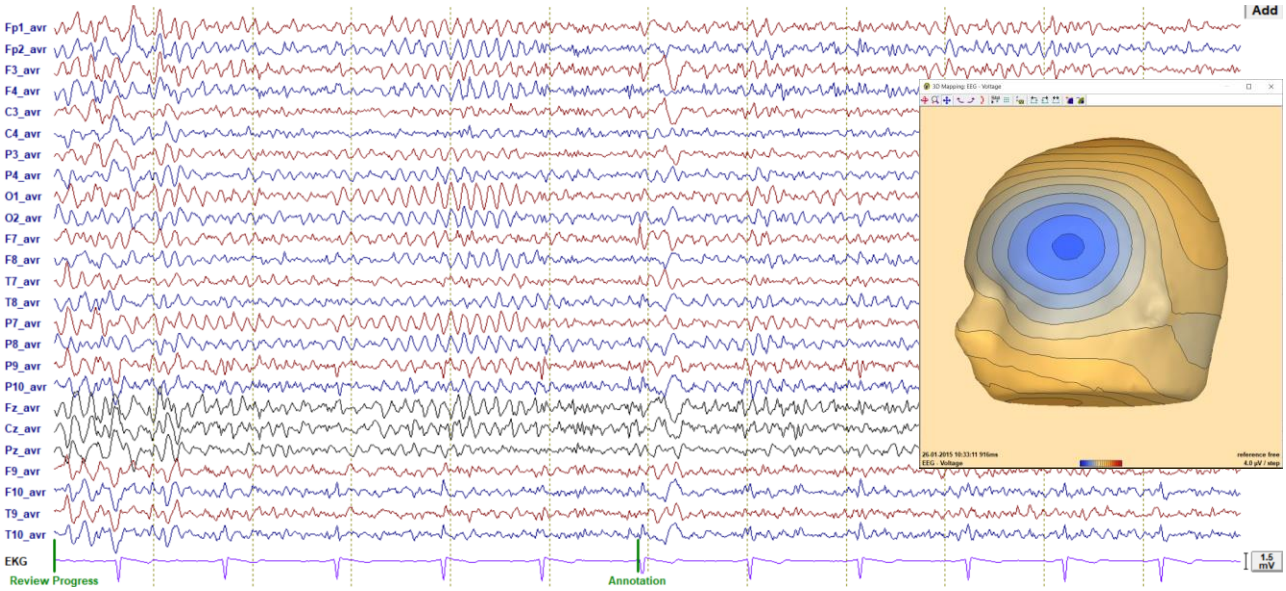

Double Banana
Add
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
Fz-Cz
Cz-Pz
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2
EKG
Scp 18/18
25 µV
250 µV
Annotation


Add
Fp1_avr
Fp2_avr
F3_avr
F4_avr
C3_avr
C4_avr
P3_avr
P4_avr
O1_avr
O2_avr
F7_avr
F8_avr
T7_avr
T8_avr
P7_avr
P8_avr
P9_avr
P10_avr
Fz_avr
Cz_avr
Pz_avr
F9_avr
F10_avr
T9_avr
T10_avr
EKG
250 µV
Annotation

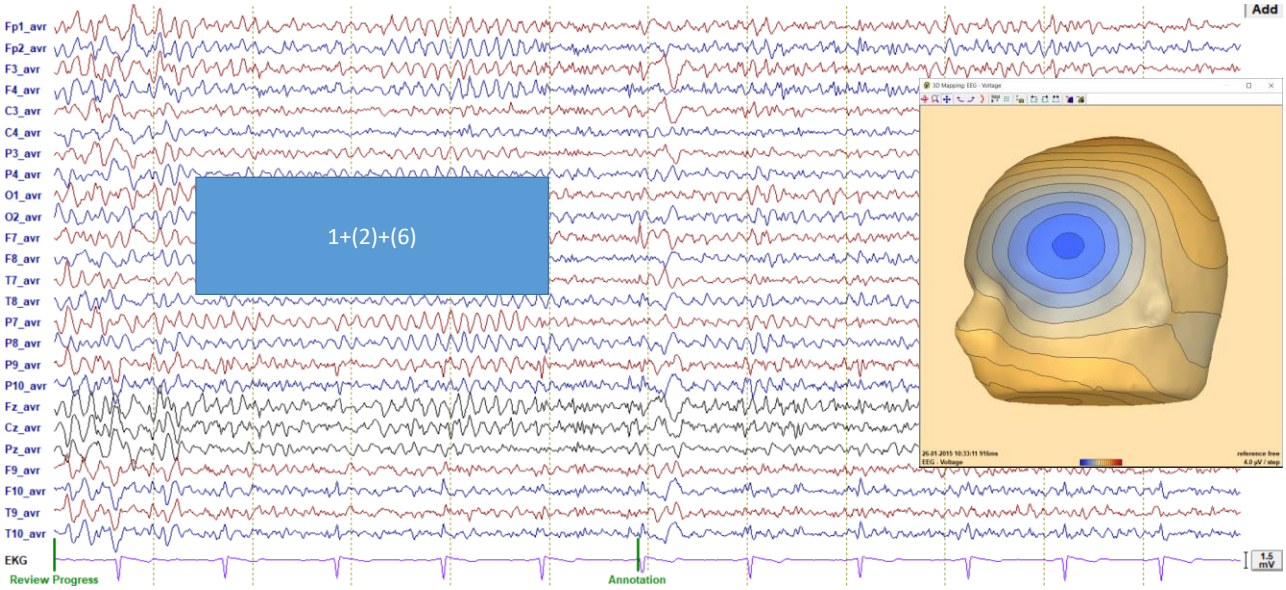
IED

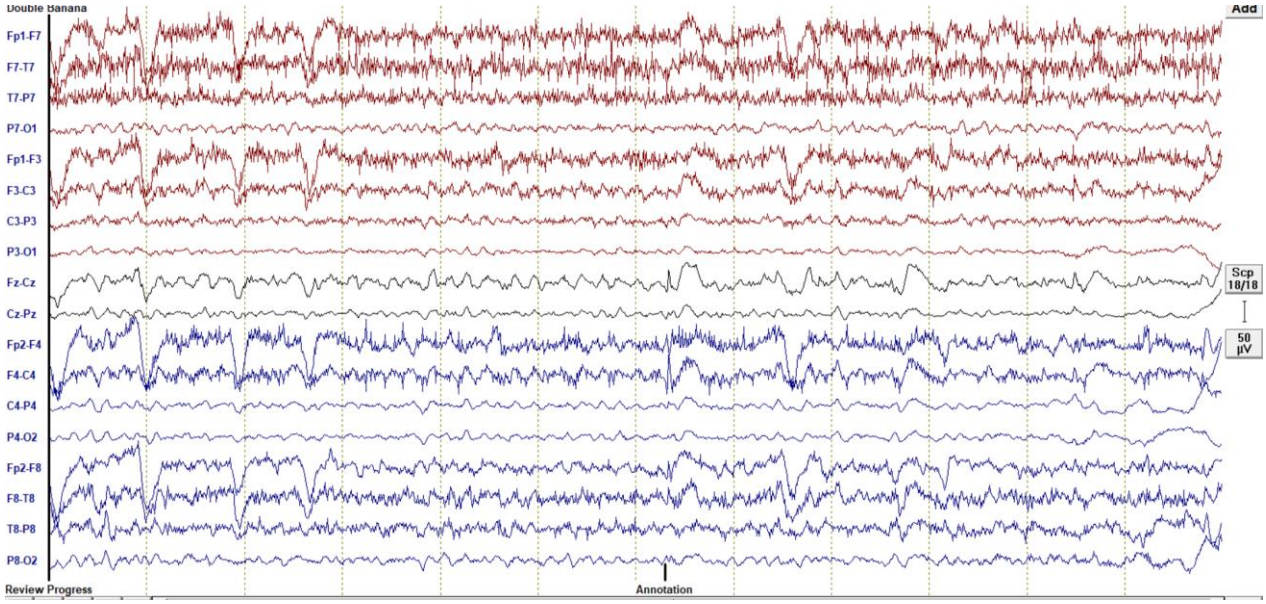

Add
Fp1_avr
Fp2_avr
F3_avr
F4_avr
C3_avr
C4_avr
P3_avr
P4_avr
O1_avr
O2_avr
F7_avr
F8_avr
T7_avr
T8_avr
P7_avr
P8_avr
P9_avr
P10_avr
Fz_avr
Cz_avr
Pz_avr
F9_avr
F10_avr
T9_avr
T10_avr
EKG
1+2+3+4+(5)+6
250 µV
Annotation

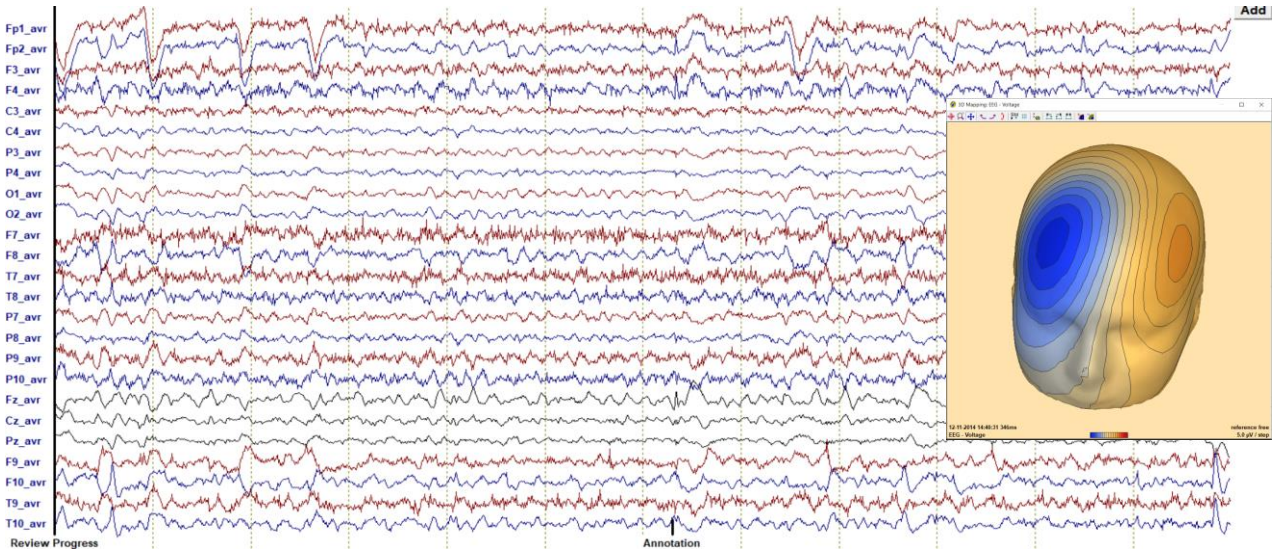

Double Banana
Add
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
Fz-Cz
Cz-Pz
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2
EKG
Scp 18/18
30 µV
1.5 mV
Review Progress
Annotation



Normal sharp transient




Double Banana
Add
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
Fz-Cz
Cz-Pz
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2
Scp 18/18
50 µV
Review Progress
Annotation


Add
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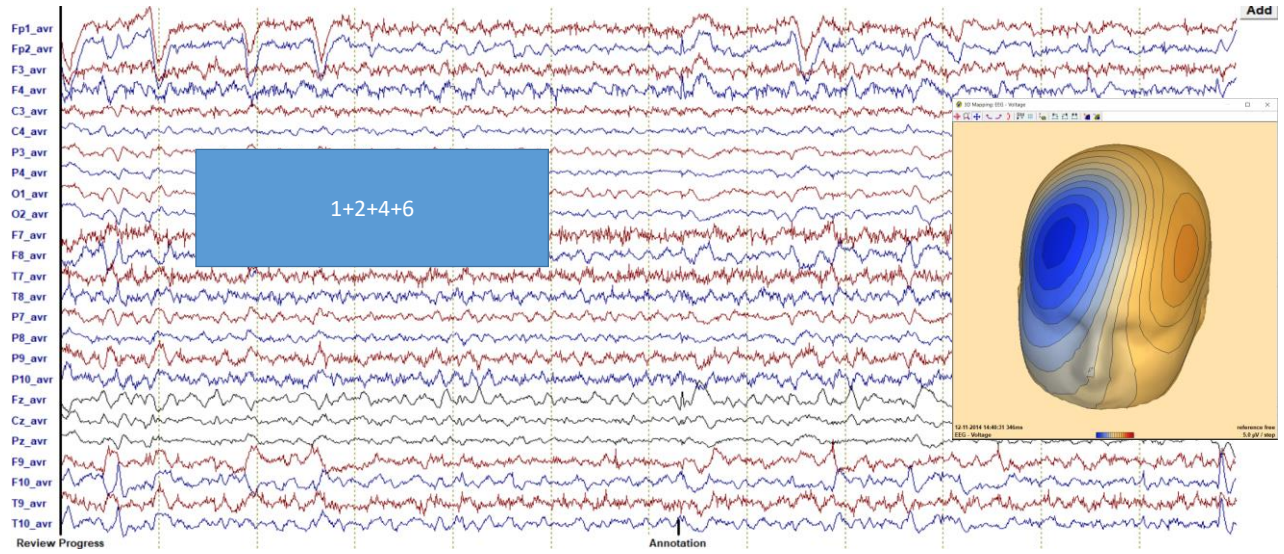
F3_avr
F4_avr
C3_avr
C4_avr
P3_avr
P4_avr
O1_avr
O2_avr
F7_avr
F8_avr
T7_avr
T8_avr
P7_avr
P8_avr
P9_avr
P10_avr
Fz_avr
Cz_avr
Pz_avr
F9_avr
F10_avr
T9_avr
T10_avr
Review Progress
Annotation

IED


Add
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C3_avr
C4_avr
P3_avr
P4_avr
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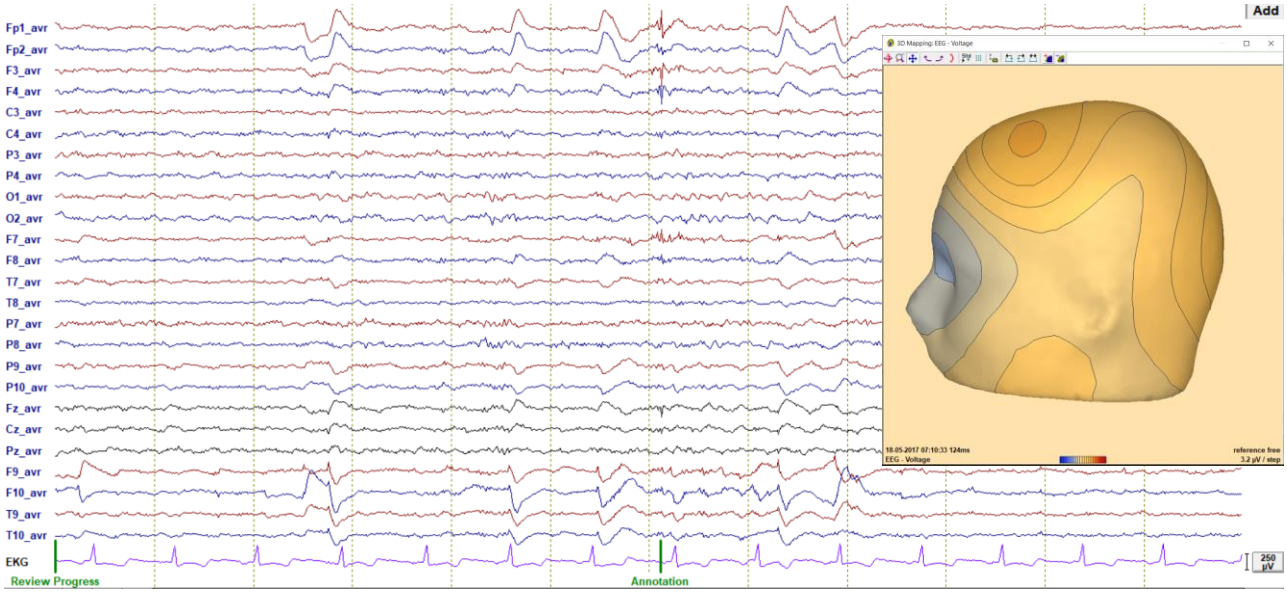
O2_avr
F7_avr
F8_avr
T7_avr
T8_avr
P7_avr
P8_avr
P9_avr
P10_avr
Fz_avr
Cz_avr
Pz_avr
F9_avr
F10_avr
T9_avr
T10_avr
1+2+4+6
Review Progress
Annotation


Double Banana
Add
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
Fz-Cz
Cz-Pz
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2
EKG
Scp 18/18
50 µV
250 µV
Review Progress
Annotation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Fp2_avr
F3_avr
F4_avr
C3_avr
C4_avr
P3_avr
P4_avr
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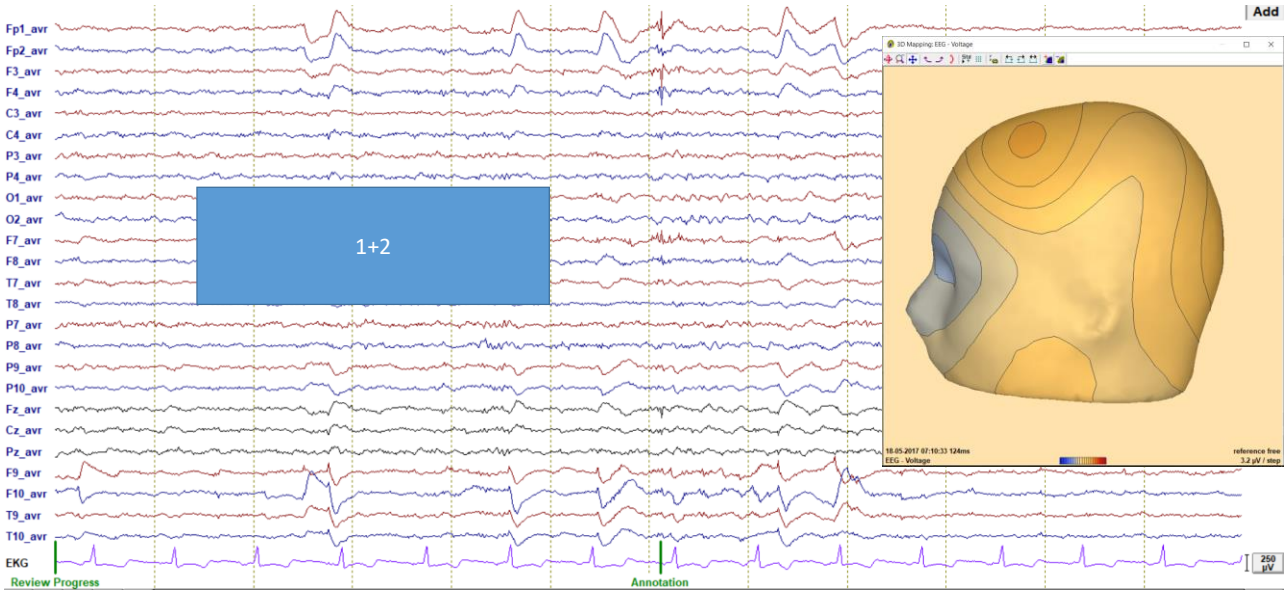
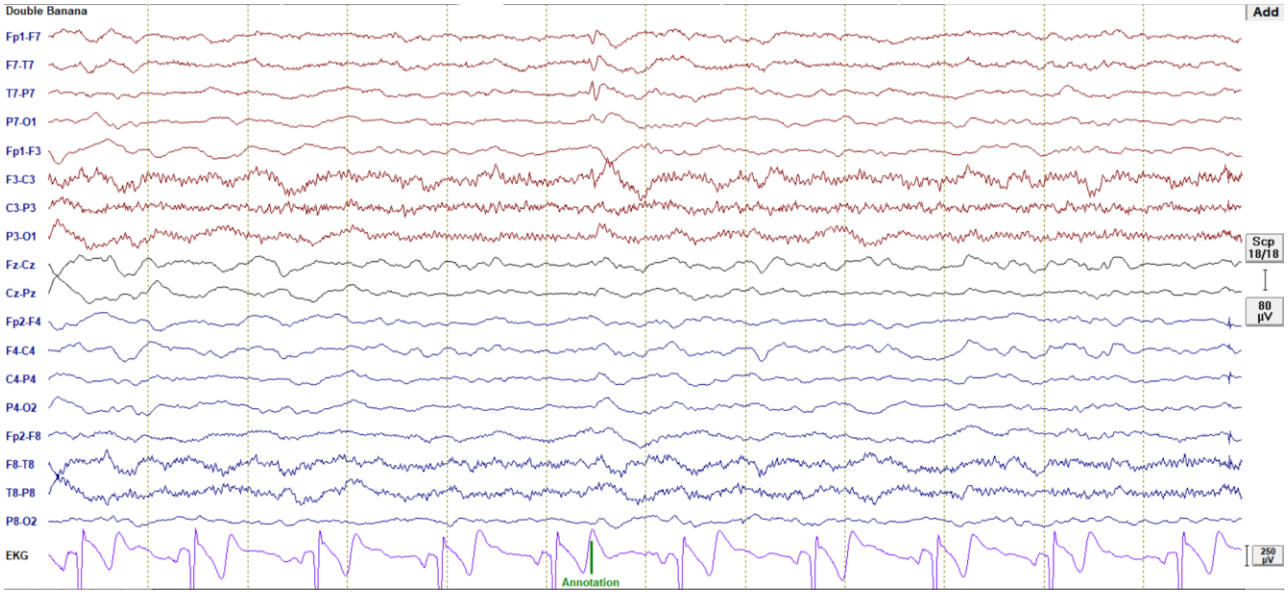
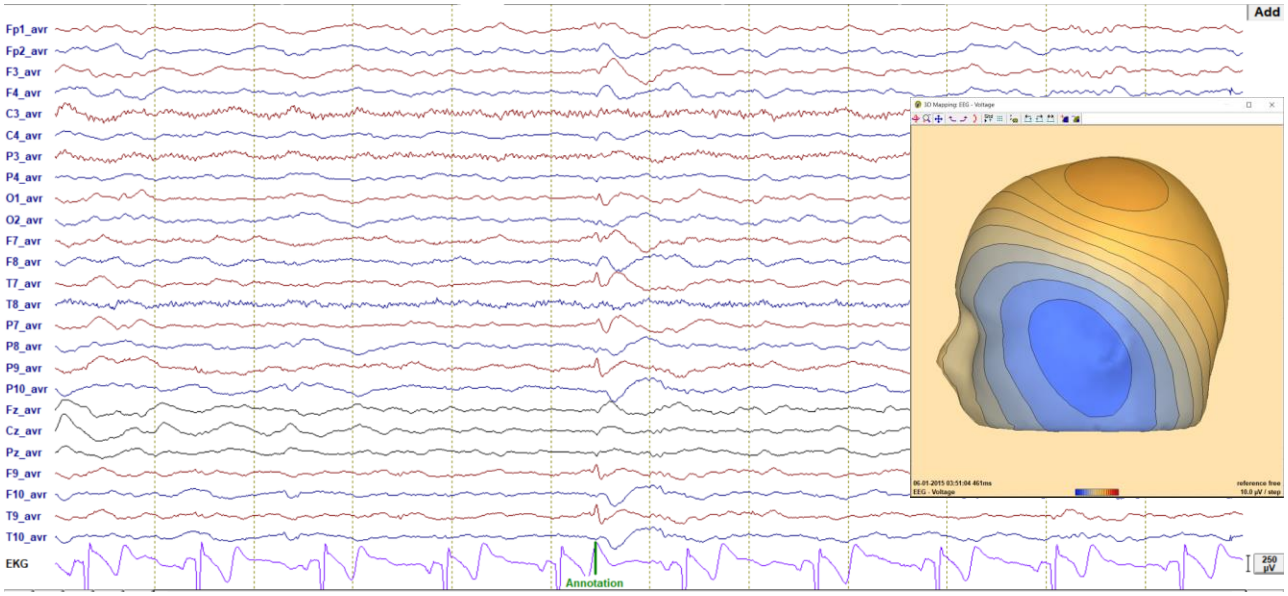
O2_avr
F7_avr
F8_avr
T7_avr
T8_avr
P7_avr
P8_avr
P9_avr
P10_avr
Fz_avr
Cz_avr
Pz_avr
F9_avr
F10_avr
T9_avr
T10_avr
EKG
Review Progress
Annotation
250 µV

Artifact


Add
Fp1_avr
Fp2_avr
F3_avr
F4_avr
C3_avr
C4_avr
P3_avr
P4_avr
O1_avr
O2_avr
F7_avr
F8_avr
T7_avr
T8_avr
P7_avr
P8_avr
P9_avr
P10_avr
Fz_avr
Cz_avr
Pz_avr
F9_avr
F10_avr
T9_avr
T10_avr
EKG
1+2
Review Progress
Annotation
250 µV


Double Banana
Add
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp1-F3
F3-C3
C3-P3
P3-O1
Fz-Cz
Cz-Pz
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp2-F8
F8-T8
T8-P8
P8-O2
EKG
Scp 18/18
80 µV
250 µV
Annotation


Add
Fp1_avr
Fp2_avr
F3_avr
F4_avr
C3_avr
C4_avr
P3_avr
P4_avr
O1_avr
O2_avr
F7_avr
F8_avr
T7_avr
T8_avr
P7_avr
P8_avr
P9_avr
P10_avr
Fz_avr
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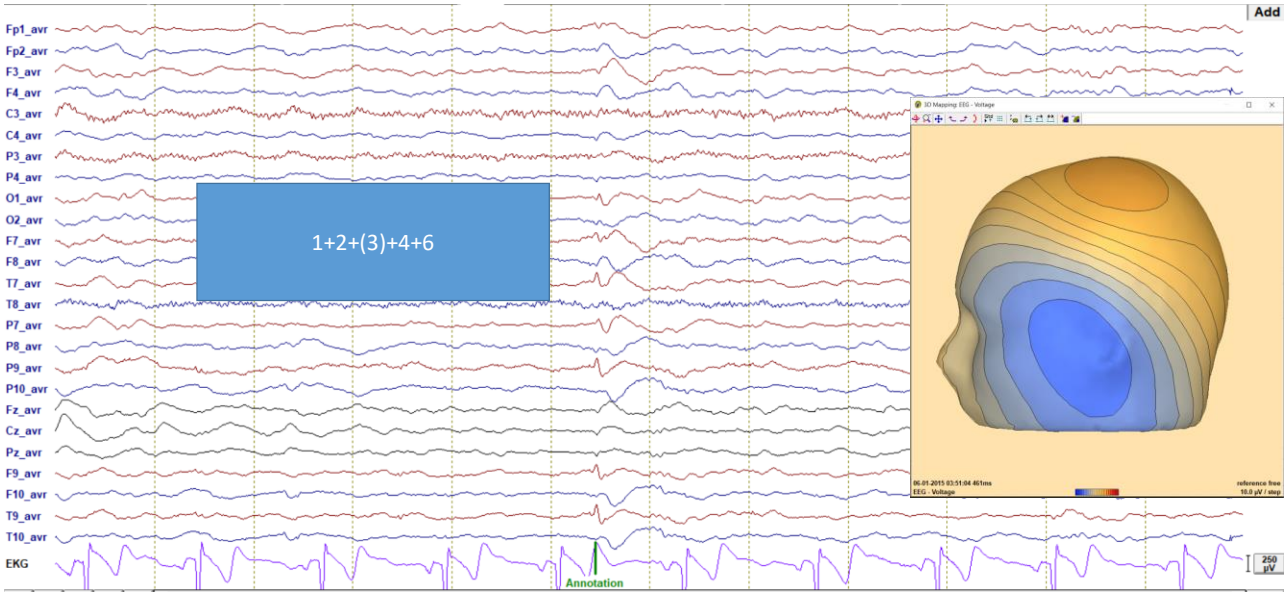
T9_avr
T10_avr
EKG
250 µV
Annotation

IED


Add
Fp1_avr
Fp2_avr
F3_avr
F4_avr
C3_avr
C4_avr
P3_avr
P4_avr
O1_avr
O2_avr
F7_avr
F8_avr
T7_avr
T8_avr
P7_avr
P8_avr
P9_avr
P10_avr
Fz_avr
Cz_avr
Pz_avr
F9_avr
F10_avr
T9_avr
T10_avr
EKG
1+2+(3)+4+6
Annotation
250 µV