



Current and future applications of BCIs

Begonya Otal, PhD
g.tec medical engineering Spain



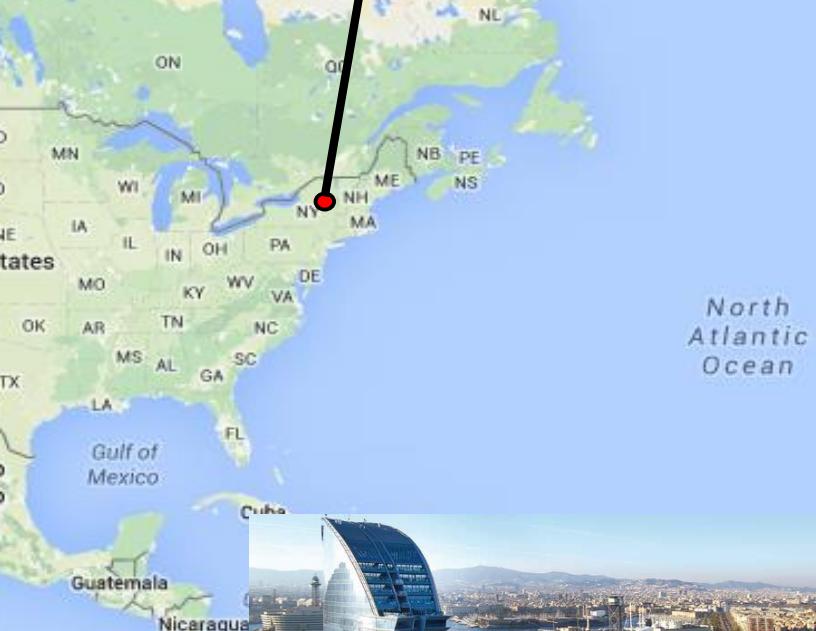
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company fields

- bio-engineering, medical electronics (bio-electricity)
- developing and offering hard- and software products for biosignal research (**single cell activity, EEG, ECoG**; muscle cells: **ECG, EMG**; other tissue: **EOG**, ...)

company description

- private company
- inter-disciplinary team (biomedical- , telematics engineers, psychologists)
- customers: universities, university hospitals, R&D departments, industry

Measuring brain electrical activity

Electroencephalogram (EEG)

8/16/32 – 64 (128) channels, 1 μ V – 100 μ V,
0 – 40 Hz, low signal-to-noise ratio, moderate
spacial resolution, high temporal resolution

Surface electrodes: 8 ...12 mm, mounted with
conductive gel/paste/dry

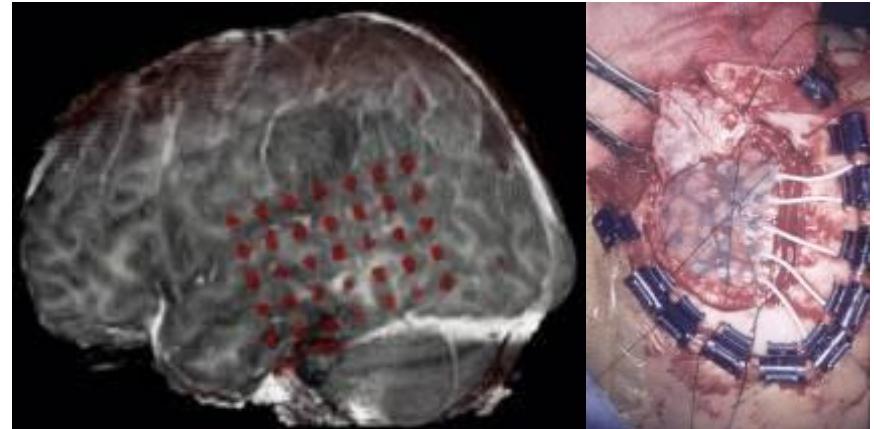


Electro-corticogram (ECoG)

closely spaced multi-electrode grids or
strips applied directly to the cortical
surface, electrode diameter ~ 4mm, up
to 500 μ V, 1 – 100 Hz

high signal-to-noise ratio, high spacial
and temporal resolution

highly invasive and limited study
opportunities



modified from University of Michigan

Hardware Development

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80/144/256
channels



g.NAUTILUS – 64 channels

Flexible positioning with g.SCARABEO electrodes



g.[®]Nautilus
WIRELESS BIOSIGNAL ACQUISITION

How to record brain activity for BCI?

Electroencephalogram (EEG)



Electrocorticogram (ECoG)



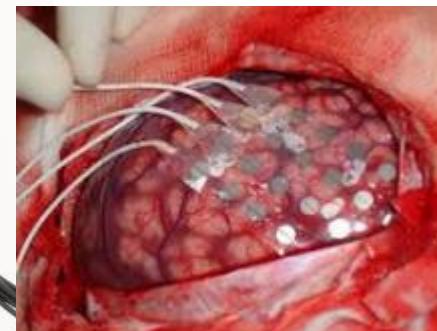
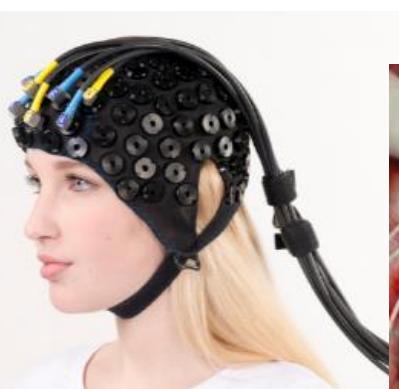
Functional Near-infrared Spectroscopy (fNIR/fNIRS)



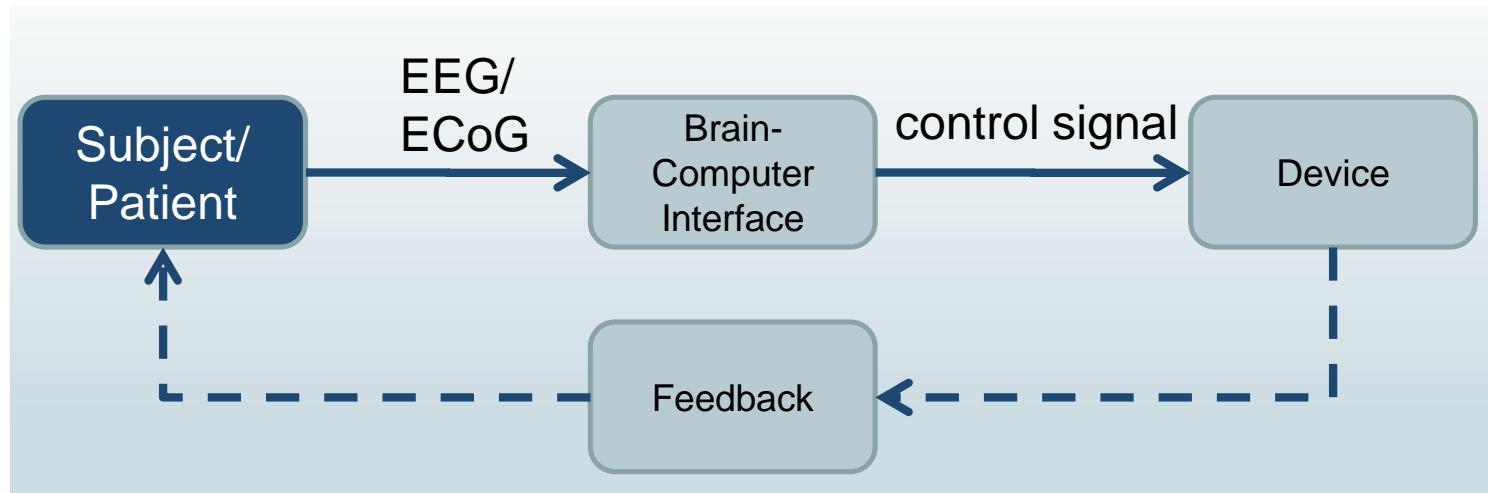
Magnetencephalogram (MEG, eg. arrays of SQUID)



Functional imaging techniques: fMRI, SPECT, PET



BCI definition



“A system for **controlling a device** e.g. computer, wheelchair or a neuroprosthesis by human intention which does not depend on the brain’s normal output pathways of peripheral nerves and muscles”
[Wolpaw et al., 2002].

HCI – Human Computer Interface

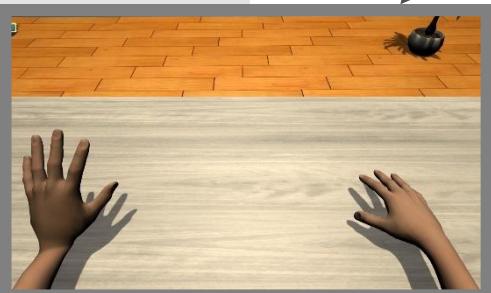
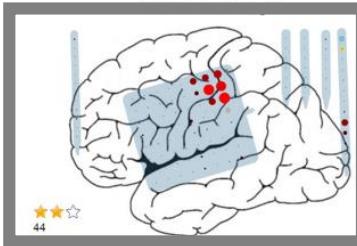
DBI – Direct Brain Interface (University of Michigan)

TTD – Thought Translation Device (University of Tübingen)

Some examples of BCI applications



BCI

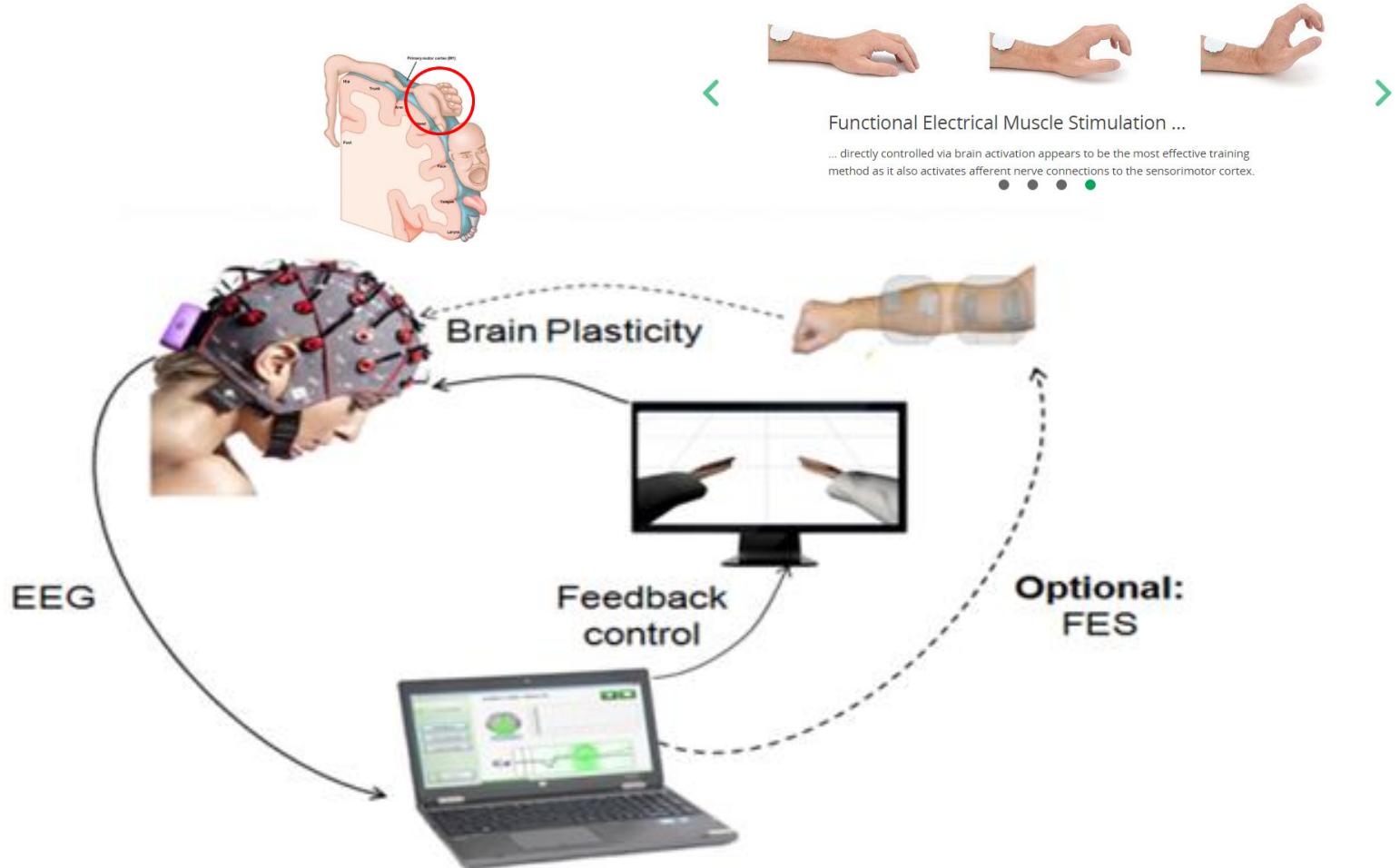


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- Stroke can lead to movement impairment.
- Physiotherapy can help users perform specific movements while imagining them.
- However, there is no objective way to measure this movement imagery.





Co-funded by the Horizon 2020 programme
of the European Union

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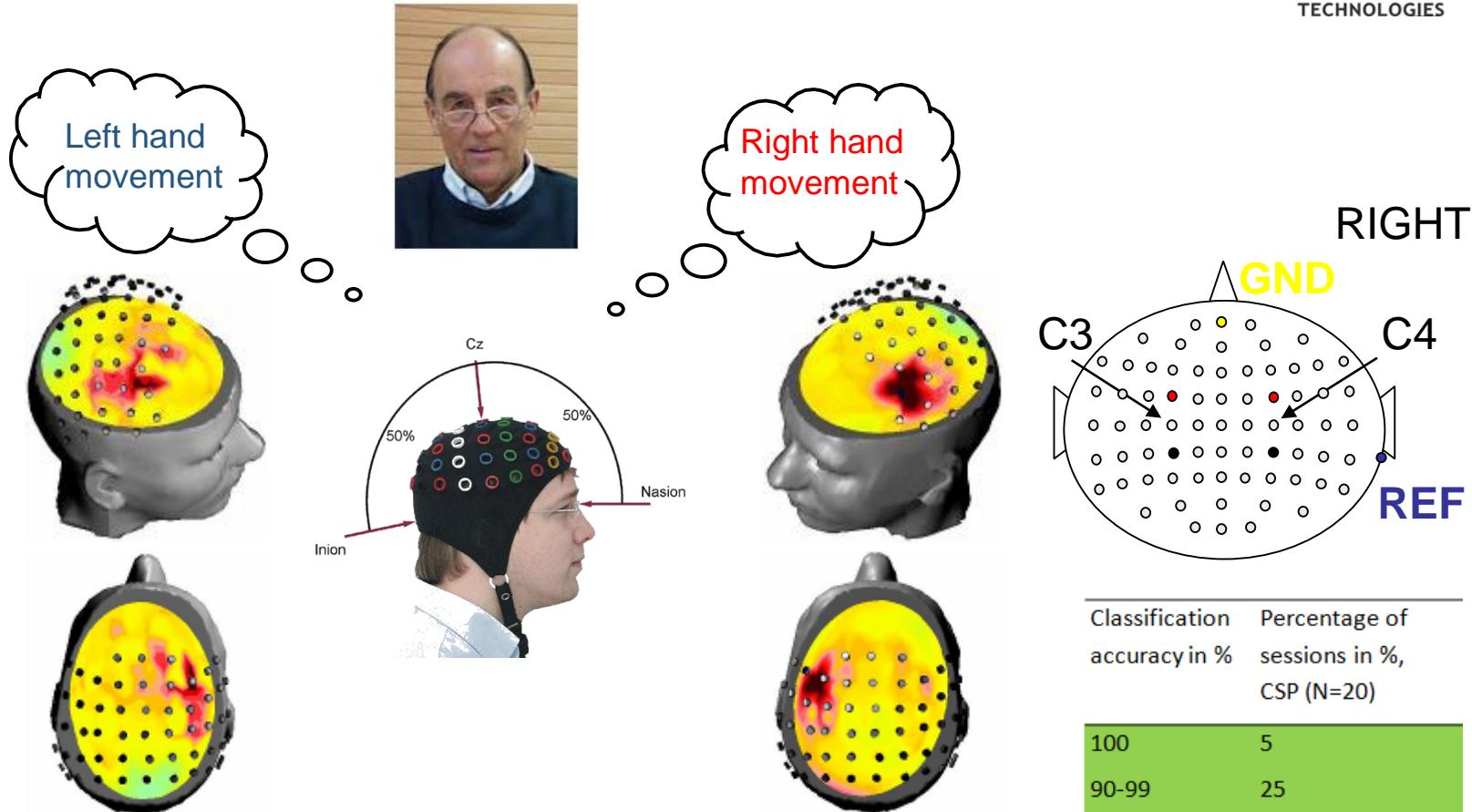
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Motor Imagery



Imagination of hand movement causes an ERD which is used to classify the side of movement.

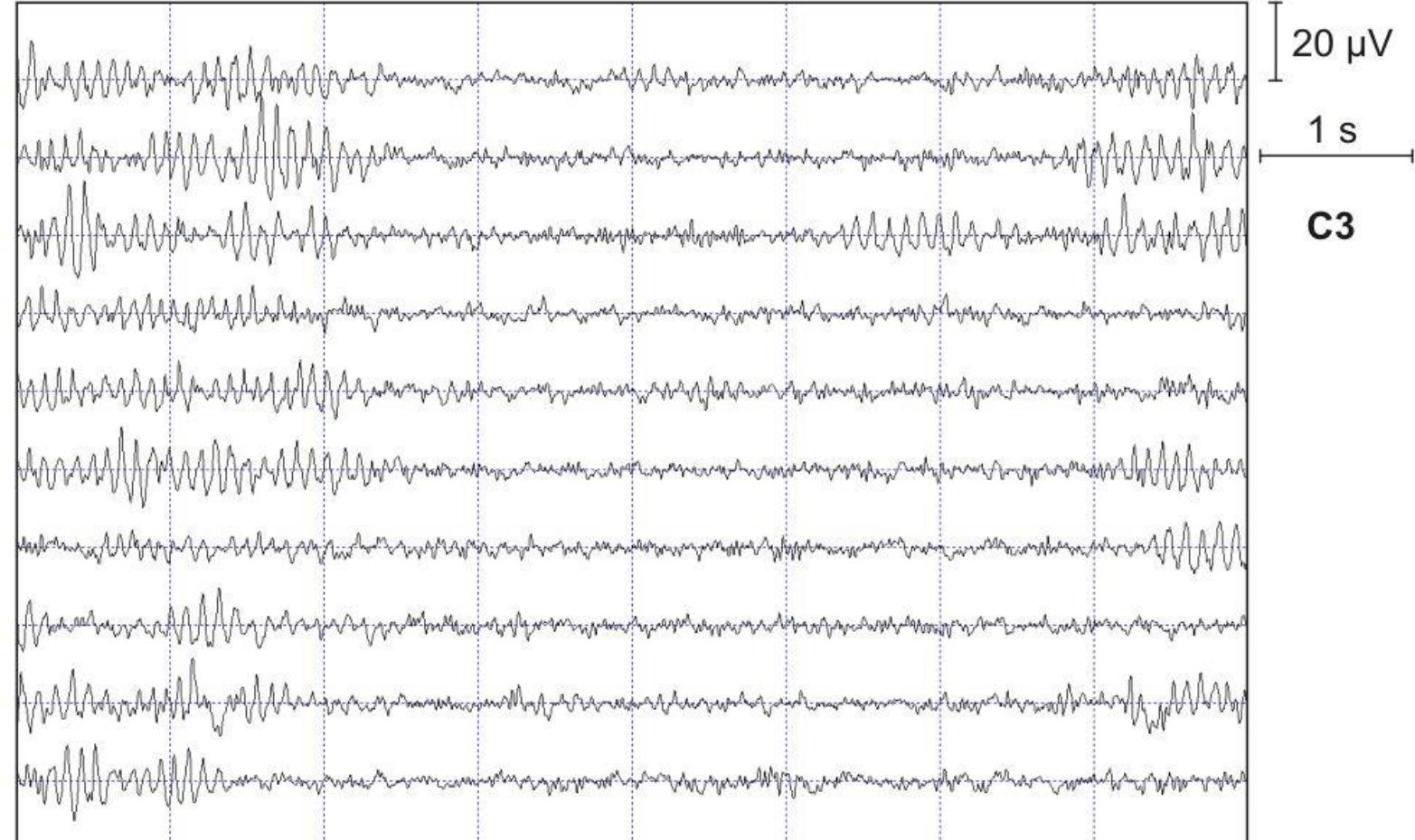
The desynchronization occurs in motor and related areas of the brain.

Classification Percentage of
accuracy in % sessions in %,
CSP (N=20)

100	5
90-99	25
80-89	25
70-79	15
60-69	25
50-59	5
Sum	100

Oscillatory Activity

11-Hz mu-activity at C3: desynchronization during a right hand motor imagery



Patient 1: born 1953, right handed,
May 12th 2014 stroke, right arm affected

Subacute Training video
[recoveriX1](#)

Rehabilitation Hospital of Iasi,
Romania

Danut Irimia, Rupert Ortner, 2014

9-hole PEG test				
Date: 2014	Left hand	Falls	Right hand	Falls
24-06	31"	0	1'5"	0
26-06	32"	0	54"	0
29-06	32"	0	45"	0
2-07	31"	0	42"	0
6-09	31"	0	42"	0
9-09	29"	0	38"	0
12-09	29"	0	34"	0
15-09	29"	0	30"	0
11-01	29"	0	30"	0



Patient 2: born 1974, right handed,
May 2010 stroke, left arm affected

Rehabilitation Hospital of Iasi,
Romania

Danut Irimia, Rupert Ortner, 2014

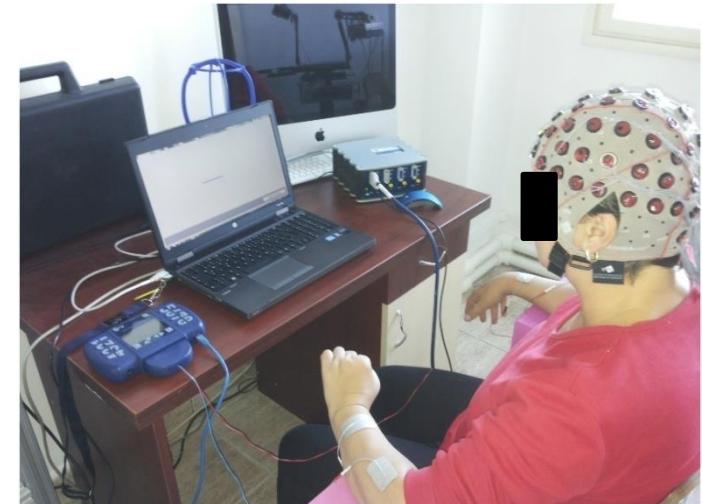
9-hole PEG test

Not done, because left hand was paralyzed

Initially:



BCI driven FES:



Scales for the measured variables

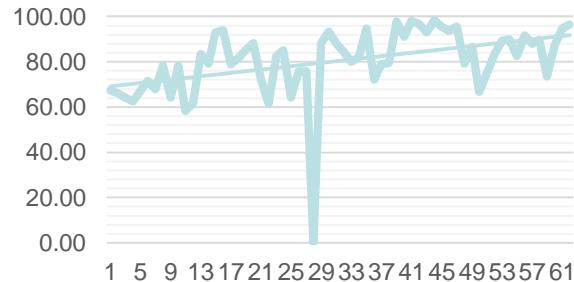
Scales
9 Hole Peg Test
Barthel Index
Fugl-Meyer Assessment
Modified Ashworth Scale
Fahn Tremor Rating Scale
VAS

Patient S0008	
Age	38 y.o.
Stroke date	2015
Therapy starts	2016
Affected arm	Right
Phase	Chronic
# sessions	30

Scales	Start	Final
Barthel Index	100	100
FMA (wrist)	8	10
Modified Ashworth Scale	1	0
Fahn Tremor Rating Scale	2	2

9HPT - Final	
Left	Right
00:17:85	07:26:58
00:15:29	03:21:71
00:14:38	01:34:14
00:14:42	03:13:18
00:16:49	01:52:52
00:16:12	01:48:67
00:15:18	02:06:75
00:14:80	02:21:96
00:16:60	01:04:24
00:13:95	01:51:96
00:15:23	01:24:73
00:13:28	01:25:15
	01:55:93

MaxAccuracy

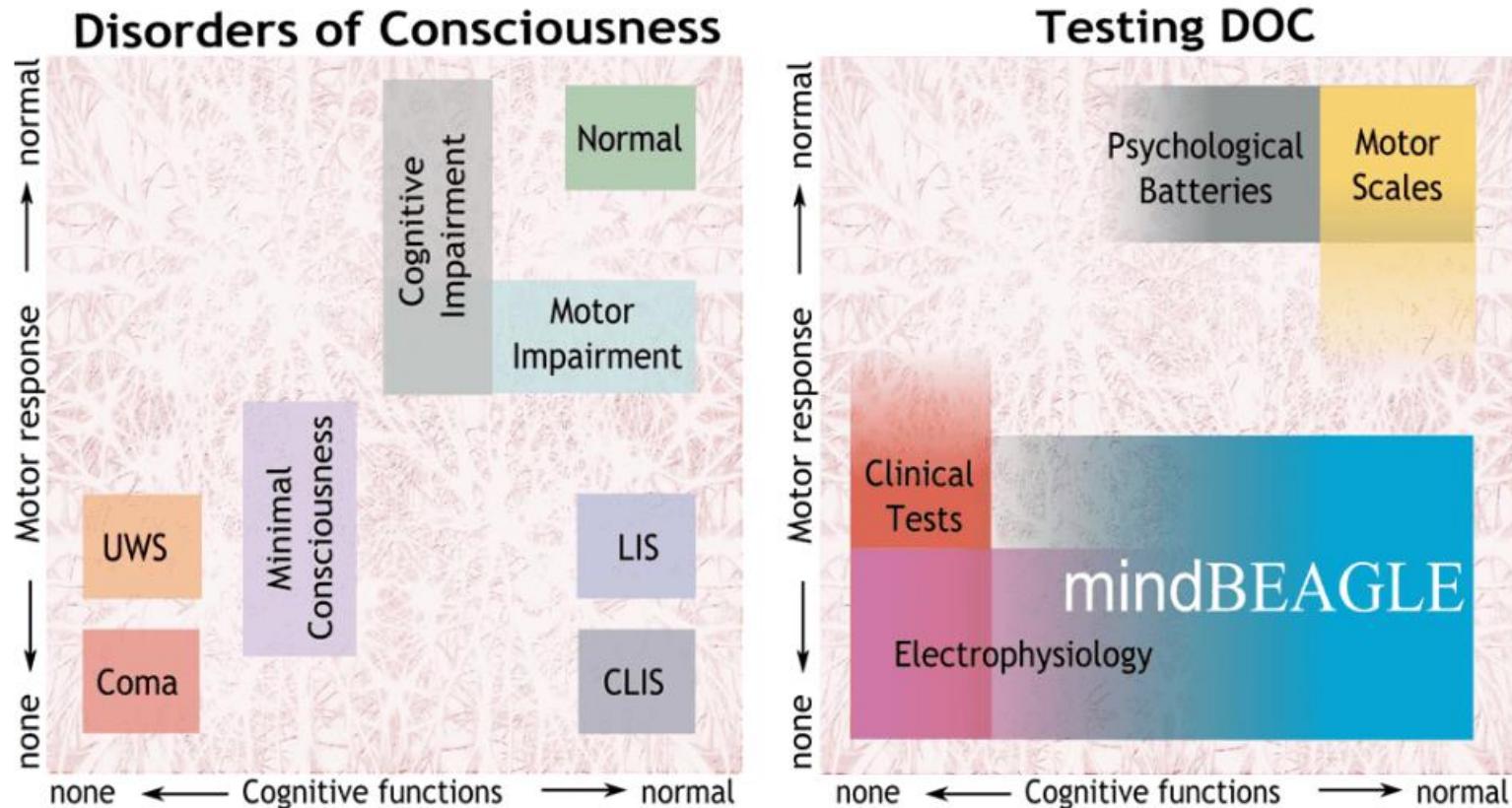


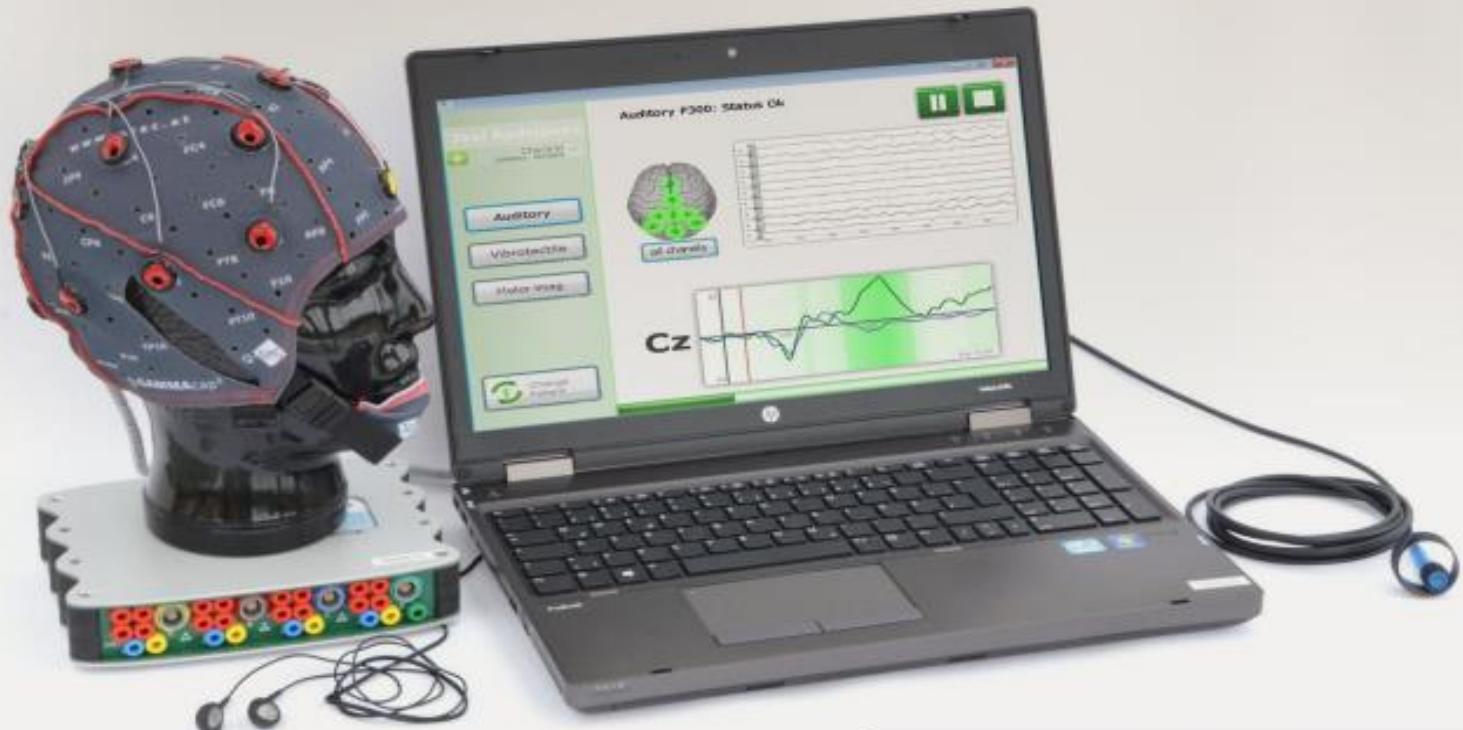


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CONSCIOUSNESS ASSESSMENT & COMMUNICATION

Motivation

- **Fact:** 43% of patients diagnosed as **vegetative** or unresponsive wakefulness state (UWS) are **reclassified** as (at least) minimally conscious when investigated by expert teams





Note: The biosignal amplifier (g.USBamp) is an FDA-listed and CE-certified medical device. The complete mindBEAGLE system is not yet a certified medical system. Positive and significant results may be interpreted as a strong indication for responsiveness of a patient but the opposite is not the case! The system must not be used to rule out consciousness or responsiveness in any patient.

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is a registered trademark of:

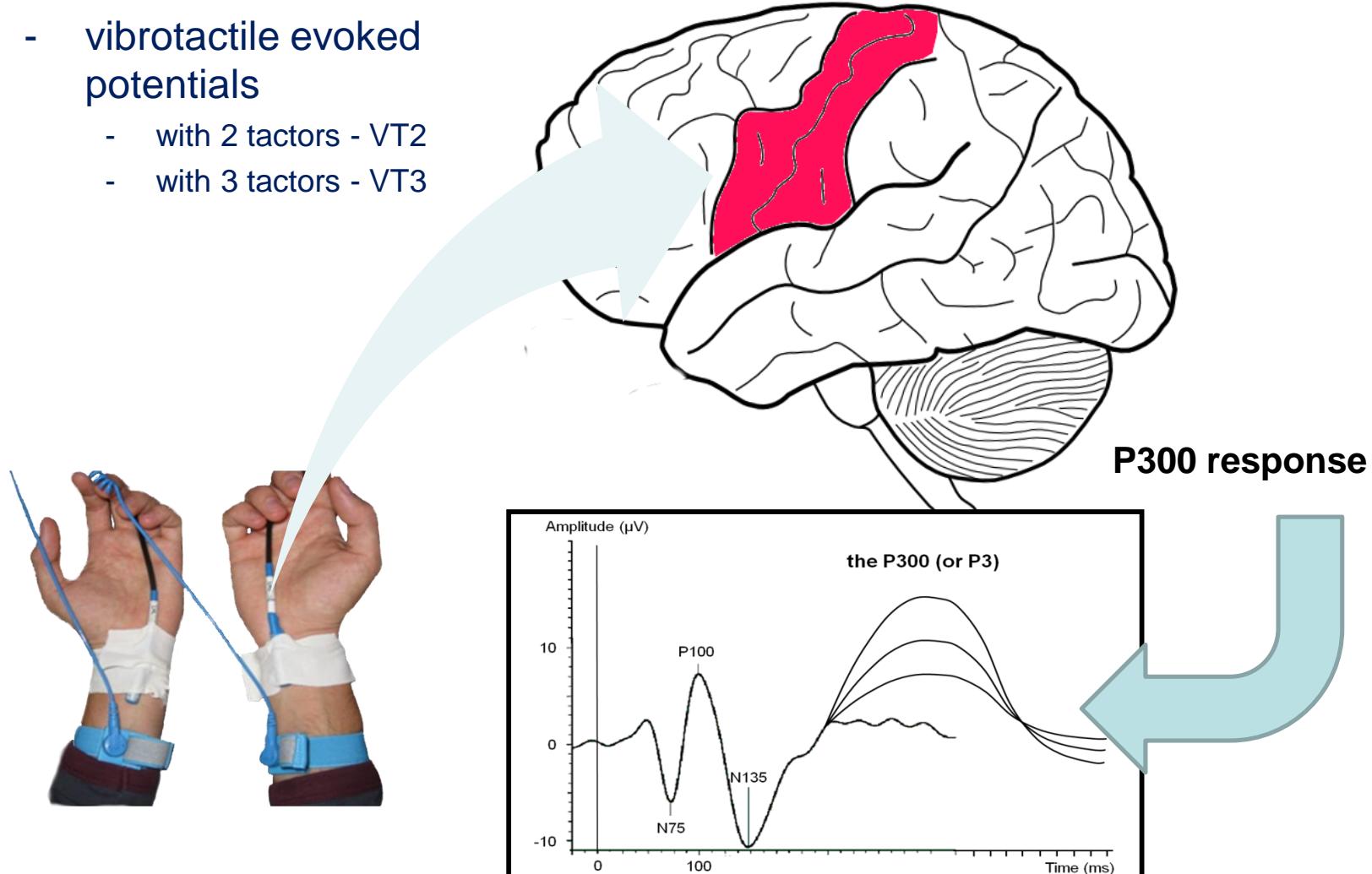


Co-funded by the Horizon 2020 programme
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Principle I - DOC assessment

- auditory evoked potentials
- vibrotactile evoked potentials
 - with 2 tactors - VT2
 - with 3 tactors - VT3

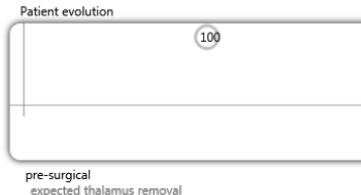


Auditory result

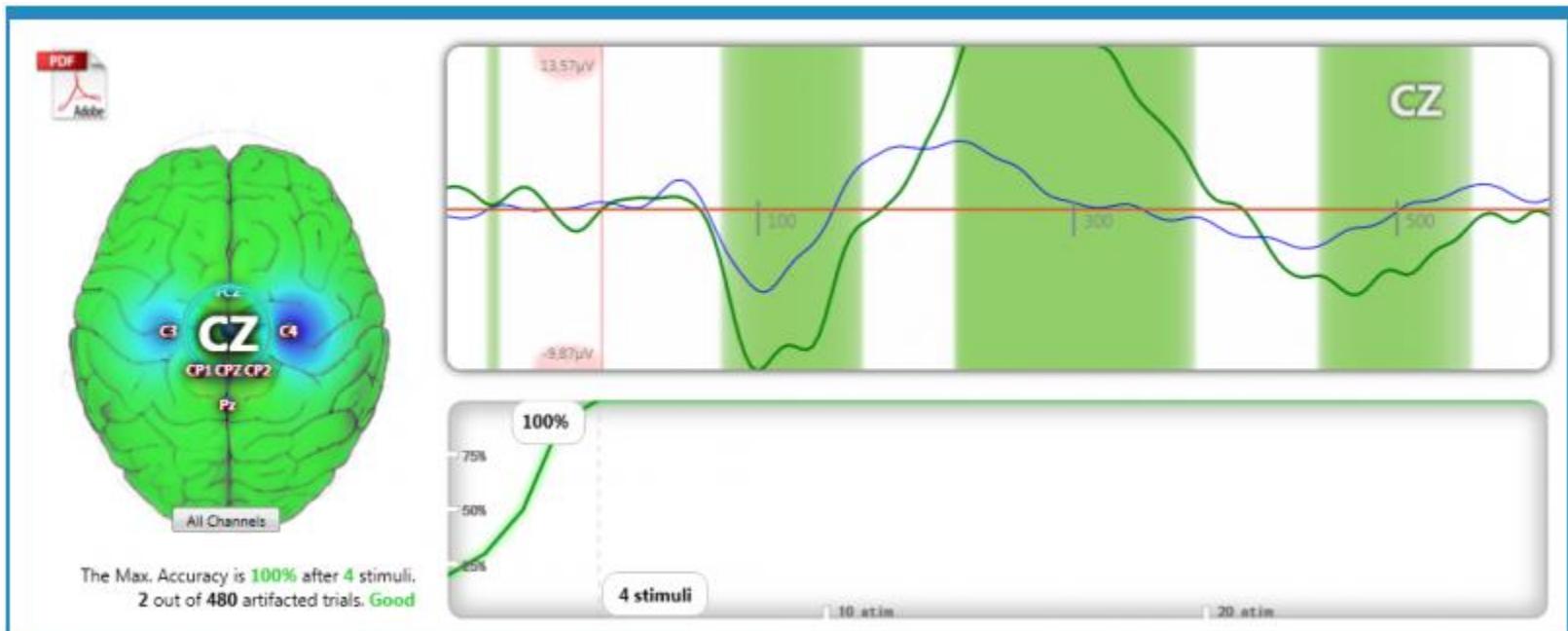
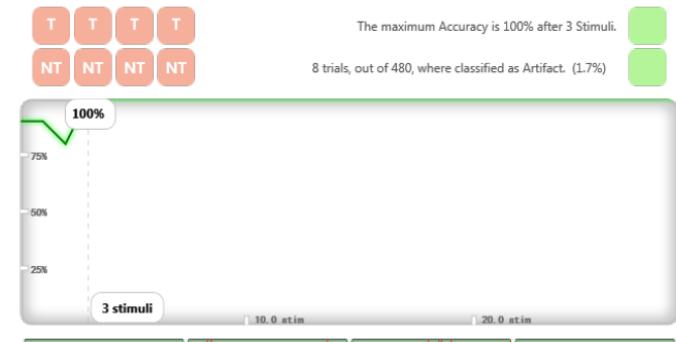
Chr. Guger - 04/06/2014 16:07:33

ec
.OGIES

8 min experimental time
Low versus high tones
BCI accuracy
EPs with significance



Physician Mr James Swift
Amplifier GUsbAmp UB-2009.07.01
Bandpass filters 0.1 .. 30Hz.
Sample rate 256
Stimuli per character 120 (15 targets)
Ratio of targets 1/8 targets
Experiment length 7 min 18 sec
Used classifier Generic Classifier (20%, 2)



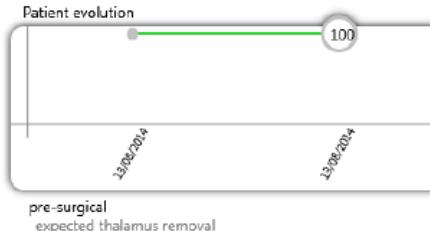
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Vibrotactile result

2.5 min experimental time
Left/right vibrotactile
stimulation
BCI accuracy
EPs with significance

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VibroTactile 2CH

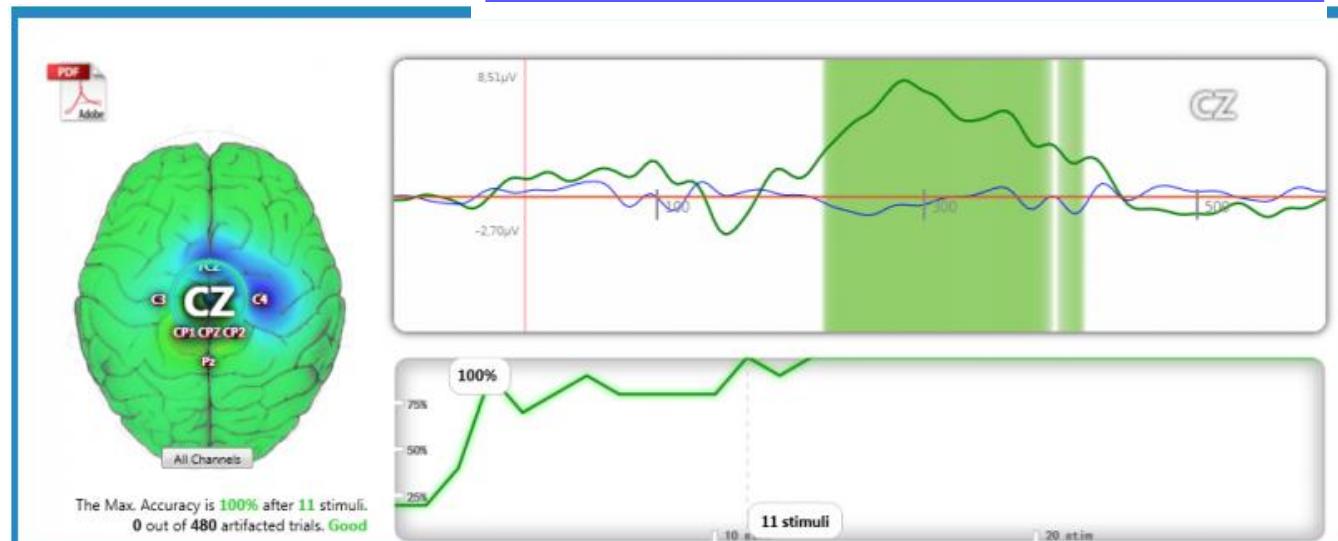
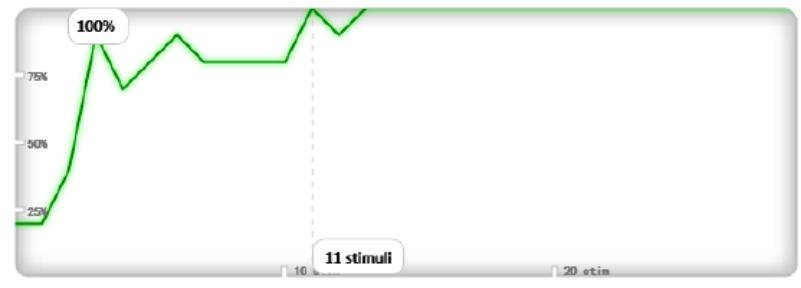


Physician Mr James Swift
Amplifier GUusbAmp UB-2009.07.12
Bandpass filters 0.1 .. 30Hz.
Sample rate 256
Stimuli per character 120 (15 targets)
Ratio of targets 1/8 targets
Experiment length 2 min 30 sec
Used classifier 100at_13_20140813_08461



The maximum Accuracy is 100% after 11 Stimuli.

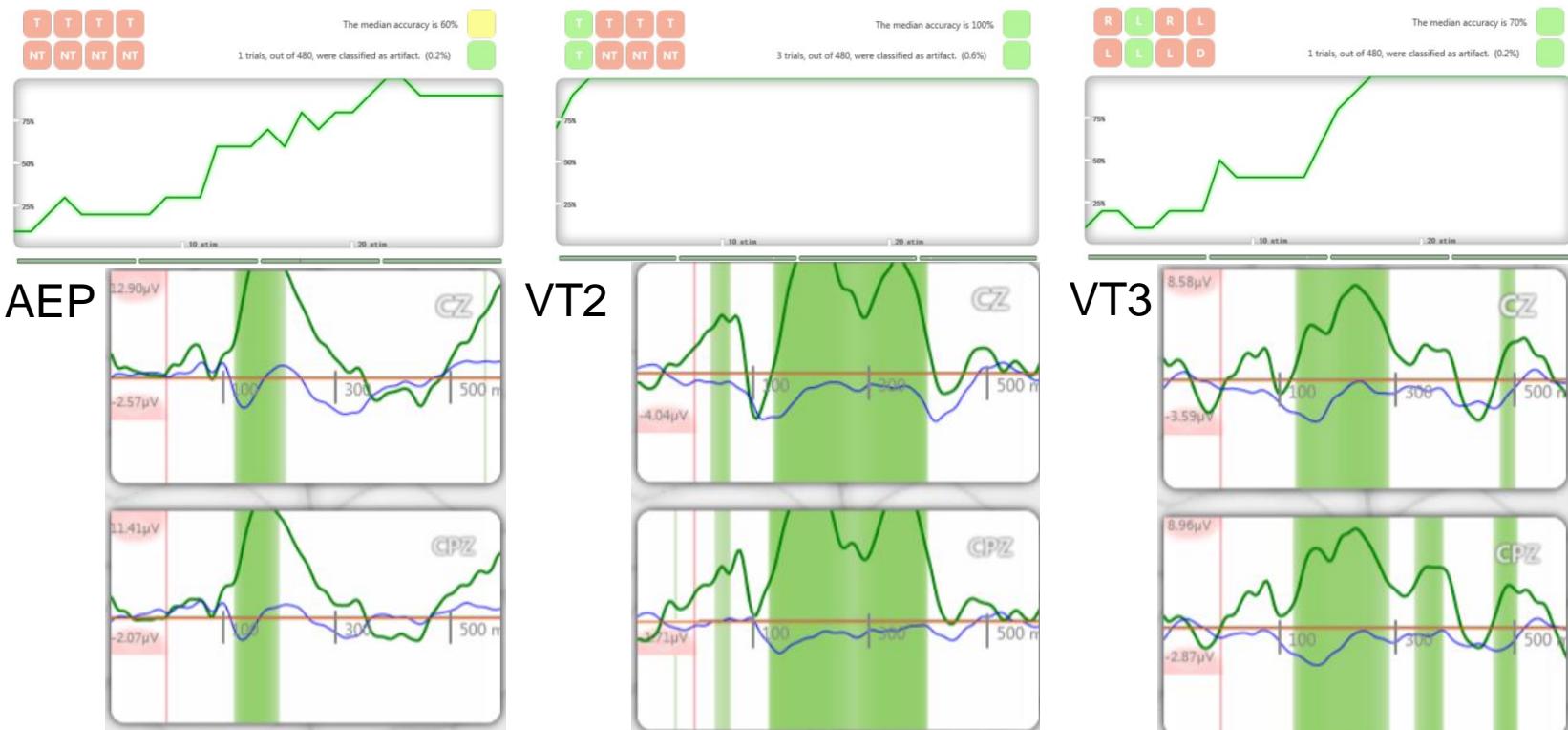
0 trials, out of 480, where classified as Artifact. (0%)



Successful assessment

MCS- on day of mindBEAGLE

Tried communication with 8 questions, she only responded yes to:
'Do you want to go swimming?'

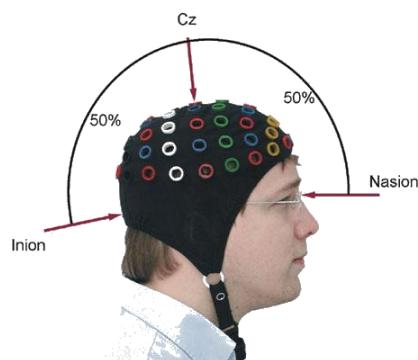


Principle II - Communication

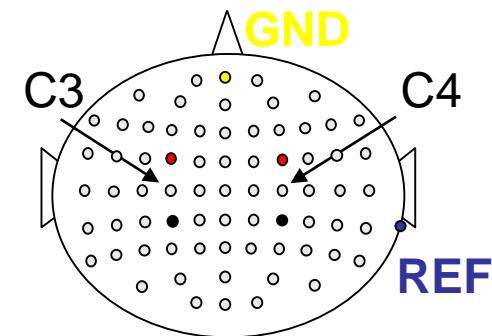
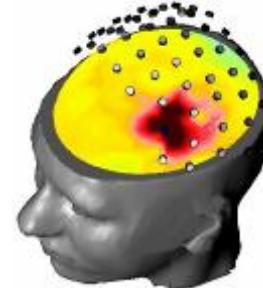
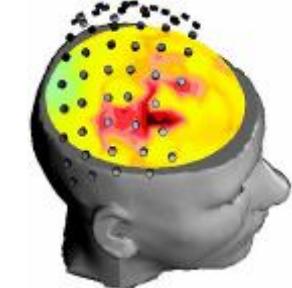


Left hand movement

Motor Imagery



Right hand movement



Classification	Percentage of sessions in %, CSP (N=20)
100	5
90-99	25
80-89	25
70-79	15
60-69	25
50-59	5
Sum	100

Imagination of hand movement causes an ERD which is used to classify the side of movement.

The desynchronization occurs in motor and related areas of the brain.



in Neuroscience | Neuroprosthetics

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Front. Neurosci., 05 May 2017 | <https://doi.org/10.3389/fnins.2017.00251>



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Complete Locked-in and Locked-in Patients: Command Following Assessment and Communication with Vibro-Tactile P300 and Motor Imagery Brain-Computer Interface Tools

Christoph Guger^{1,2*}, Rossella Spataro³, Brendan Z. Allison¹, Alexander Heilinger¹, Rupert Ortner²,
 Woosang Cho² and Vincenzo La Bella³

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²g.tec Medical Engineering GmbH, Schiedlberg, Austria

³ALS Clinical Research Center, Biomedicina e Neuroscienze Cliniche (BioNeC), University of Palermo, Palermo, Italy



ALS/LIS Participants

TABLE 2 | Overview of healthy controls and patients participating in this study.

#	Sex	Age (years)	Diagnosis	Disease duration (month)	Mechanical ventilation	Clinical state	Rec. site
HEALTHY CONTROLS							
S1	F	42	Healthy	-	-	-	GT
S2	M	43	Healthy	-	-	-	GT
S3	M	38	Healthy	-	-	-	GT
PATIENTS							
P1	F	61	ALS	149	yes	CLIS	PA
P2	M	67	ALS	97	yes	LIS	PA
P3	F	76	ALS	145	no	LIS	PA
P4	F	75	ALS	184	yes	CLIS	PA
P5	F	68	ALS	89	yes	LIS	PA
P6	M	63	ALS	27	yes	LIS	PA
P7	F	62	ALS	70	yes	CLIS	PA
P8	M	68	ALS	52	yes	LIS	PA
P9	F	65	ALS	84	no	LIS	PA
P10	M	37	ALS	103	yes	LIS	PA
P11	M	58	ALSFTD	21	yes	LIS	PA
P12	F	46	ALS	136	yes	LIS	PA

"ALSFTD" means "ALS with frontotemporal dementia."

LIS results – Median classification accuracy

Pat.	Sess. #	VT2 [%]	VT3 [%]	VT3 Com	MI [%]	MI Com
P1	1	100	100	9/10	51	-
P2	1	100	70	7/10	73	4/5
P3	1	100	90	8/10	59	-
P4	1	20	70	7/10	47	-
P5	1	99	100	9/10	83	5/5
P6	1	80	100	9/10	56	-
P7	1	40	40	-	-	-
	2	-	20	-	-	-
P8	1	70	100	8/10	49	-
P9	1	40	10	-	-	-
P10	1	100	50	-	54	-
	2	-	90	8/10	-	-
P11	1	70	20	-	52	-
	2	-	20	-	-	-
P12	1	100	60	-	42	-
	2	-	70	7/10	74	5/5
Average		76,6	63,1	8/10	58,2	4,7

LIS results

EPs and accuracies for VT2, VT3, and MI

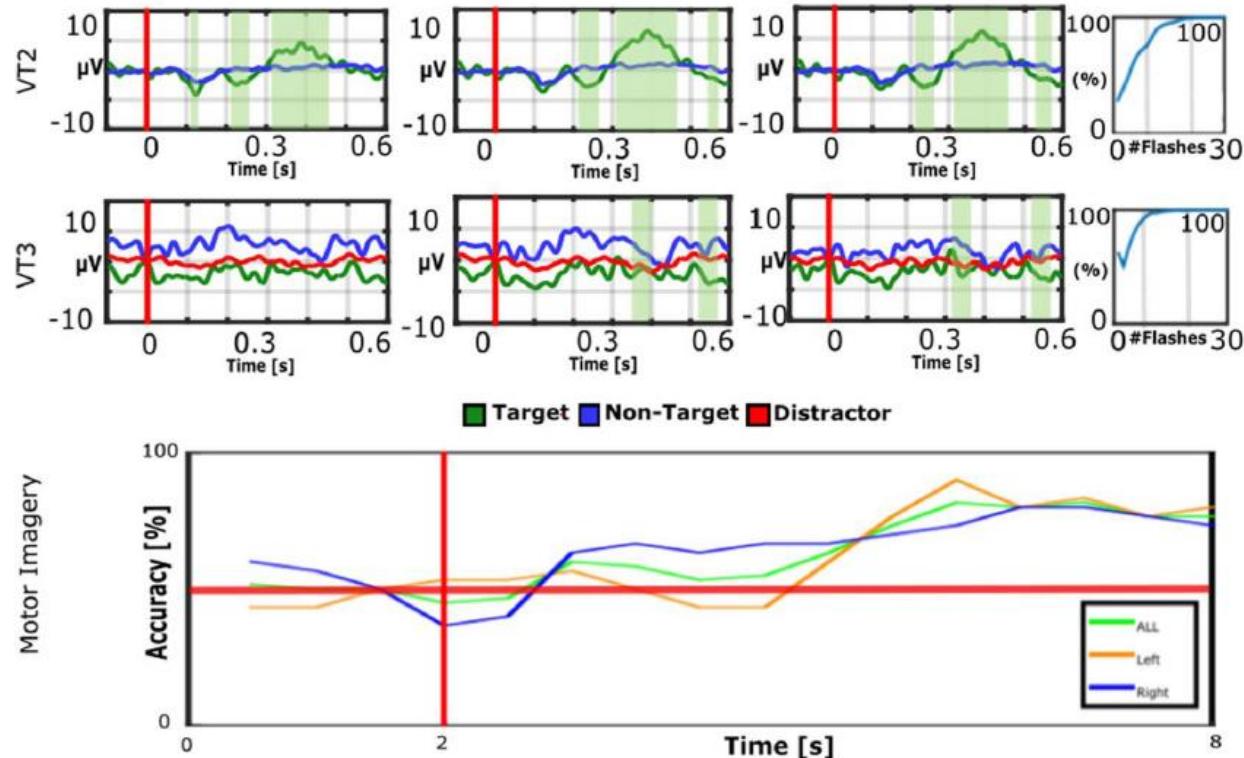
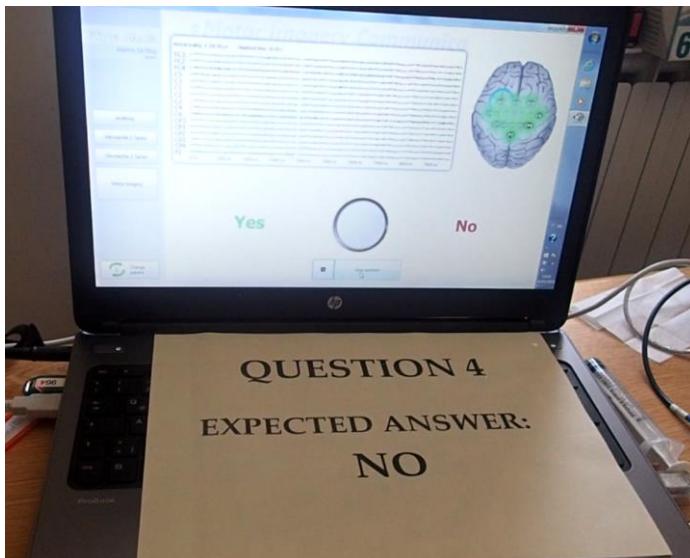


FIGURE 3 | EPs and accuracies for VT2, VT3, and MI runs of LIS patient 5. The patient achieved an average accuracy of 83% for MI, 100% for VT2, and 100% for VT3. Communication was possible with the MI and VT3 paradigms. In the bottom figure, the vertical red line indicates when the cue is presented to the subject, while the horizontal red line represents 50% accuracy (corresponding to chance performance).

University of Palermo, Vincenzo La Bella, Rossella Spataro



„can listen to us....  ES



and communicate

[Video NO](#)

[Video YES](#)

[General video](#)

MINIMAL CONSCIOUSNESS STATE: A P300 AND MOTOR IMAGERY BRAIN-COMPUTER INTERFACE FOR ASSESSMENT & COMMUNICATION

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Centre Hospitalier Universitaire de Nîmes, France (frederic.pellas@chu-nimes.fr)

Ren Xu, Woosang Cho, Brendan Z. Allison, Christoph Guger

Guger Technologies OG, Herbersteinstrasse 60, A-8020 Graz, Austria, (xu, cho, allison, guger@gtec.at)

MCS Participants

- MCS patients participated in this study
 - measurements performed at CHU Nîmes, France (Dr. Pellas)
 - approved by local ethical committee
 - consent form obtained via the legal representative of the patients

P	Sex	Age (years)	Diagnosis	Disease Duration (month)	Mechanical ventilation	Clinical State
1	F	21	TBI	12	No	MCS-
2	F	56	TBI	50	No	MCS+
3	M	35	ME	23	No	MCS+
TBI: Traumatic Brain Injury; ME: Meningoencefalitis; MCS: Minimal Consciousness State.						

Classification accuracies

- Median classification accuracies are shown for
 - AEP assessment run lasts 8 min (*15 targets vs. 105 non-targets*)
 - VT2 / VT3 assessment runs last 2.5 min (*4 instructions with 15 targets each*)
 - AEP and VT2 quick test (QT) last 38 seconds
 - VT3 communication, it takes 38 seconds to answer 1 question
 - MI lasts roughly 9 min (*30 left and 30 right hand trials*)

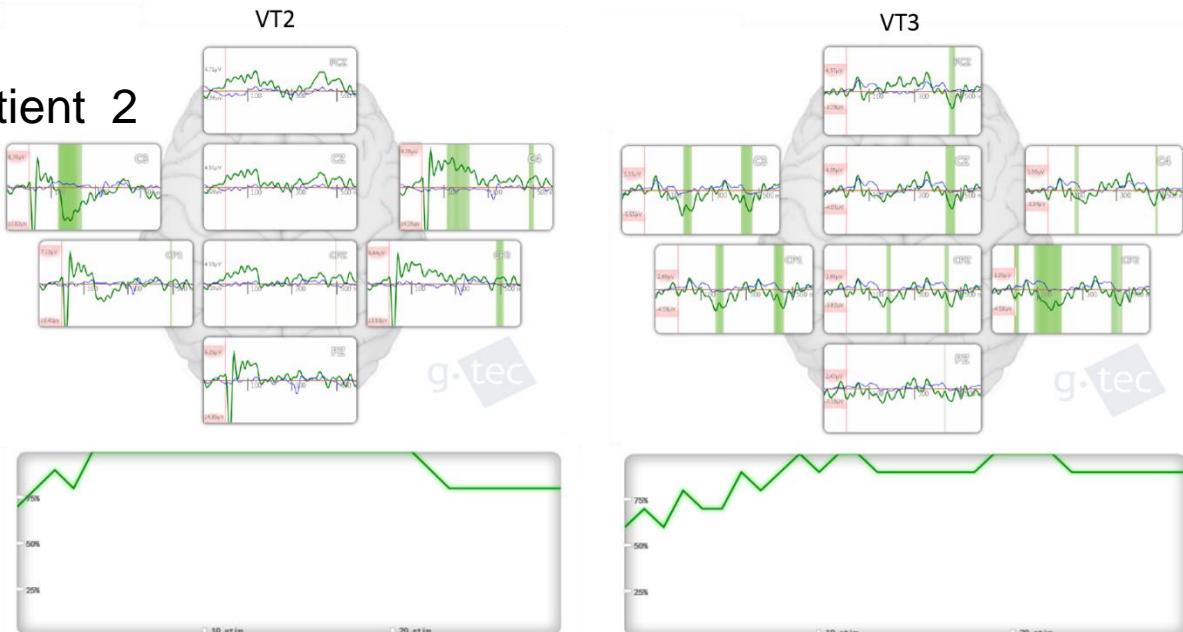
P	Session #	AEP [%]	QT	VT2 [%]	QT	VT3 [%]	VT3 Com	MI [%]	MI Com
1	1	20	-	70	Yes	10	No	51	-
	2	-	-	-	-	0	No	-	-
2	1	80	Yes	50	No	10	No	53.8	No
	2	-	-	80	Yes	30	No	-	-
	3	-	-	85	Yes	-	-	-	-
	4	100	Yes	100	Yes	40	No	44	No
	5	-	-	-	-	90	YES	-	-
3	1	40	No	100	Yes	90	No	51.3	No
	2	-	-	-	-	40	No	-	-

Vibro-tactile EPs – P1 and P2

- Patient 1

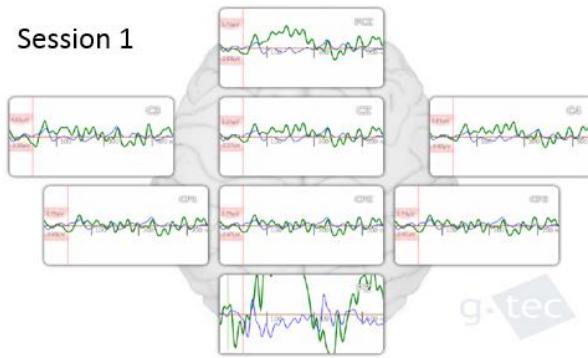


- Patient 2

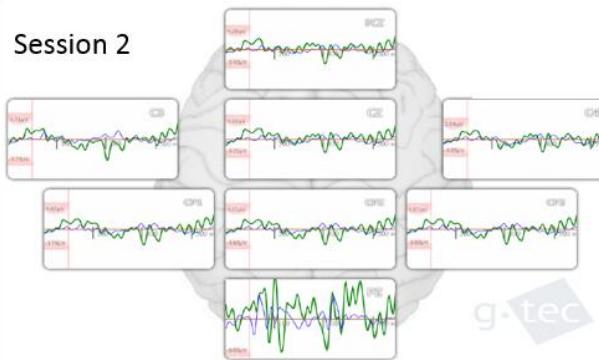


VT3 paradigm – P2/multiple sessions

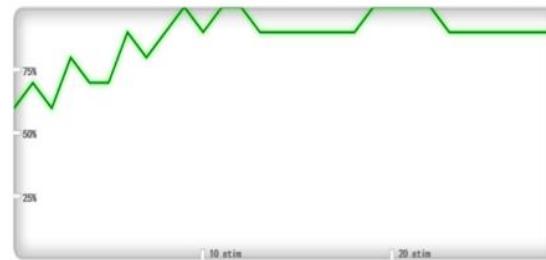
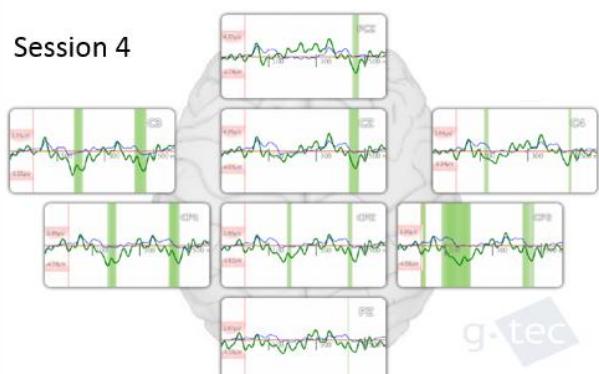
Session 1



Session 2



Session 4



Discussion

- We showed some **preliminary but positive** results of a BCI system for assessment and communication in some MCS patients
- We observed **differences among patients and sessions.**
- **Fluctuations** on the same patient (sessions) may reflect the **unstable status of MCS patients** → multiple assessments are necessary
- The success of AEP and VT paradigms on MCS patients may indicate the **intact auditory or tactile sensory pathway**
- **Low performance** on MI paradigm (ERD/ERS) may be due **lack of training or tiredness**
- **Possible communication via VT3 paradigms** show that “MCS (mis)diagnosed” patients may follow instructions

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Products & Solutions

BCI Components

- (A) g.MOBIIlab+ EEG version multi-purpose version
- (B) g.USBamp 16 channels 32 channels 48 channels 64 channels
- (C) g.Hlamp 80 channels 144 channels 256 channels
- (D) g.Nautilus active-gel active-dry 8 channels 16 channels 32 channels
- (E) g.GAMMAcap
- (F) Consumables
- (G) Electrodes active passive dry

Recommended setup for a fully equipped BCI lab

Room dimension: >5x6m

Room dimension: >5x6m

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Room dimension: >5x6m

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Sensors

- GSR
- Blood pressure
- Respiration
- Temperature
- Pulse
- Acceleration
- More sensors

Electrical stimulator

-

g.STIMbox

g.SSVEPbox

Software

Software

Examples

- P300
- Motor imagery
- SSVEP
- CSP/RehaBCI
- Vibro-tactile P300
- Ping-Pong game
- Hyperscanning
- Hybrid BCI
- EMG/EOG control
- Training material
- EEG lecture
- EP lecture
- BCI lecture

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Thanks!

