

Current and future applications of BCIs

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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

Electroencephalogram (EEG)

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

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

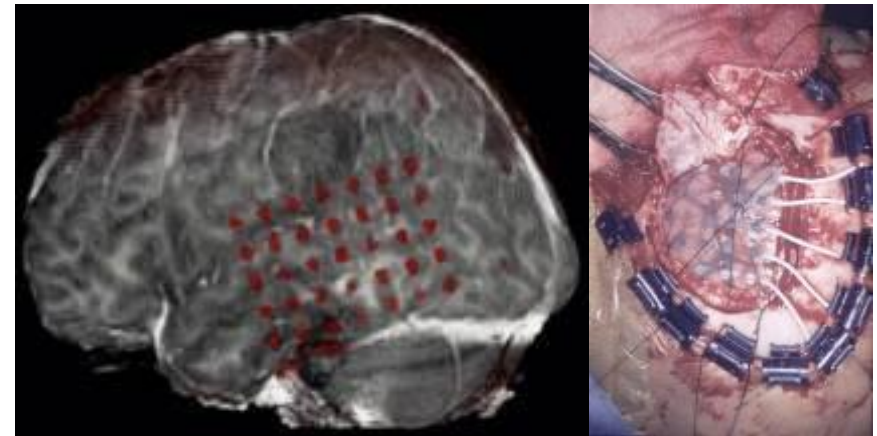


Electro-corticogram (ECoG)

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

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

highly invasive and limited study
opportunities



modified from University of Michigan

Hardware Development



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)



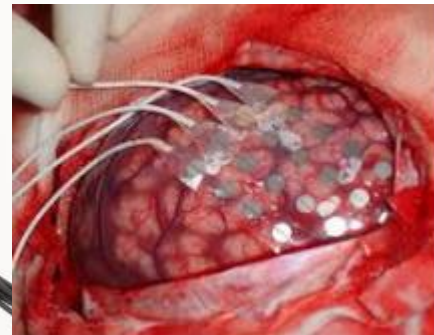
Functional Near-infrared Spectroscopy (fNIR/fNIRS)

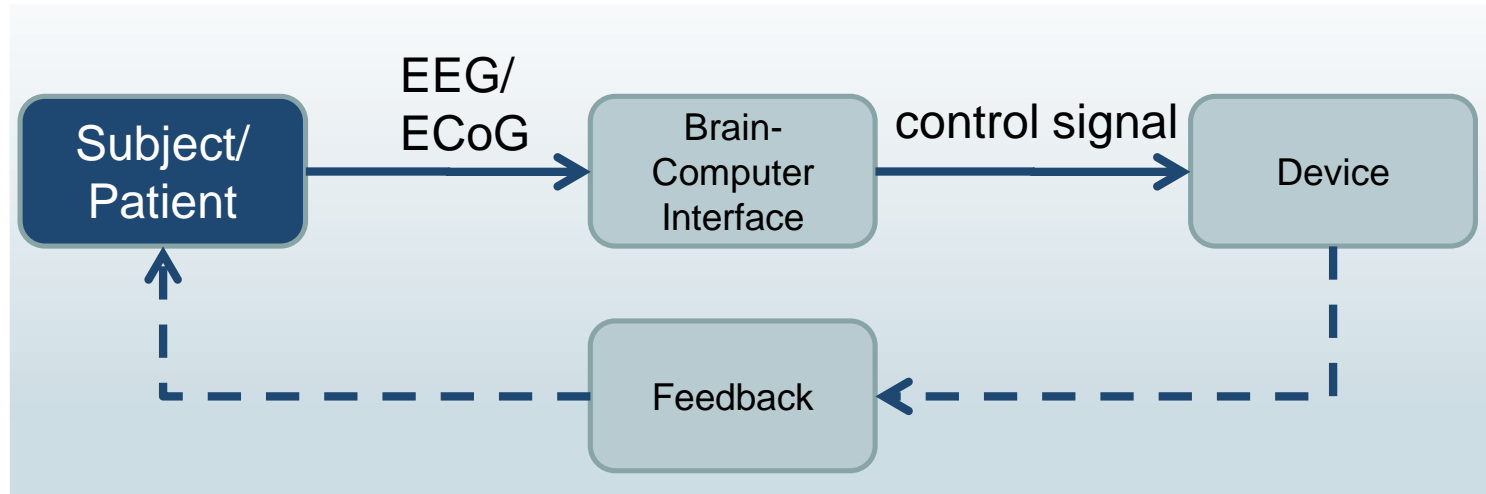


Magnetencephalogram (MEG, eg. arrays of SQUID)



Functional imaging techniques: fMRI, SPECT, PET





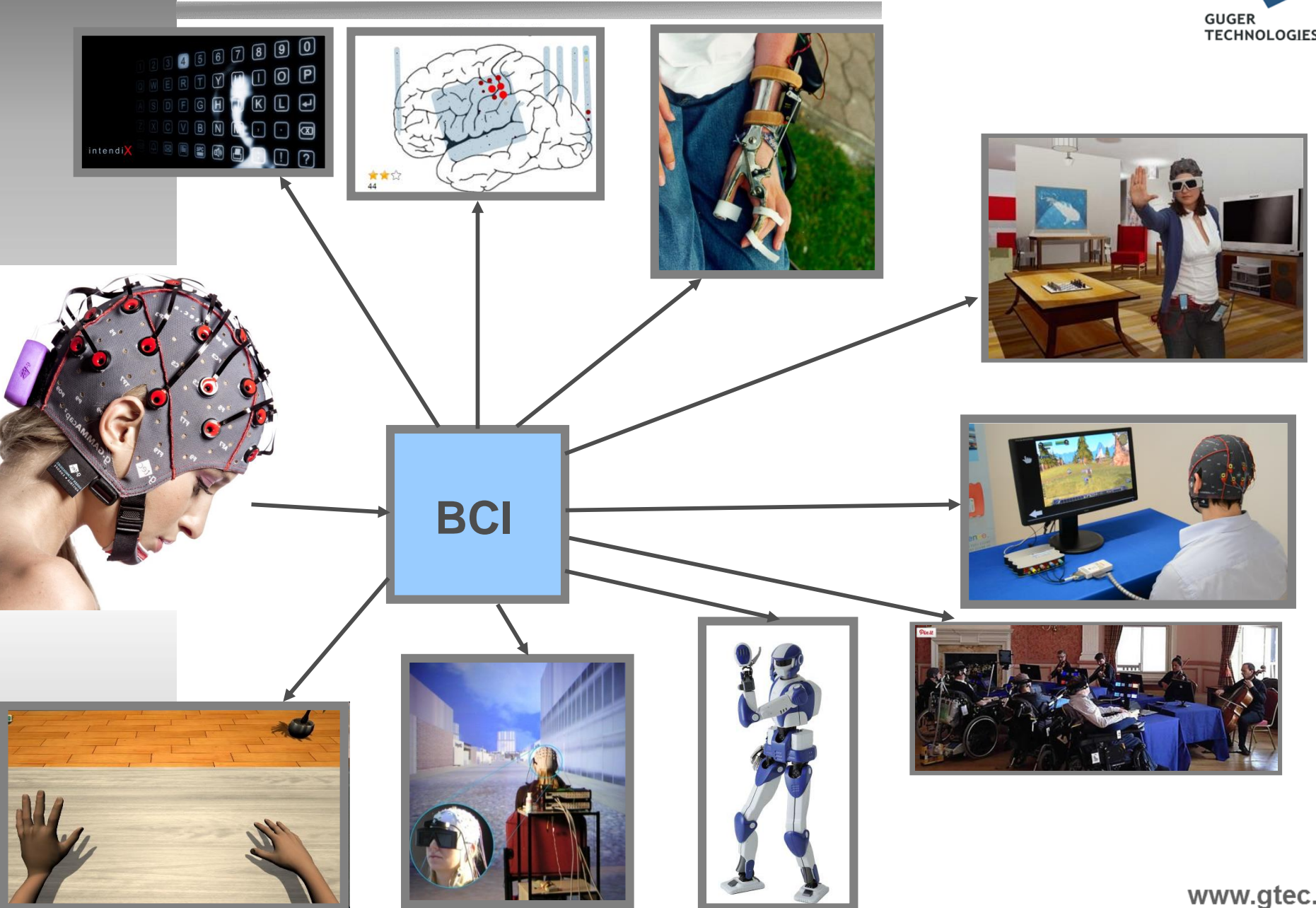
“A system for **controlling a device** e.g. computer, wheelchair or a neuroprosthesis by human intention which does not depend on the brain’s normal output pathways of peripheral nerves and muscles” [Wolpaw et al., **2002**].

HCI – Human Computer Interface

DBI – Direct Brain Interface (University of Michigan)

TTD – Thought Translation Device (University of Tübingen)

Some examples of BCI applications

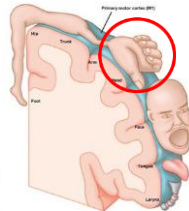


recoveriX GYM



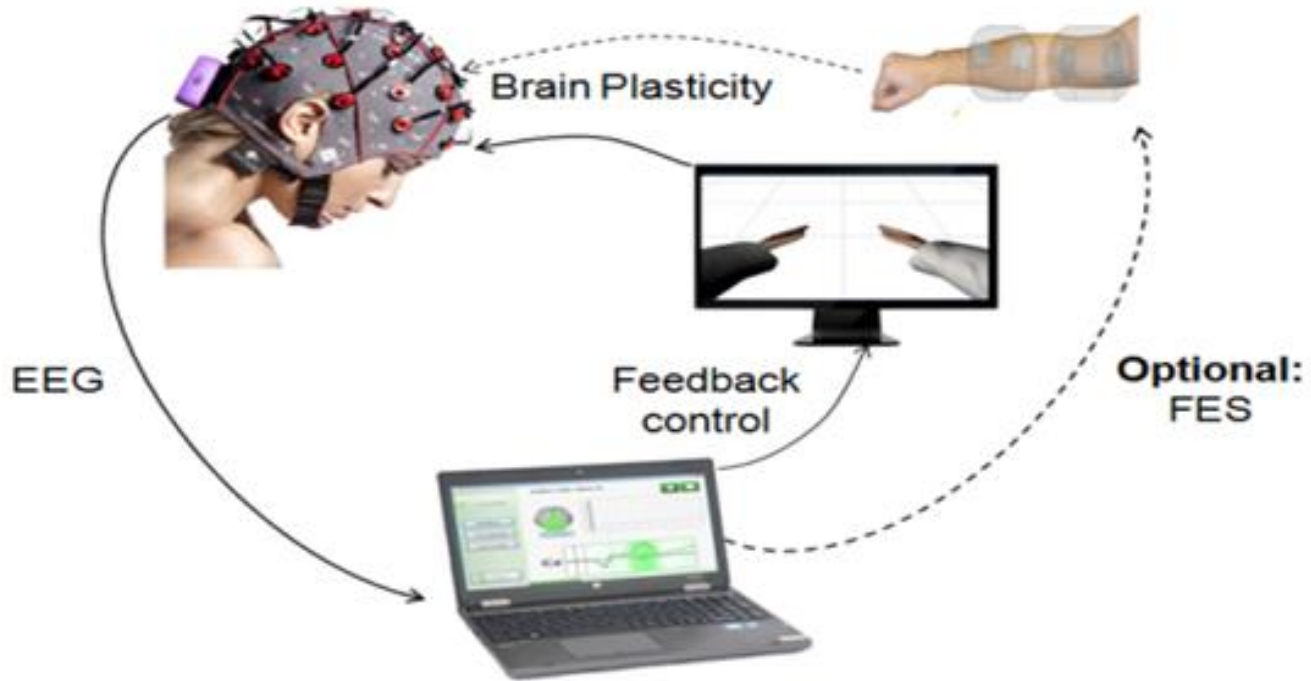
- Stroke can lead to movement impairment.
- Physiotherapy can help users perform specific movements while imagining them.
- However, there is no objective way to measure this movement imagery.





Functional Electrical Stimulation ...

... directly controlled via brain activation appears to be the most effective training method as it also activates afferent nerve connections to the sensorimotor cortex.

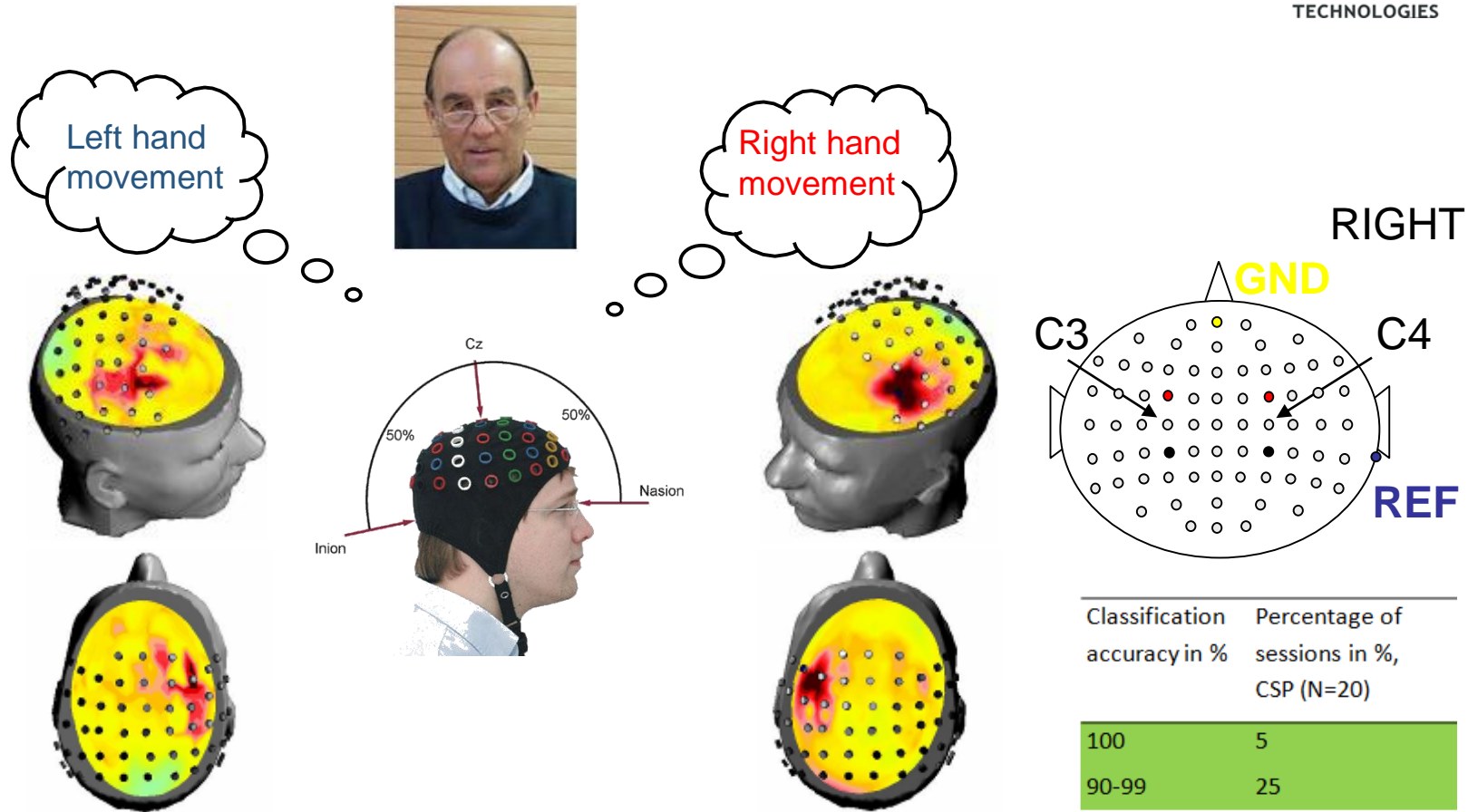


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Motor Imagery



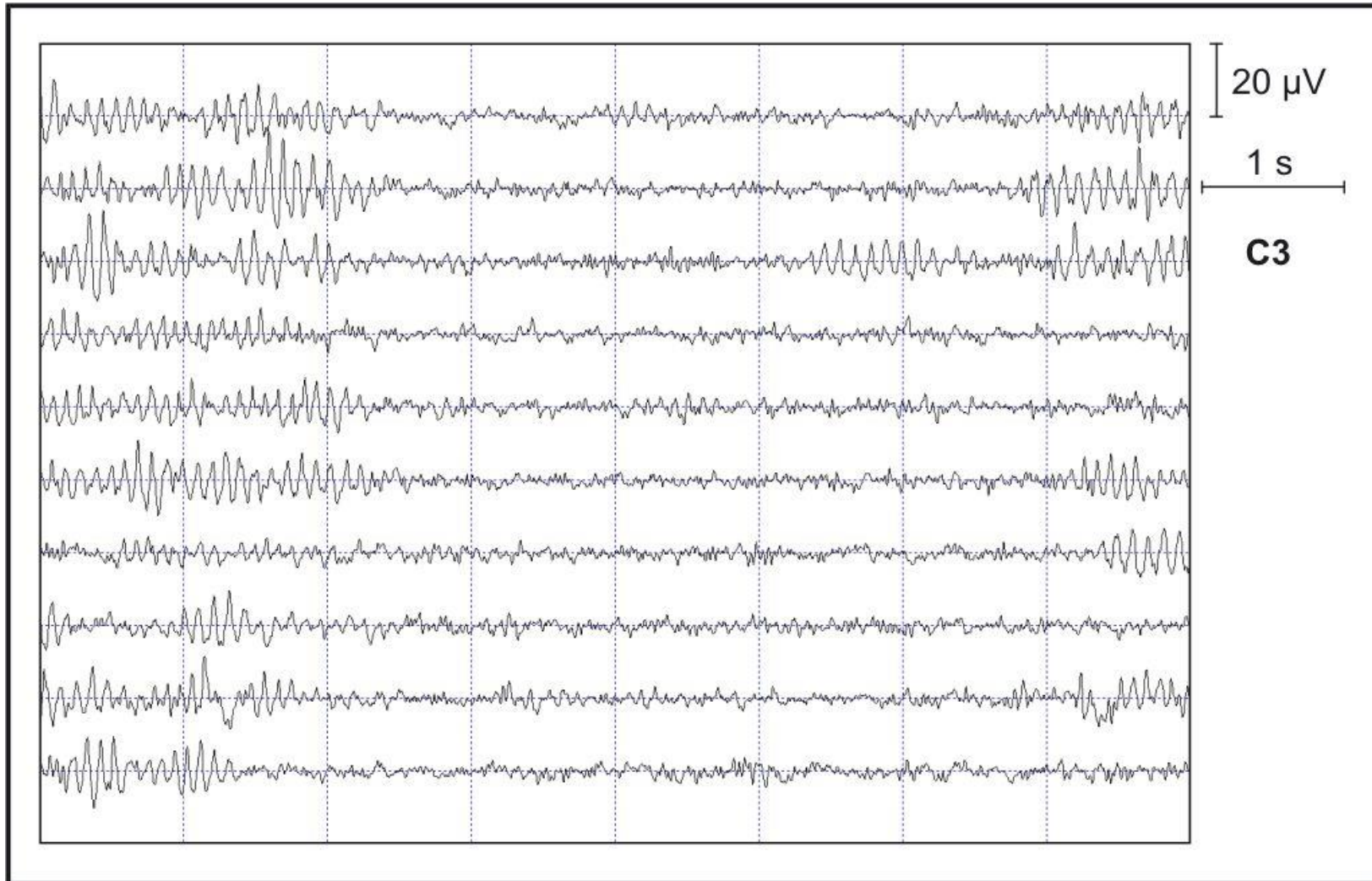
Imagination of hand movement causes an ERD which is used to classify the side of movement.

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

Classification	Percentage of 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

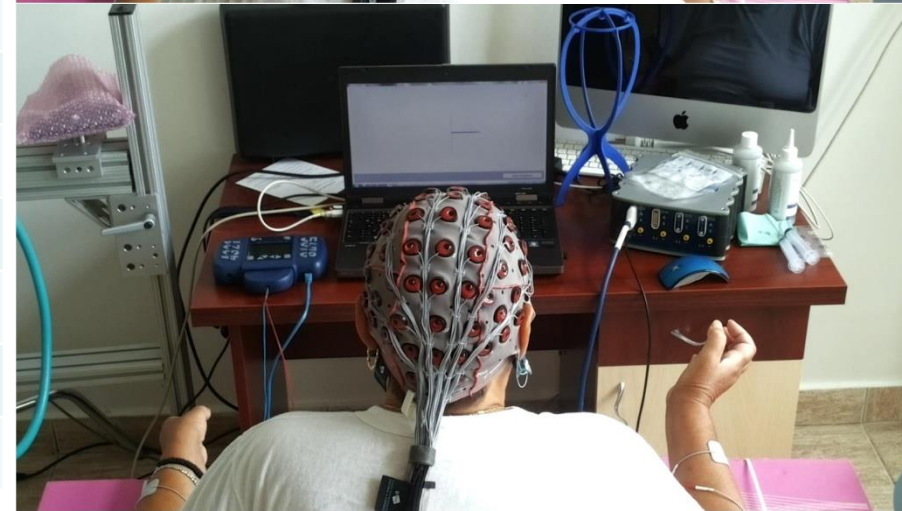
[recoveriX1](#)

Rehabilitation Hospital of Iasi,
Romania

Danut Irimia, Rupert Ortner, 2014

9-hole PEG test

Date:	Left hand	Falls	Right hand	Falls
2014				
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

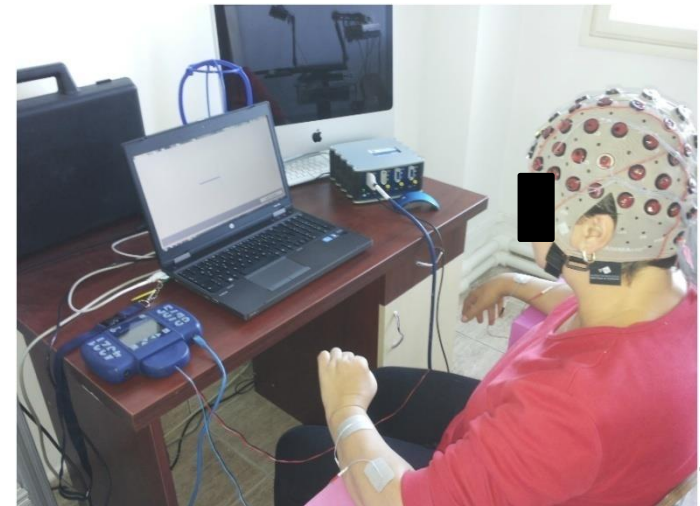
ChronicTraining video

[recoveriX2](#)

Initially:



BCI driven FES:



Scales for the measured variables

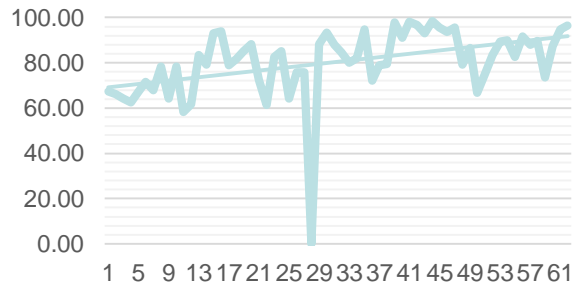
Scales
9 Hole Peg Test
Barthel Index
Fugl-Meyer Assessment
Modified Ashworth Scale
Fahn Tremor Rating Scale
VAS

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

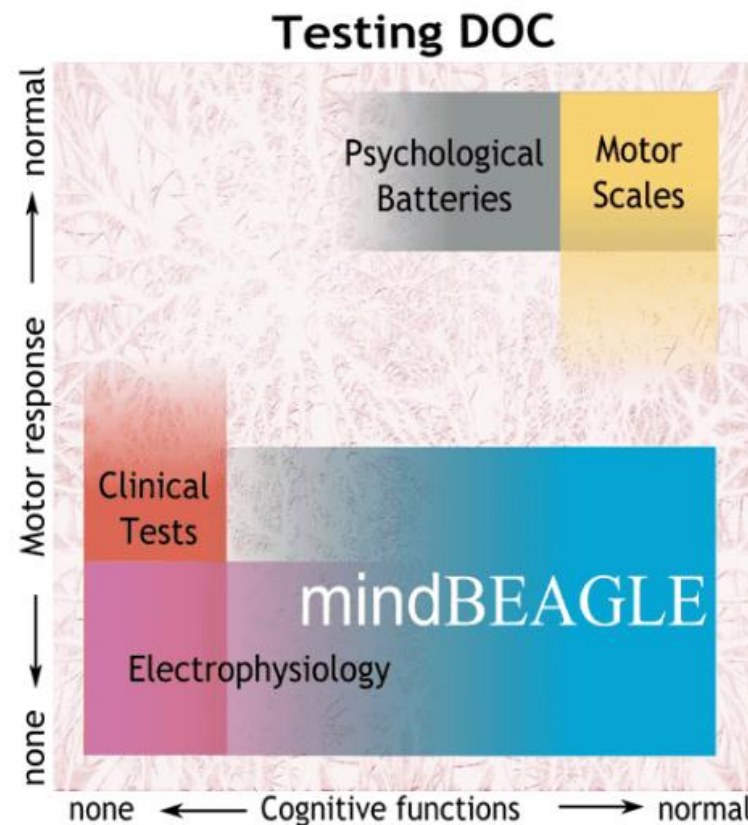
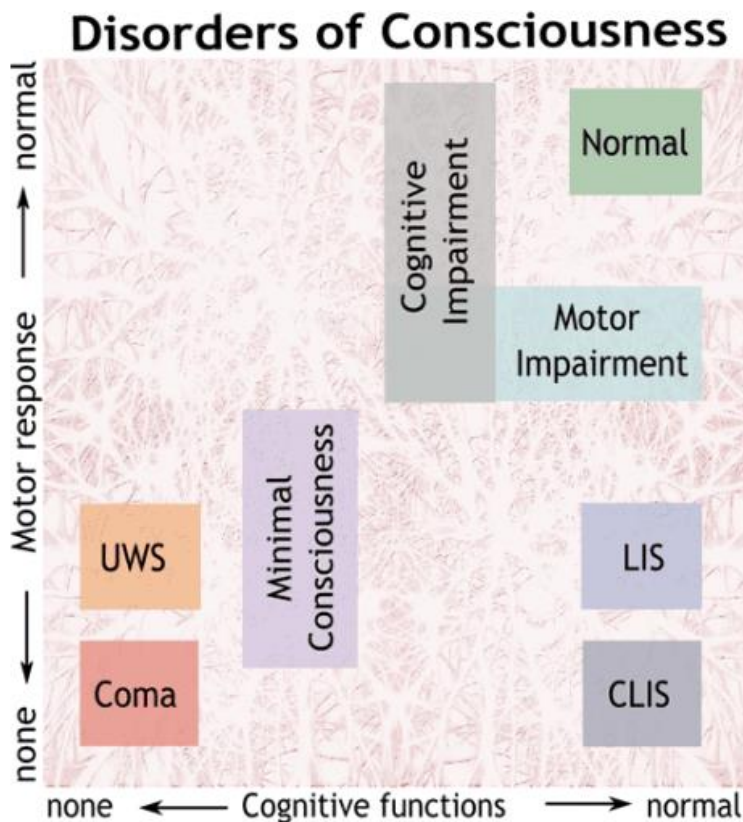
9HPT - Final	
Left	Right
00:17:85	07:26:58
00:15:29	03:21:71
00:14:38	01:34:14
00:14:42	03:13:18
00:16:49	01:52:52
00:16:12	01:48:67
00:15:18	02:06:75
00:14:80	02:21:96
00:16:60	01:04:24
00:13:95	01:51:96
00:15:23	01:24:73
00:13:28	01:25:15
	01:55:93

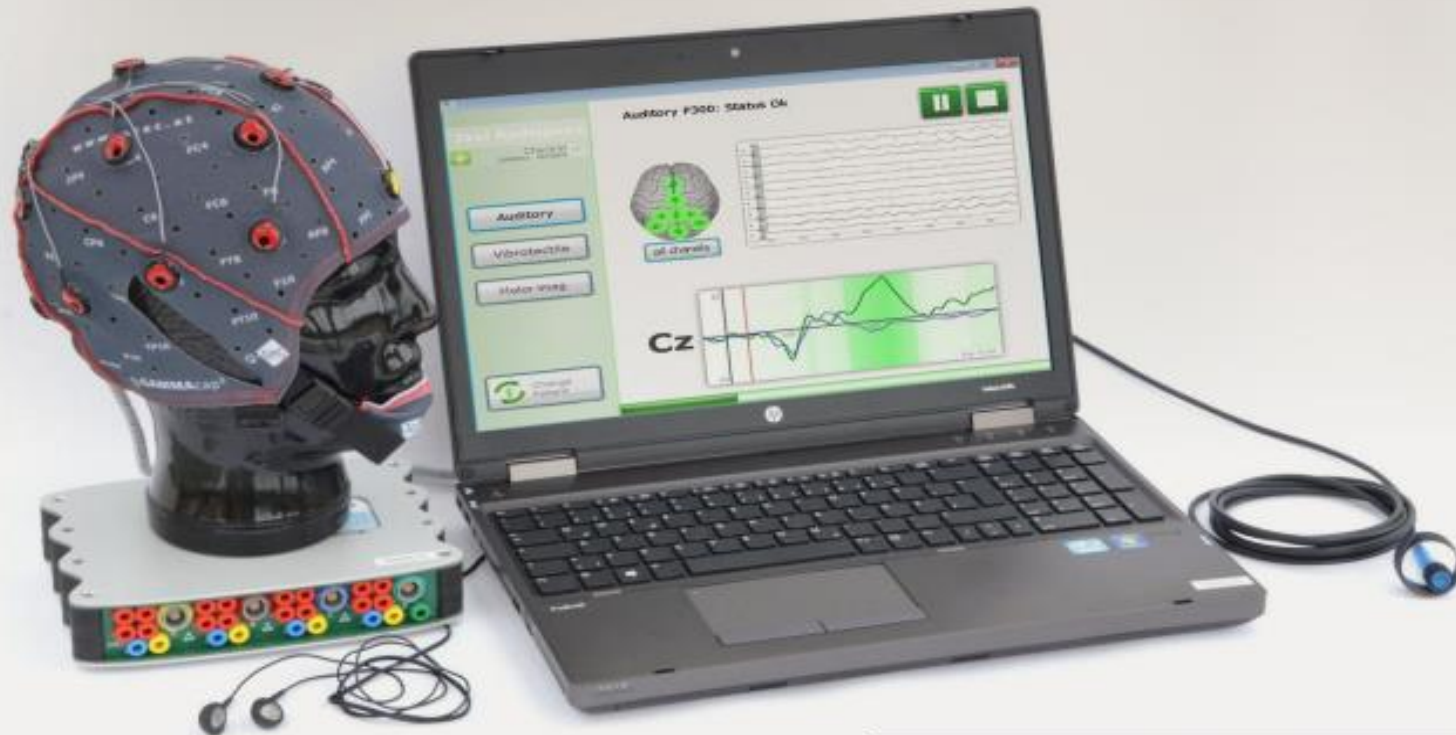
MaxAccuracy





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





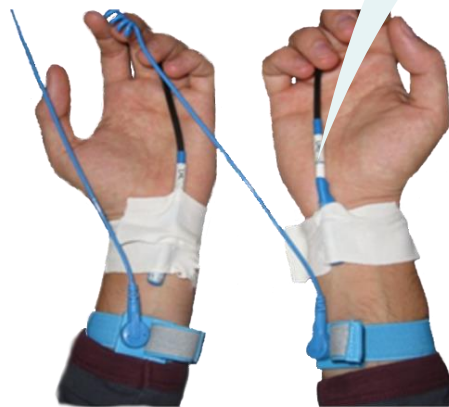
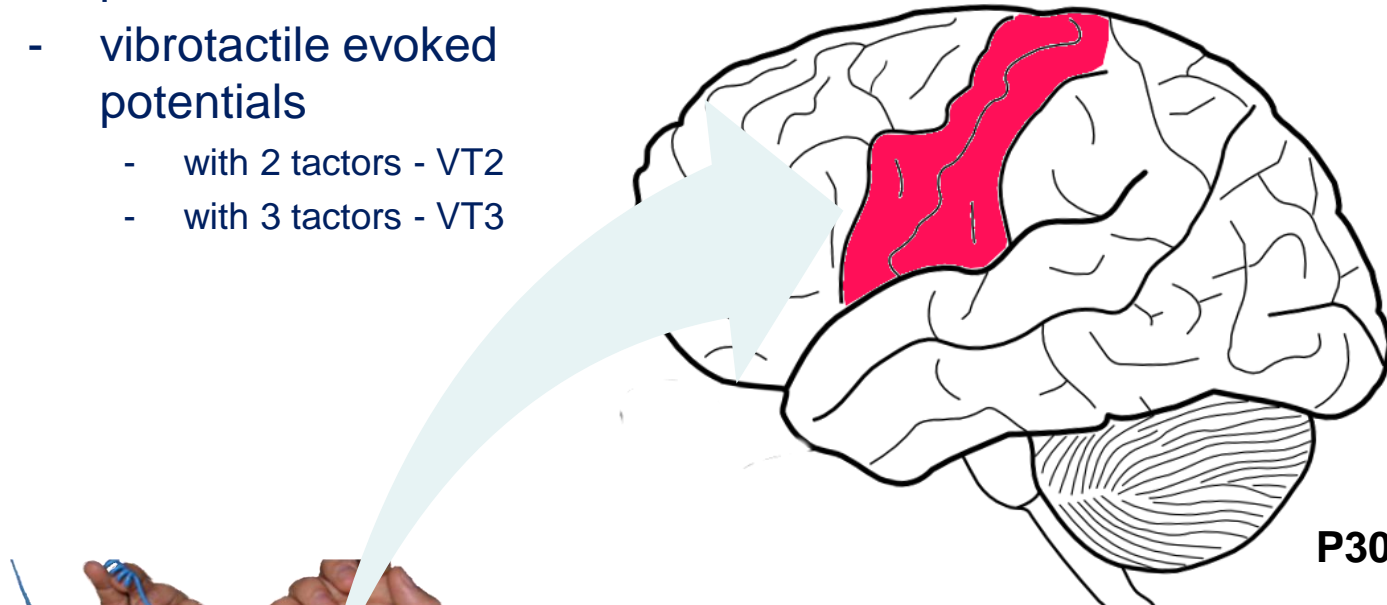
Note: The bio-signal amplifier (g.usBamp) is an FDA-listed and CE-certified medical device. The complete mindBEAGLE system is not yet a certified medical system. Positive and significant results may be interpreted as a strong indication for responsiveness of a patient but the opposite is not the case!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

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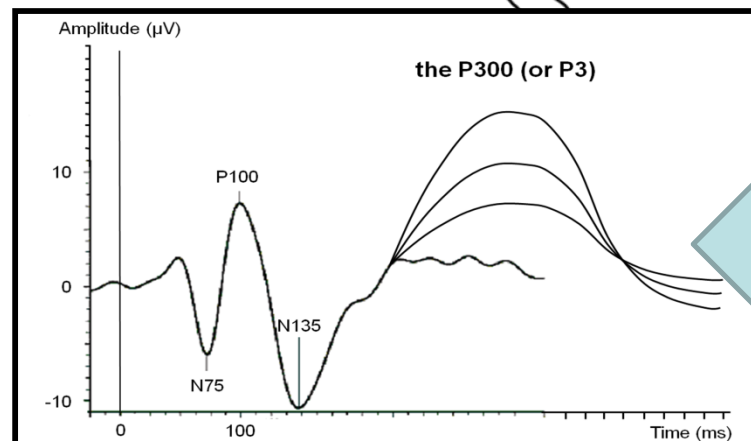


Principle I - DOC assessment

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



P300 response



Auditory result

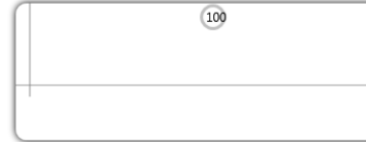
8 min experimental time
Low versus high tones
BCI accuracy
EPs with significance

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

Auditory P300



Patient evolution



pre-surgical
expected thalamus removal

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)

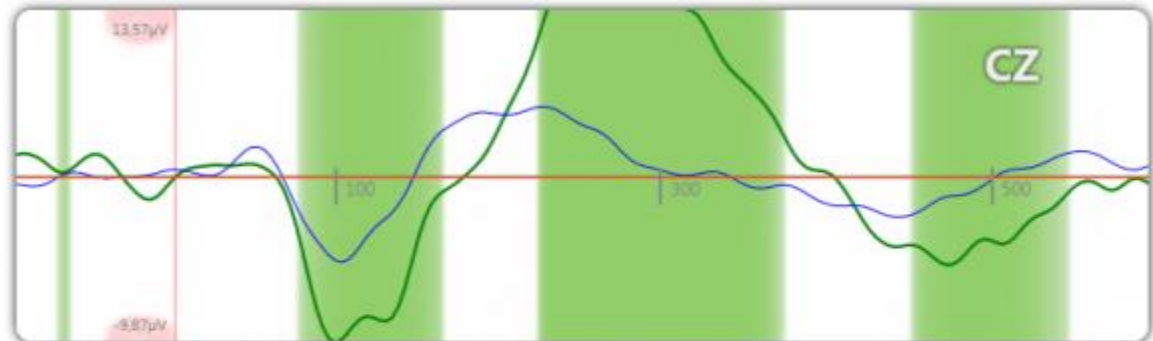


The maximum Accuracy is 100% after 3 Stimuli.

8 trials, out of 480, where classified as Artifact. (1.7%)



The Max. Accuracy is 100% after 4 stimuli.
2 out of 480 artifacted trials. Good

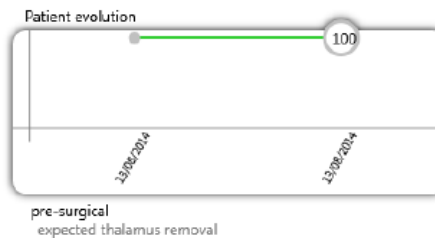


Vibrotactile result

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

Chr. Guger - 13/08/2014 09:01:57

VibroTactile 2CH

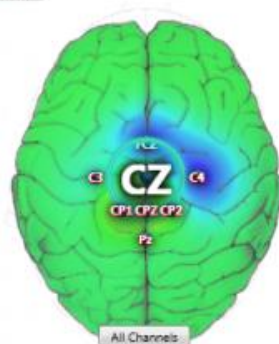
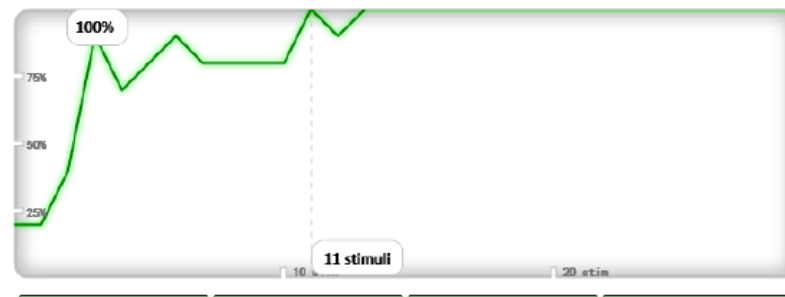


Physician Mr James Swift
Amplifier GUsbAmp UB-2009.07.12
Bandpass filters 0.1 - 30Hz.
Sample rate 256
Stimuli per character 120 (15 targets)
Ratio of targets 1/8 targets
Experiment length 2 min 30 sec
Used classifier 100at_13_20140813_0845

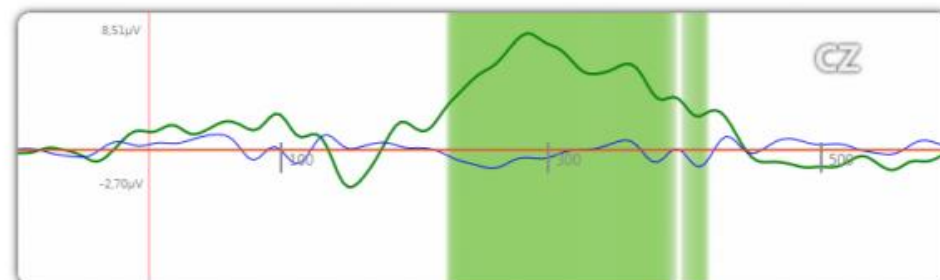


The maximum Accuracy is 100% after 11 Stimuli

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



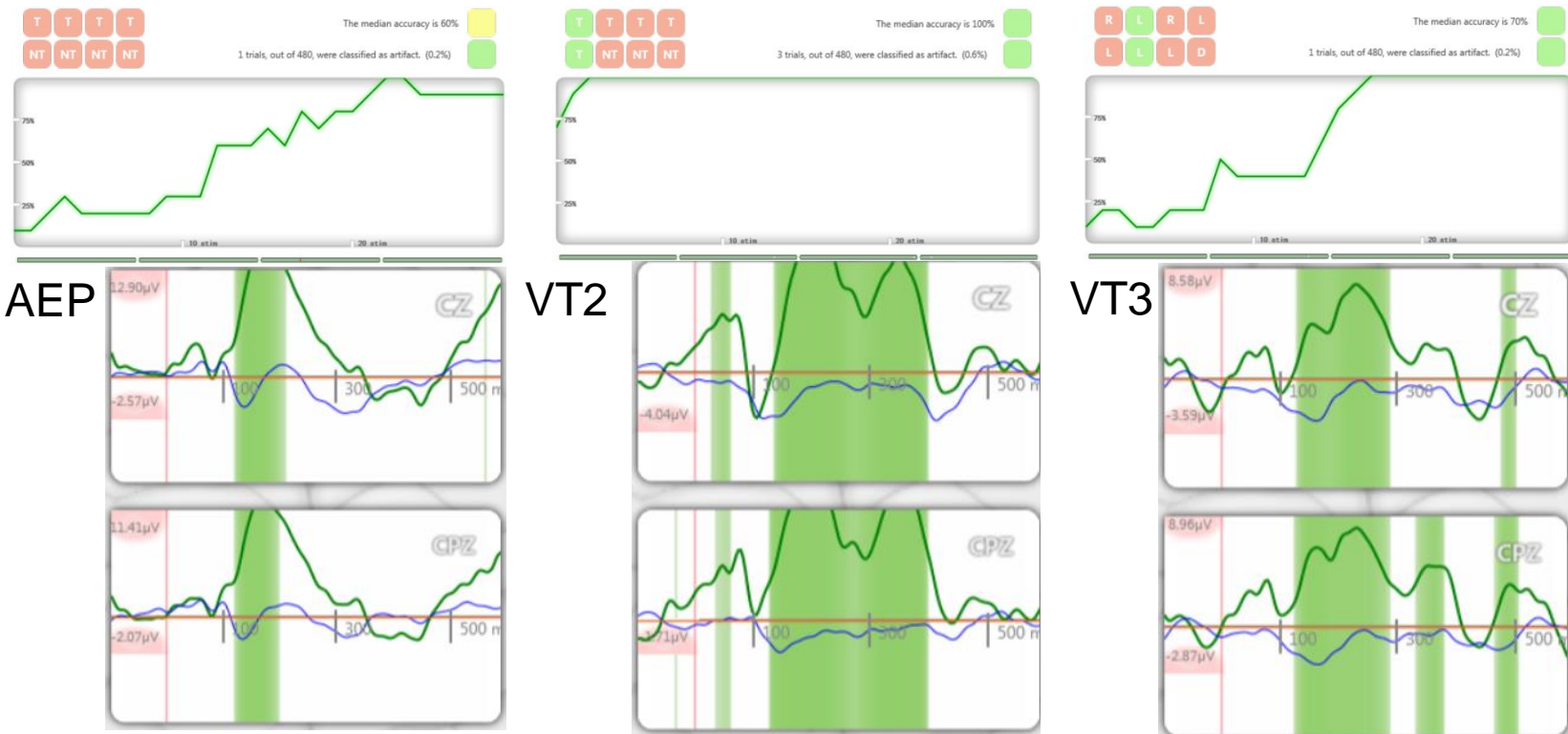
The Max. Accuracy is 100% after 11 stimuli.
0 out of 480 artifacted trials. Good



Successful assessment

MCS- on day of mindBEAGLE

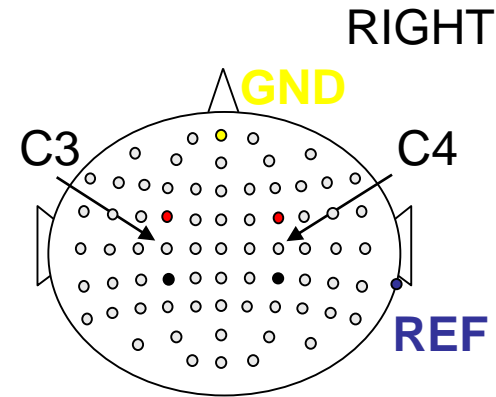
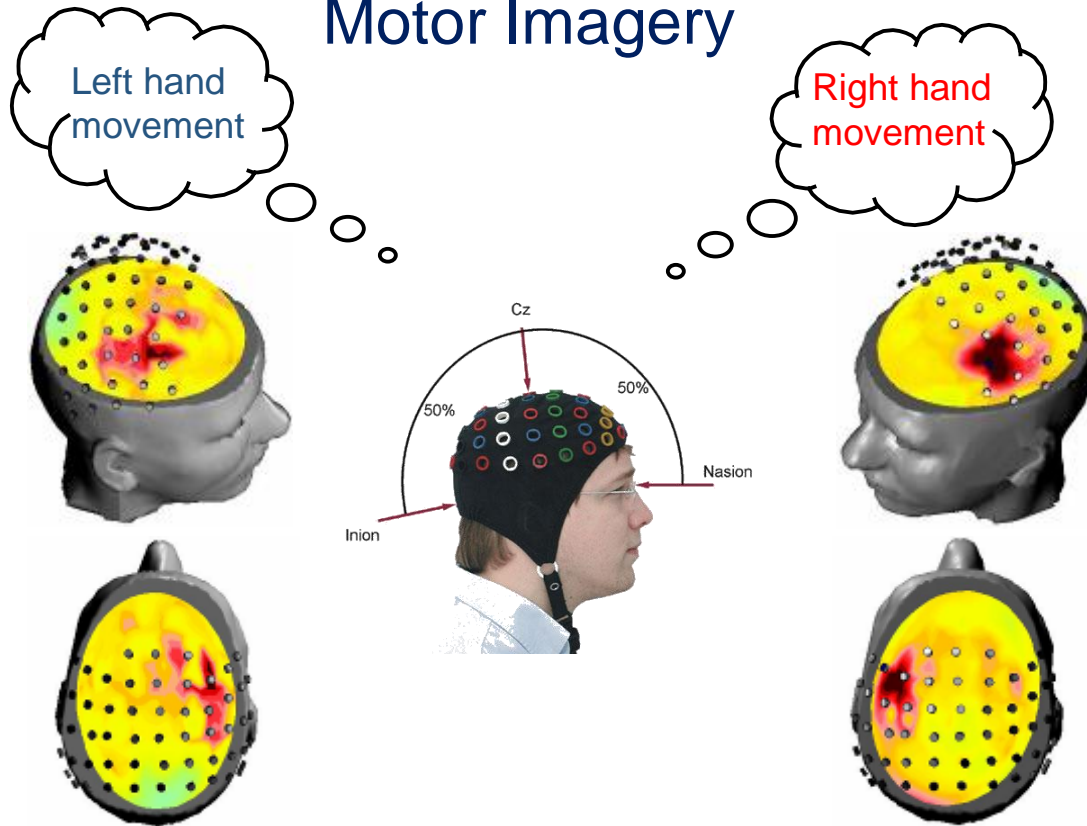
Tried communication with 8 questions, she only responded yes to:
'Do you want to go swimming?'



Principle II - Communication



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 %	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	

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

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ORIGINAL RESEARCH ARTICLE

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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

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3,043
TOTAL VIEWS

 score 513

 View Article Impact



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

EPs and accuracies for VT2, VT3, and MI

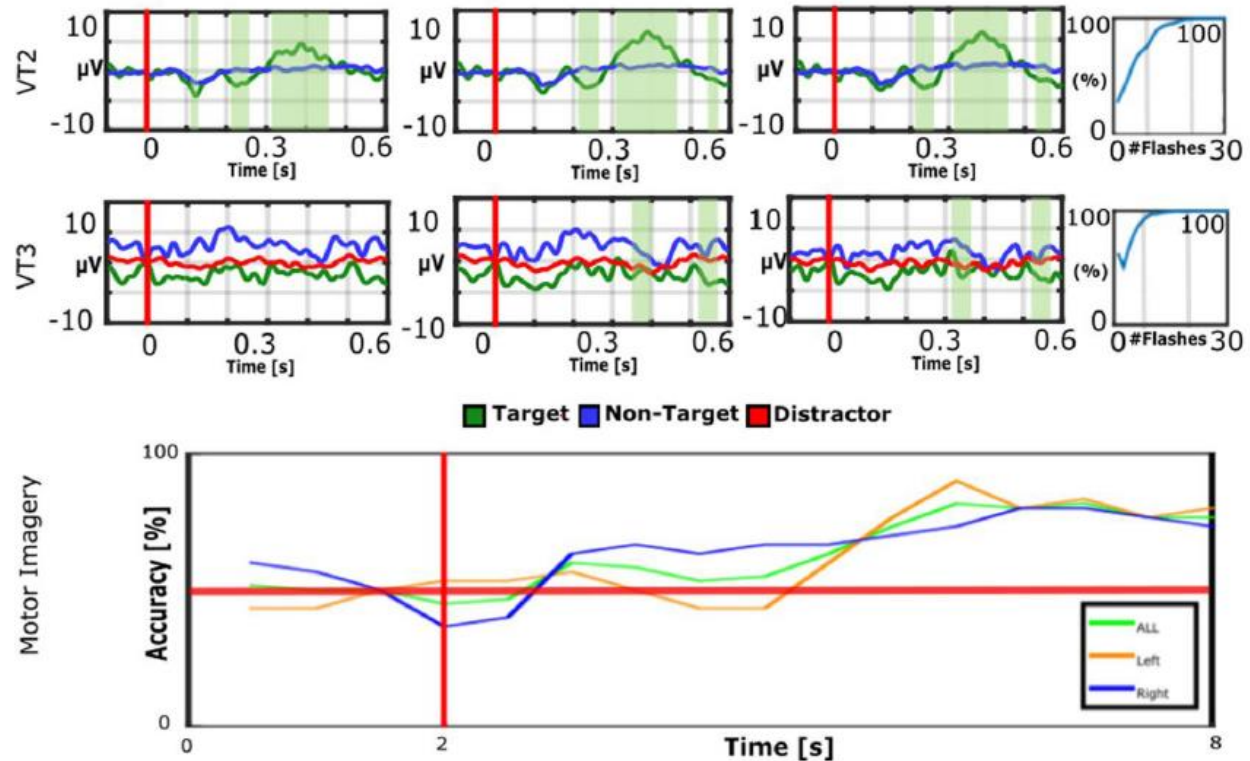

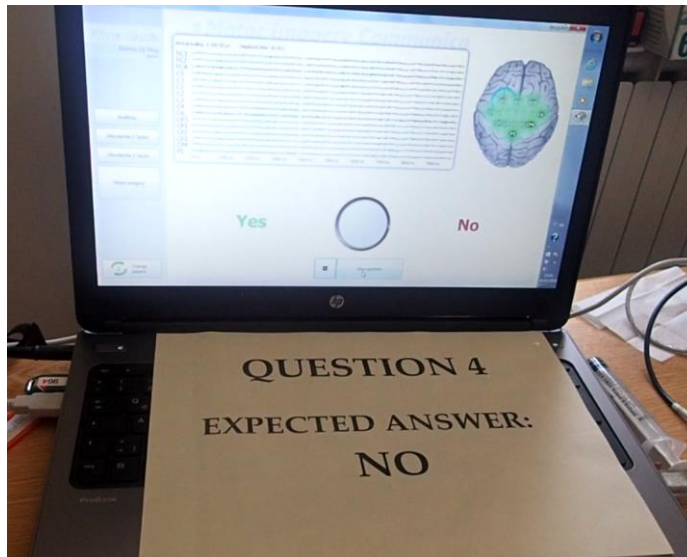


FIGURE 3 | EPs and accuracies for VT2, VT3, and MI runs of LIS patient 5. The patient achieved an average accuracy of 83% for MI, 100% for VT2, and 100% for VT3. Communication was possible with the MI and VT3 paradigms. In the bottom figure, the vertical red line indicates when the cue is presented to 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 ASSESMENT & COMMUNICATION

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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.

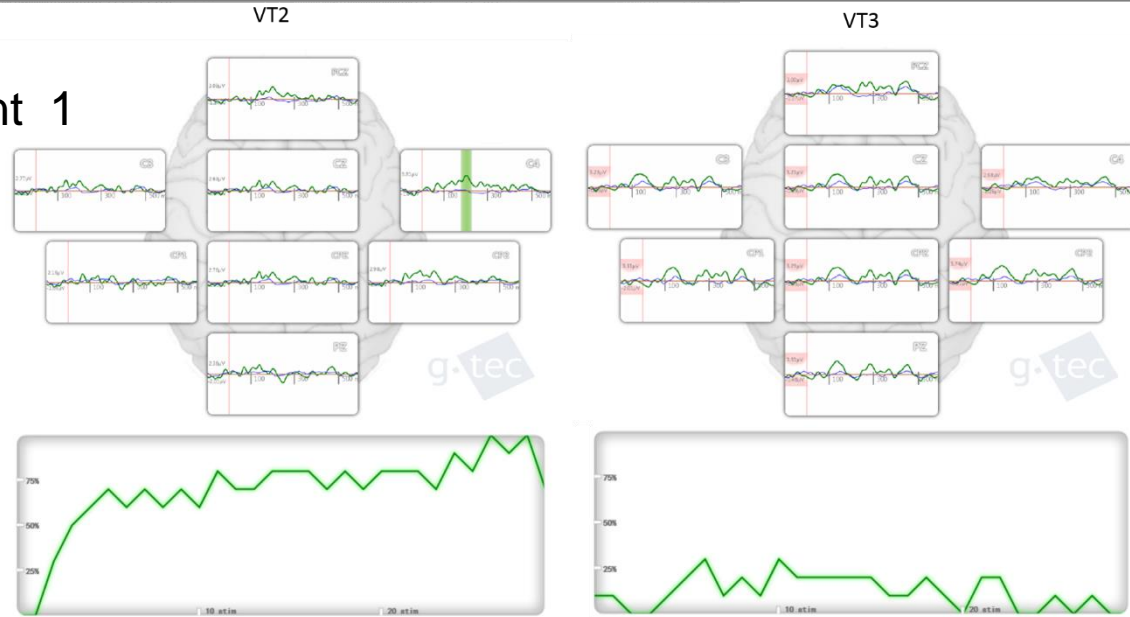
Classification accuracies

- 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*)

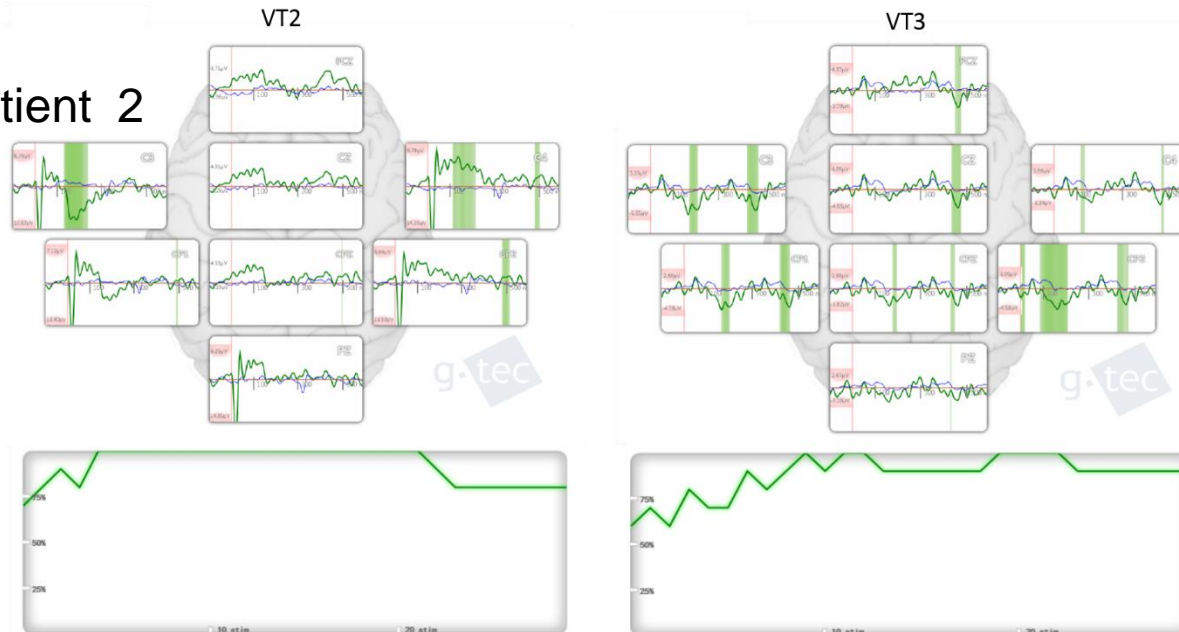
P	Session #	AEP [%]	QT	VT2 [%]	QT	VT3 [%]	VT3 Com	MI [%]	MI Com
1	1	20	-	70	Yes	10	No	51	-
	2	-	-	-	-	0	No	-	-
2	1	80	Yes	50	No	10	No	53.8	No
	2	-	-	80	Yes	30	No	-	-
	3	-	-	85	Yes	-	-	-	-
	4	100	Yes	100	Yes	40	No	44	No
	5	-	-	-	-	90	YES	-	-
3	1	40	No	100	Yes	90	No	51.3	No
	2	-	-	-	-	40	No	-	-

Vibro-tactile EPs – P1 and P2

- Patient 1

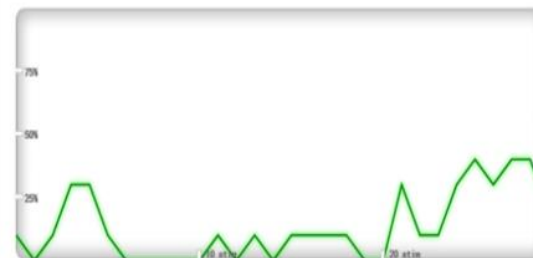
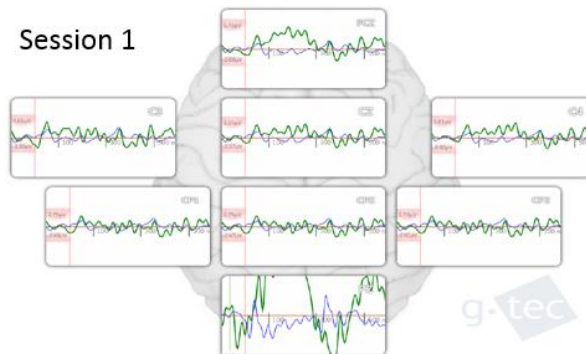


- Patient 2

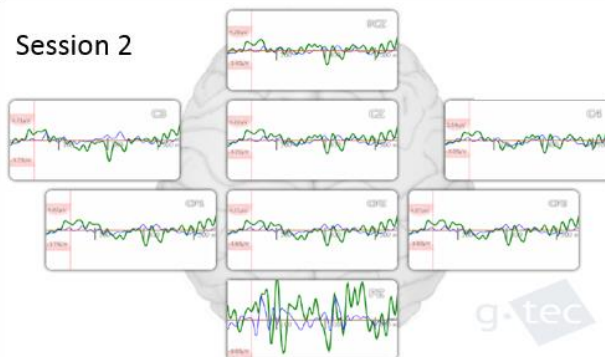


VT3 paradigm – P2/multiple sessions

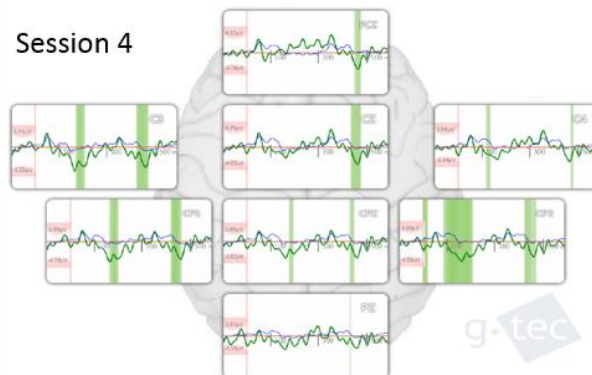
Session 1



Session 2



Session 4



- 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



- A** g.MOBilab+ EEG version
 multi-purpose version



g.GAMMAcap



Consumables

- Electrodes active
 passive
 dry



- B** g.USBamp 16 channels
 32 channels
 48 channels
 64 channels



- C** g.HIamp 80 channels
 144 channels
 256 channels



- D** g.Nautilus 8 channels
 16 channels
 32 channels



- Eyetracker (screen-mounted)
 Eyetracker (head-mounted)



Electrical stimulator



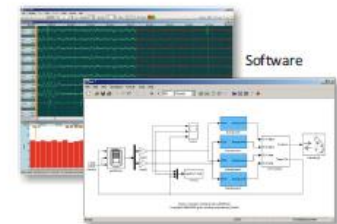
g.STIMbox
 g.SSVEPbox



Impedance tester
 Signal generator



VR-system



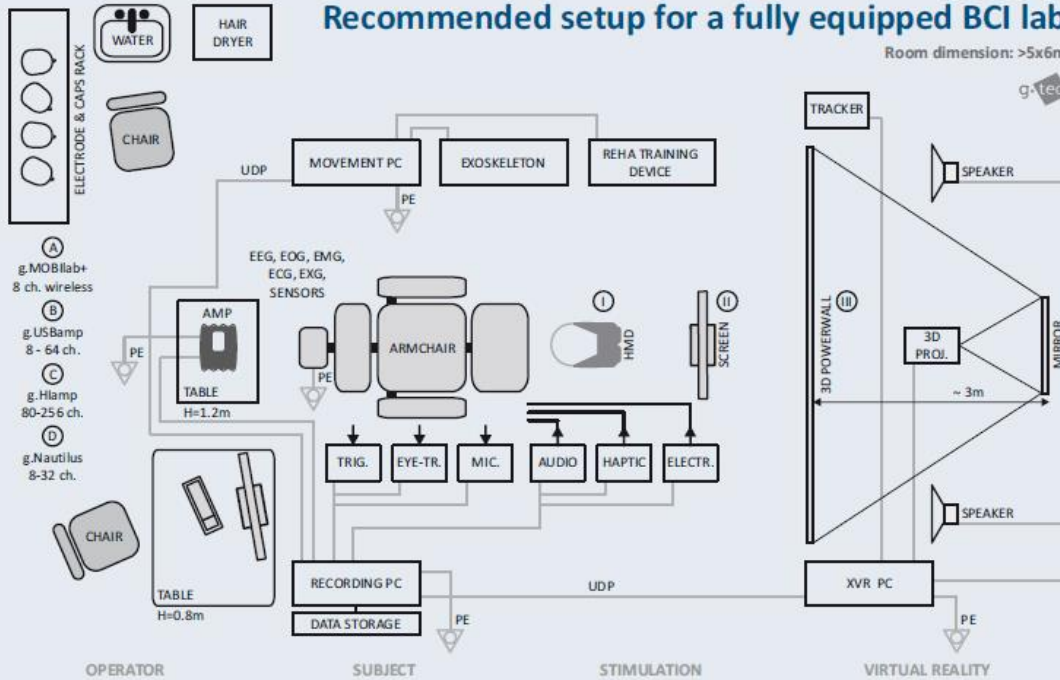
Software

- | | |
|---|---|
| <input type="checkbox"/> g.RECorder | <input type="checkbox"/> Examples |
| <input type="checkbox"/> g.BSanalyze | <input type="checkbox"/> P300 |
| <input type="checkbox"/> g.HIsys (Simulink) | <input type="checkbox"/> Motor imagery |
| <input type="checkbox"/> g.HIsys (LabVIEW) | <input type="checkbox"/> SSVEP |
| <input type="checkbox"/> IntendiX | <input type="checkbox"/> CSP/RehaBCI |
| <input type="checkbox"/> BCI2000 | <input type="checkbox"/> Vibro-tactile P300 |
| <input type="checkbox"/> C/MATLAB/Linux API | <input type="checkbox"/> Ping-Pong game |
| <input type="checkbox"/> g.RTanalyze | <input type="checkbox"/> Hyperscanning |
| <input type="checkbox"/> g.PHYSIOobserver | <input type="checkbox"/> Hybrid BCI |
| <input type="checkbox"/> g.UOPinterface | <input type="checkbox"/> EMG/EKG control |
| <input type="checkbox"/> mindBEAGLE | Training material |
| <input type="checkbox"/> cortiQ | <input type="checkbox"/> EEG lecture |
| <input type="checkbox"/> Eyetracker interface | <input type="checkbox"/> EP lecture |
| <input type="checkbox"/> g.NEEDaccess | <input type="checkbox"/> BCI lecture |

Request an offer for a complete lab
 minimum basic advanced

Recommended setup for a fully equipped BCI lab

Room dimension: >5x6m



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