SOCIETÀ ITALIANA DI FISICA

Neuronal networks and Electroceuticals

Franca Tecchio

Istc, Cnr

***Let's** - Laboratory of **E**lectrophysiology for **T**ranslational neuro**S**cience*
Via Palestro & Gemelli Hospital, Rome, Italy

Neuronal networks and Electroceuticals

Electroceuticals

neuromodulation via neurodynamics knowledge

Individual neurodynamics & personalized neuromodulation

population-based & individual-based

Medical physics & Electroceuticals

A new profession?

Franca Tecchio

Zoom, September 16th, 2021

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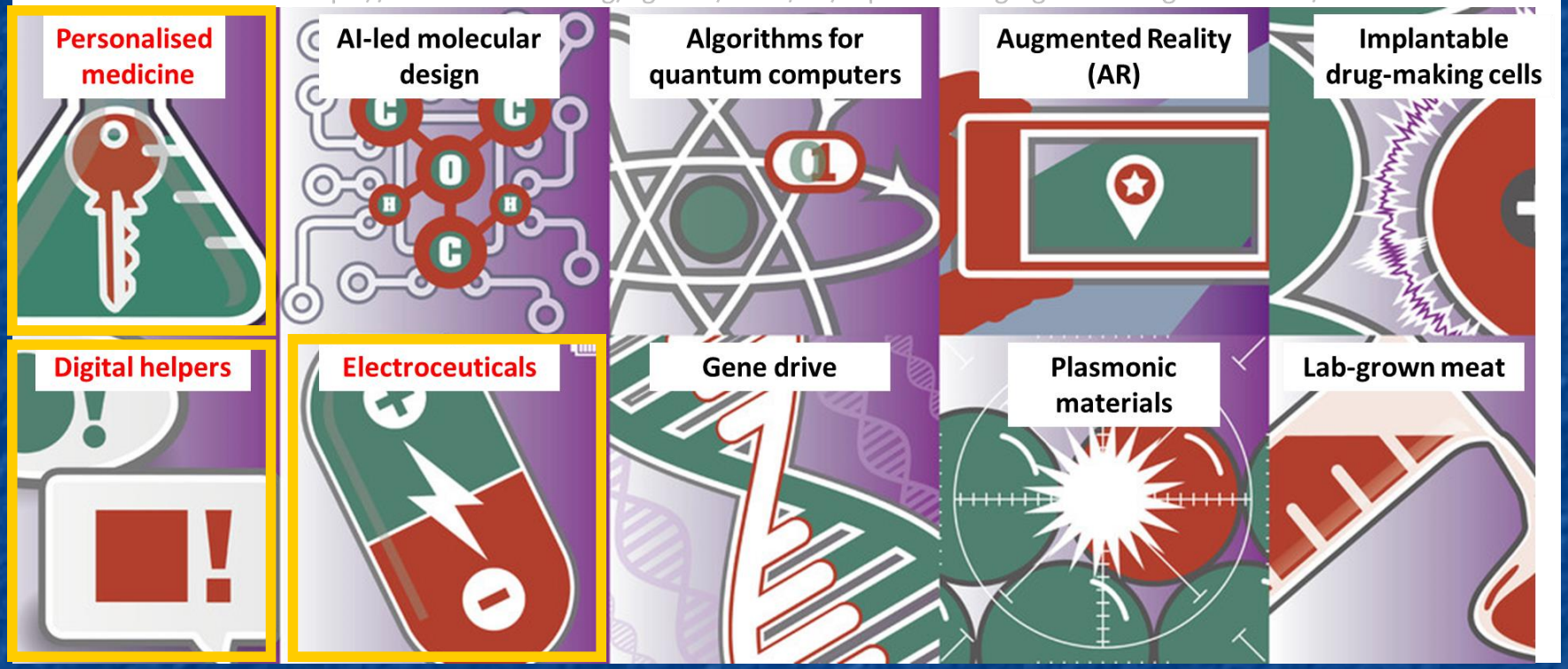
WORLD ECONOMIC FORUM

Davos 2018

Top 10 emerging technologies

https://www.weforum.org/agenda/2018/09/top-10-emerging-technologies-of-2018/



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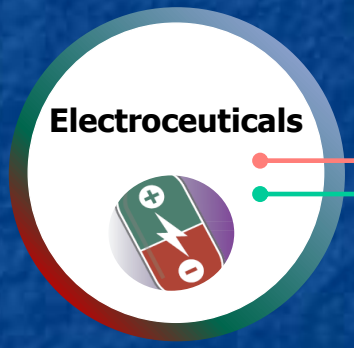
Electroceuticals

devices that treat ailments with electrical signals



Invasive

- Heart
  -
  - Pacemaker `60
- Brain
  -
  - Deep Brain Stimulation (DBS) FDA 2002
- Peripheral Nerves
  -
  - Vagal Nerve stimulation 1997

Non - Invasive

- Brain
  -
  - rTMS
  -
  - transcranial Electric Stimulation (tES)
- Peripheral Nerves
  -
  - Vagal Nerve

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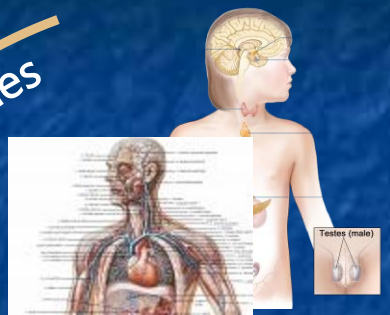
Endocrine system

Cytokines

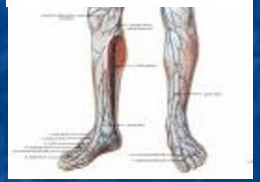
Hormones

Hormones

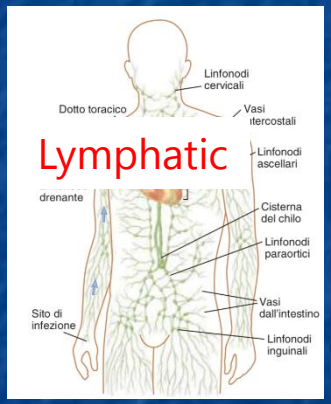
Neuropeptides



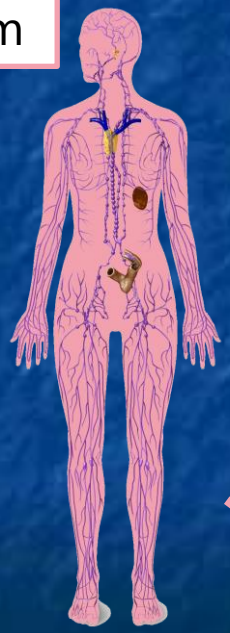
Circulatory



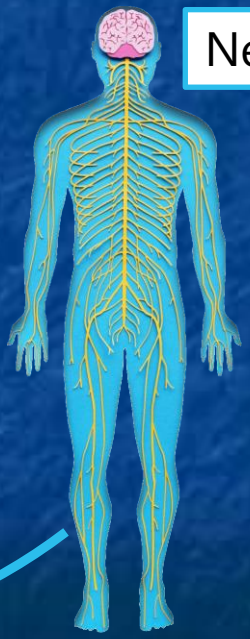
Immune system



Lymphatic

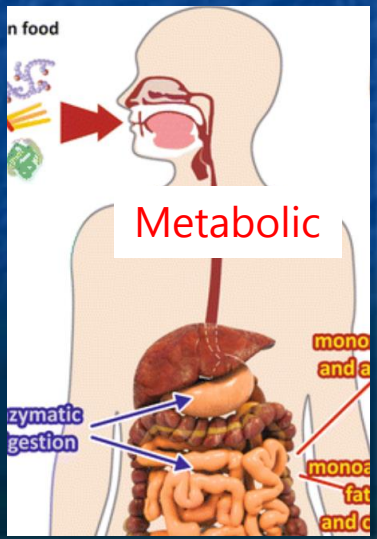


Nervous system



Cytokines

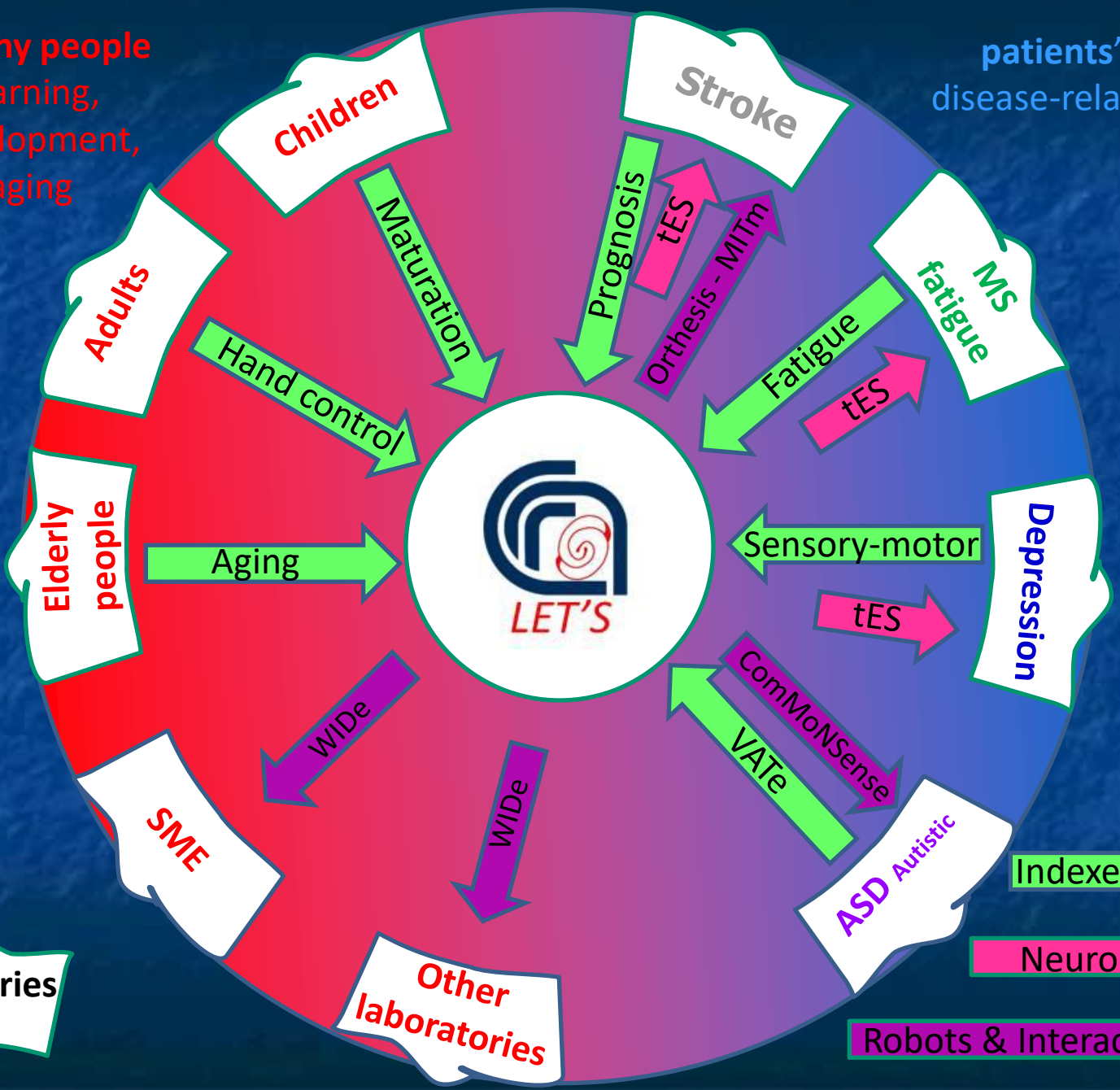
Neuropeptides



works to build interventions supporting

healthy people learning, development, aging

patients' relief from disease-related sufferance



Actions

Indexes sensitive to

Neuromodulation

Robots & Interacting Devices

Beneficiaries

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Electroceuticals

neuromodulation via neurodynamics knowledge

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Fatigued MS people

Population

Beneficiaries: Chronic fatigued people with MS

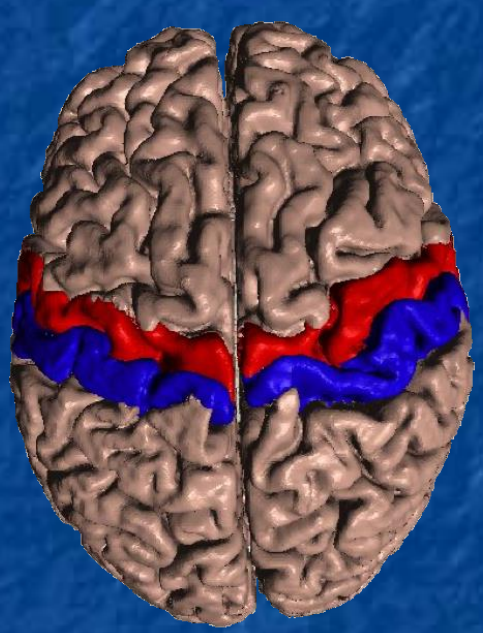
- 50% people with MS perceive fatigue as most invalidating symptom
- No effective treatments with major side effects
- Neuronal electric activity (neurodynamics) imbalances

Drug	Side effect
Amantadine	Dizziness Headache Insomnia Nausea Anxiety Ache
Modafinil	
Fluoxetina	
Fampyra	

Fatigued MS people

Population alteration

Neurodynamics alteration



M1: increased excitability

S1: decreased excitability

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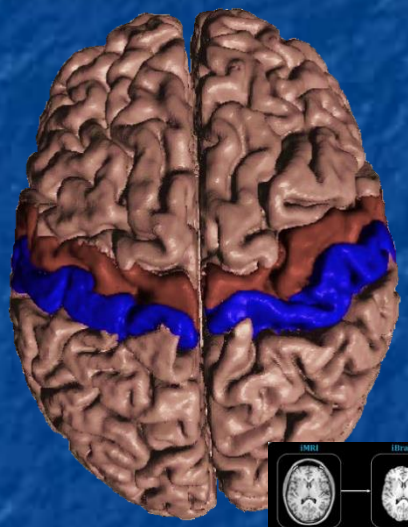
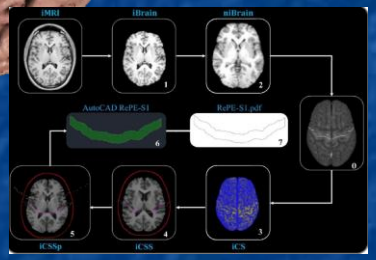
Fatigued MS people

Intervention

Personalized Neuromodulation **FaReMuS** (Fatigue Relief in Multiple Sclerosis)

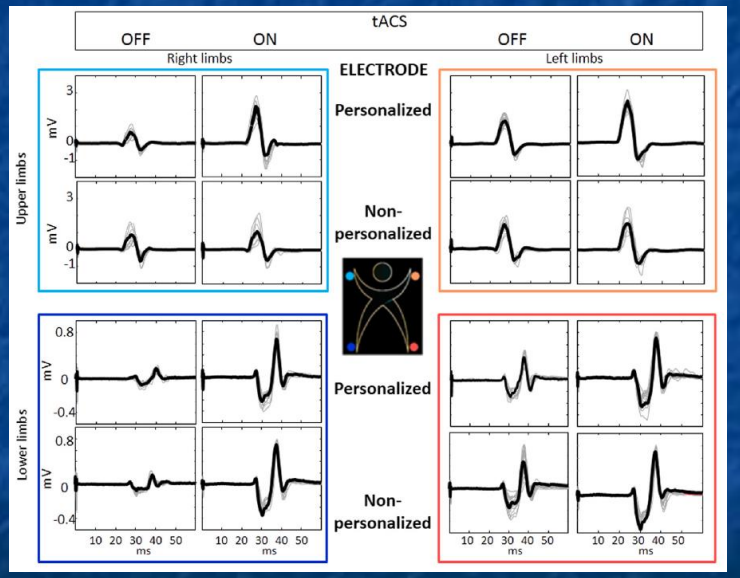


Anode: Regional Personalized Electrode (35 cm^2), shaped on MRI derived individual cortical folding; Cathode: Oz (70 cm^2)



Personalizing the electrode is necessary to neuromodulate an extended Cortical region

Tecchio et al FrontHumNeurosci 2013
Cancelli et al FrontNeurosci 2018



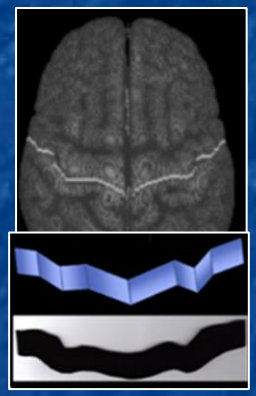
Cancelli et al BrainStim 2015
12 HVs

Fatigued MS people

Intervention

Randomized Controlled Trials (RCT) double-blind cross-over

Before Day 0



Electrode Shaping

Block 1 (Real/Sham)

Electrode positioning

tDCS stimulation

Day 1, 2, 3, 4, 5

Block 2 (Sham/Real)

Electrode positioning

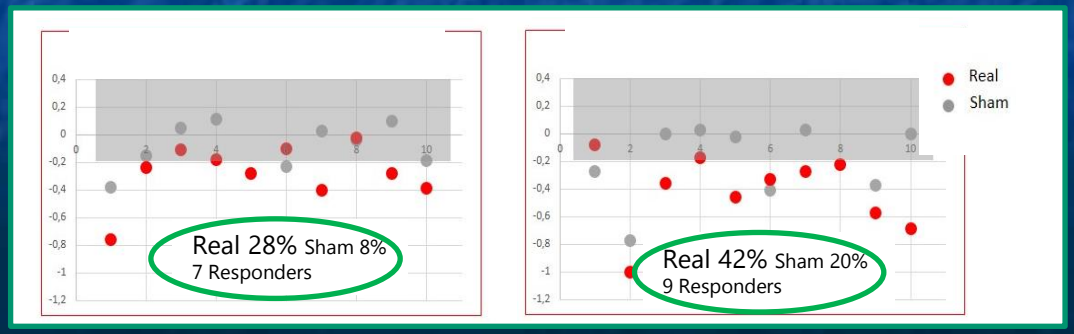
tDCS stimulation

Day 1, 2, 3, 4, 5

*2 independent CONSORT-Class1 RCTs – **Faremus** efficacy*

(Consolidated Standards of Reporting Trials) checklist for RCTs of non-pharmacologic treatments

	Effect Size [large>0.8]
Tecchio et al J Neurol 2014	1.1
Cancelli et al MSJ 2018	1.6



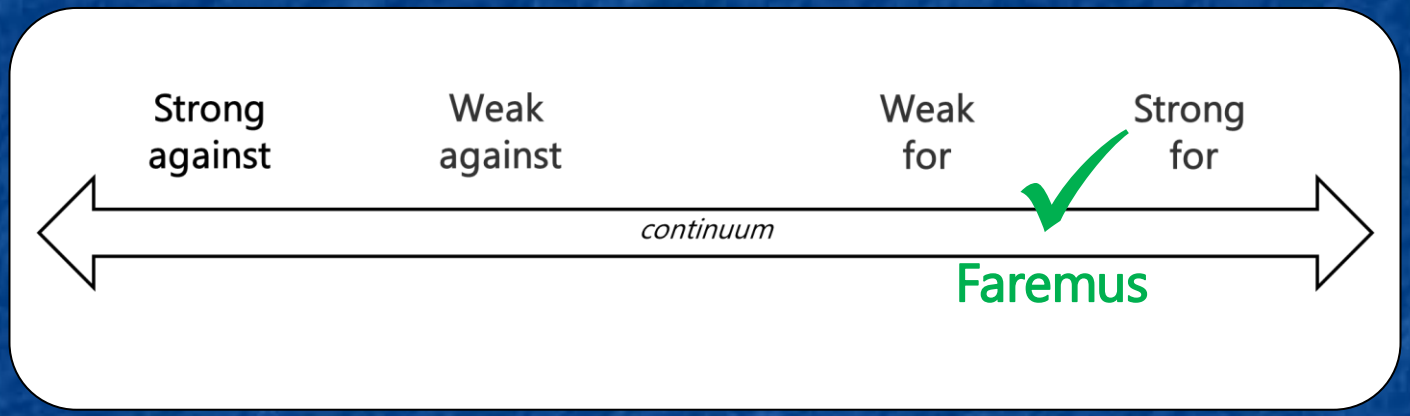
tES neuromodulation

Recommendation within PICO framework

Cochrane collaboration guidelines:

Grading of Recommendations, Assessment, Development and Evaluation

GRADE strength of recommendation



Gianni Bertoli Simonelli et al submitted

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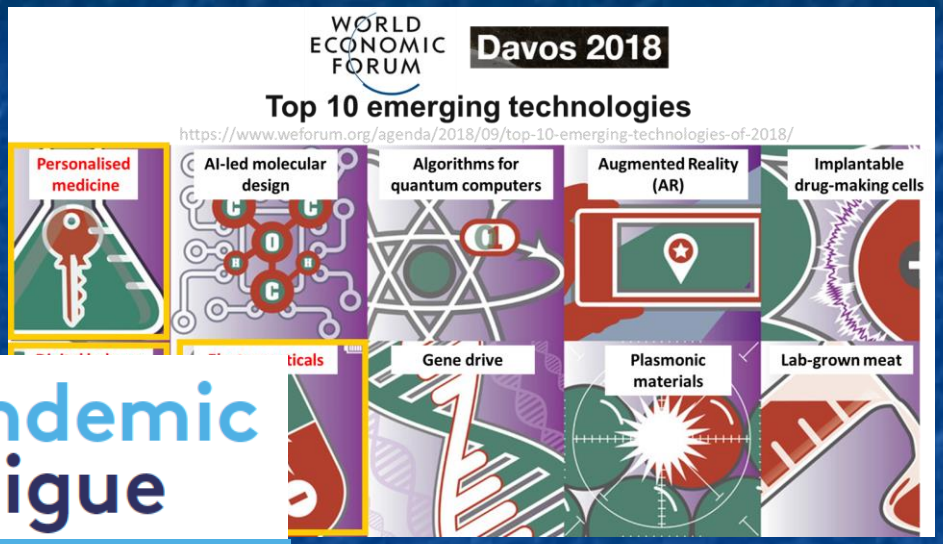
Fatigued people

Electroceuticals

Functional > Structural



Pandemic fatigue

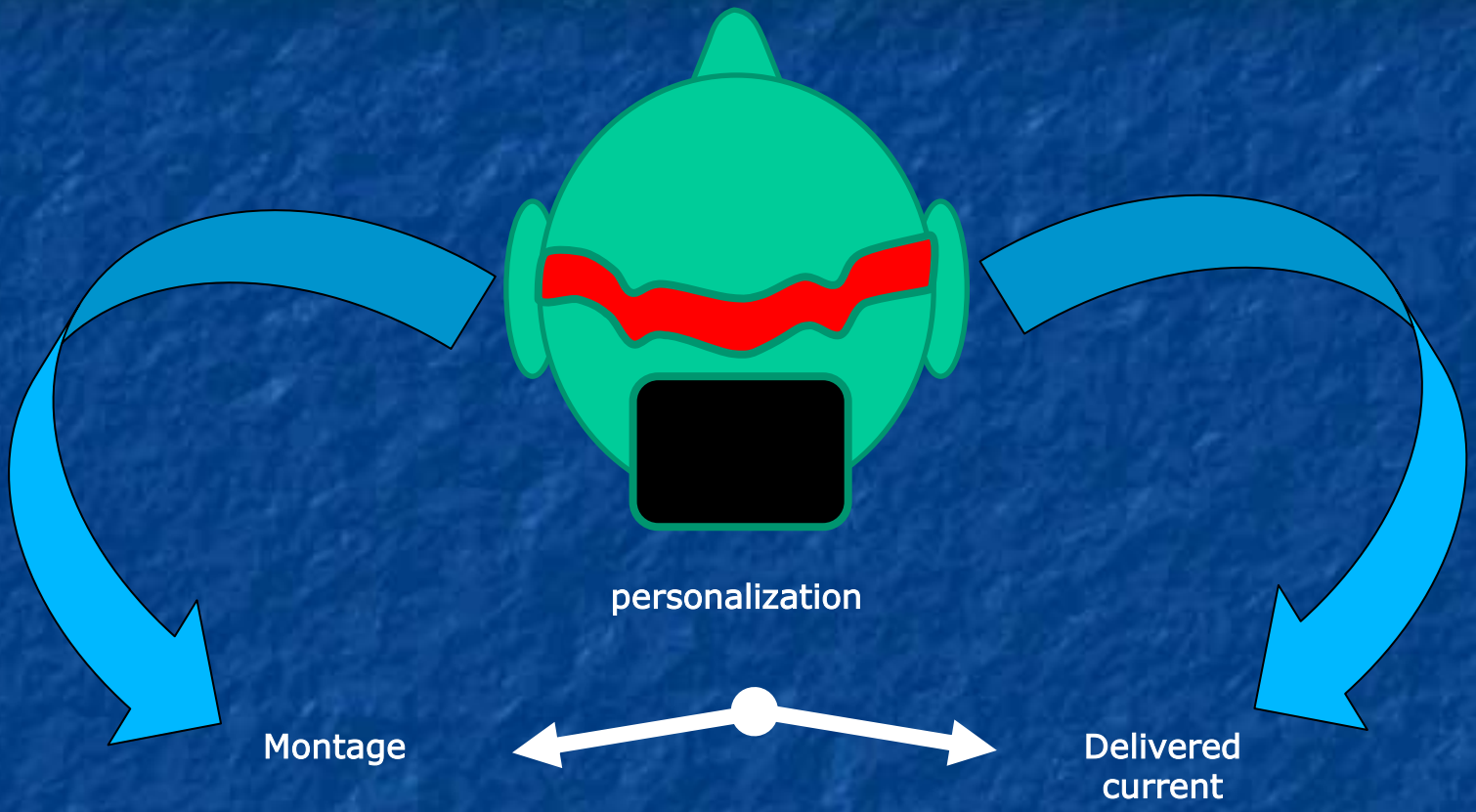
World Health Organization
REGIONAL OFFICE FOR Europe

Sensory parietal orig

Personalized neuromodulation Faremus

EPIC adventure

Electroceuticals Personalization



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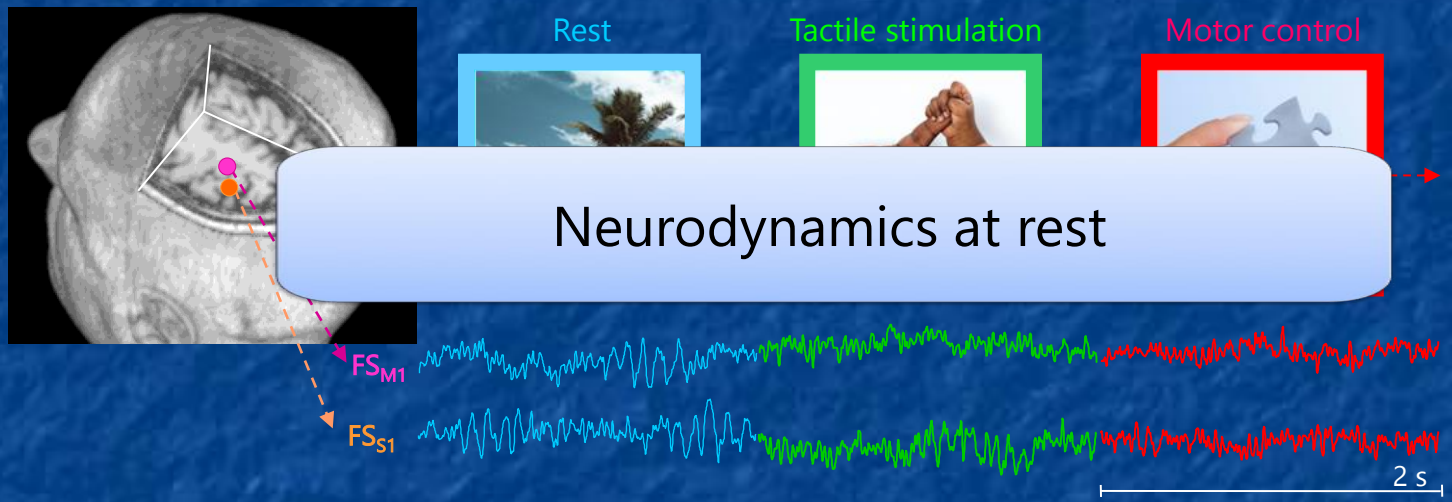
LET'S developed a new concept-source identification method with MEG/EEG/EMG: the

Functional Source Separation (FSS)

which exploits a

specific functional fingerprint of the source neurodynamics

-instead of the source's position-



Methods

Procaro et al IJNT 2017
Porcaro & Tecchio Book Chapter 2015
Porcaro et al Neuroimage 2010
Porcaro et al ClinPh 2009
Porcaro et al Hum Brain Mapp 2009
Porcaro et al Hum Brain Mapp 2008
Barbati et al Hum Brain Mapp 2008
Tecchio et al J Physiol 2007, Review
Barbati et al Hum Brain Mapp 2006

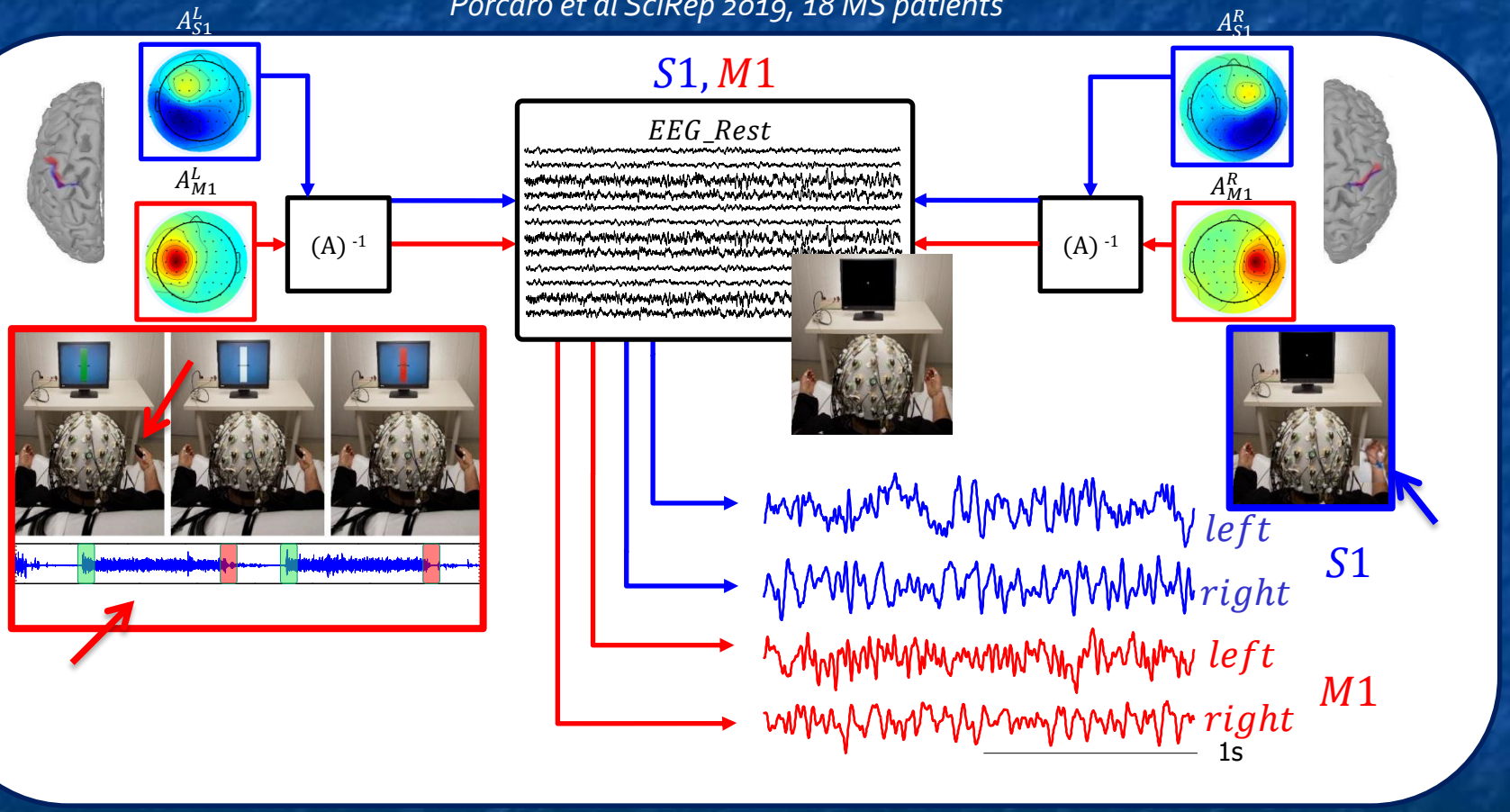
Investigation tool

Ferracuti et al ComputMetProgBiomed 2020
Procaro et al SciRep 2019
Procaro et al NI 2019
Ji et al Front Neurorobot 2019
Cottone et al JN 2018
Cottone et al Brain Struc Func 2017
Melgari et al Neurosci 2013
Procaro et al ClinPh 2013
Di Pino, Porcaro et al RNN 2012
Pellegrino et al RNN 2012
Porcaro et al Neuroimage 2011
Pittaccio et al Hum Brain Mapp 2011
Tecchio et al Brain 2009
Betti et al J Neurosci 2009
Tecchio et al Neuroimage 2008
Tecchio et al Neuroimage 2007

Neuronal Network investigation

Functional Source Separation (FSS)

Porcaro et al SciRep 2019, 18 MS patients



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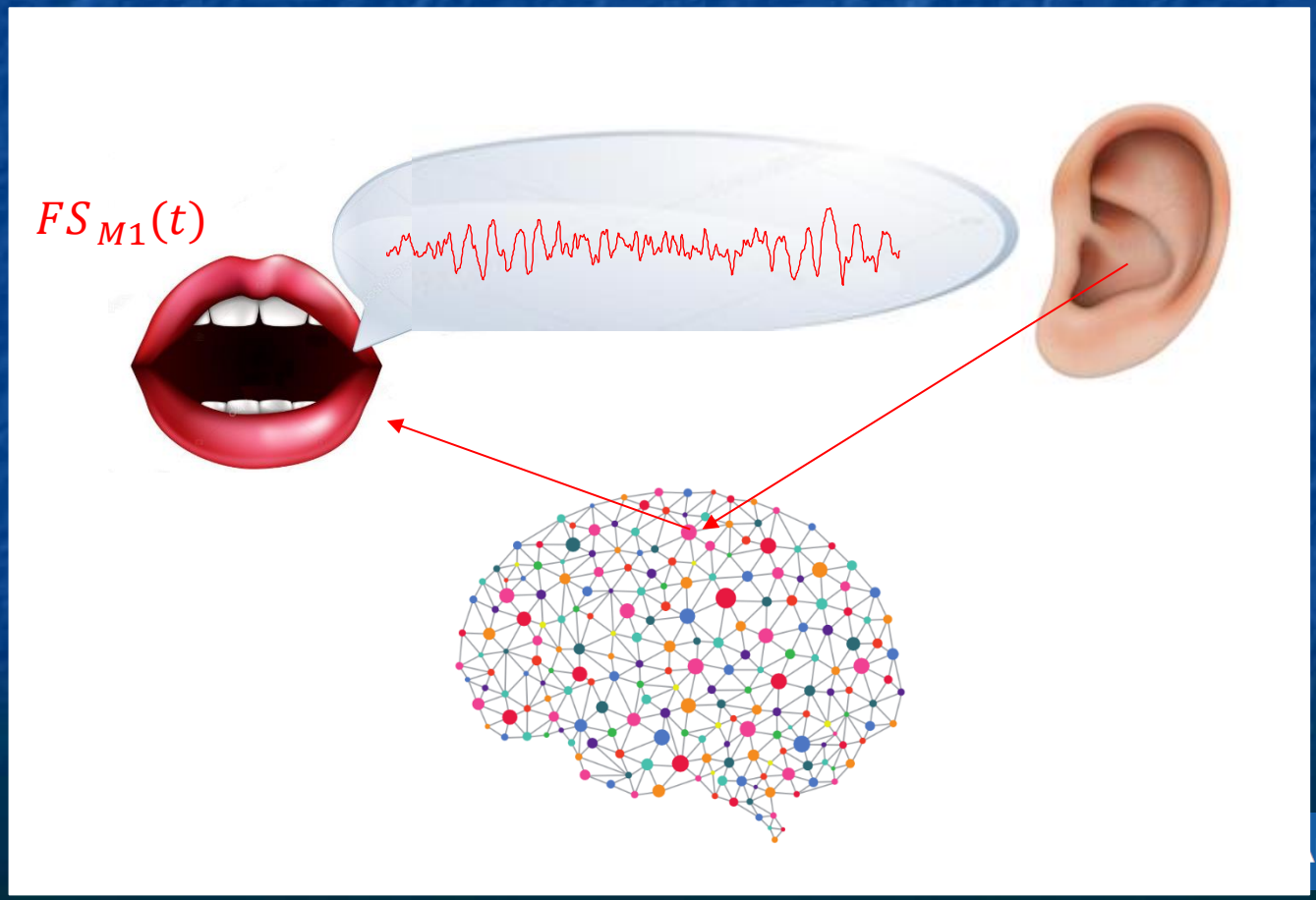
Diverse symptoms Electroceuticals Personalization

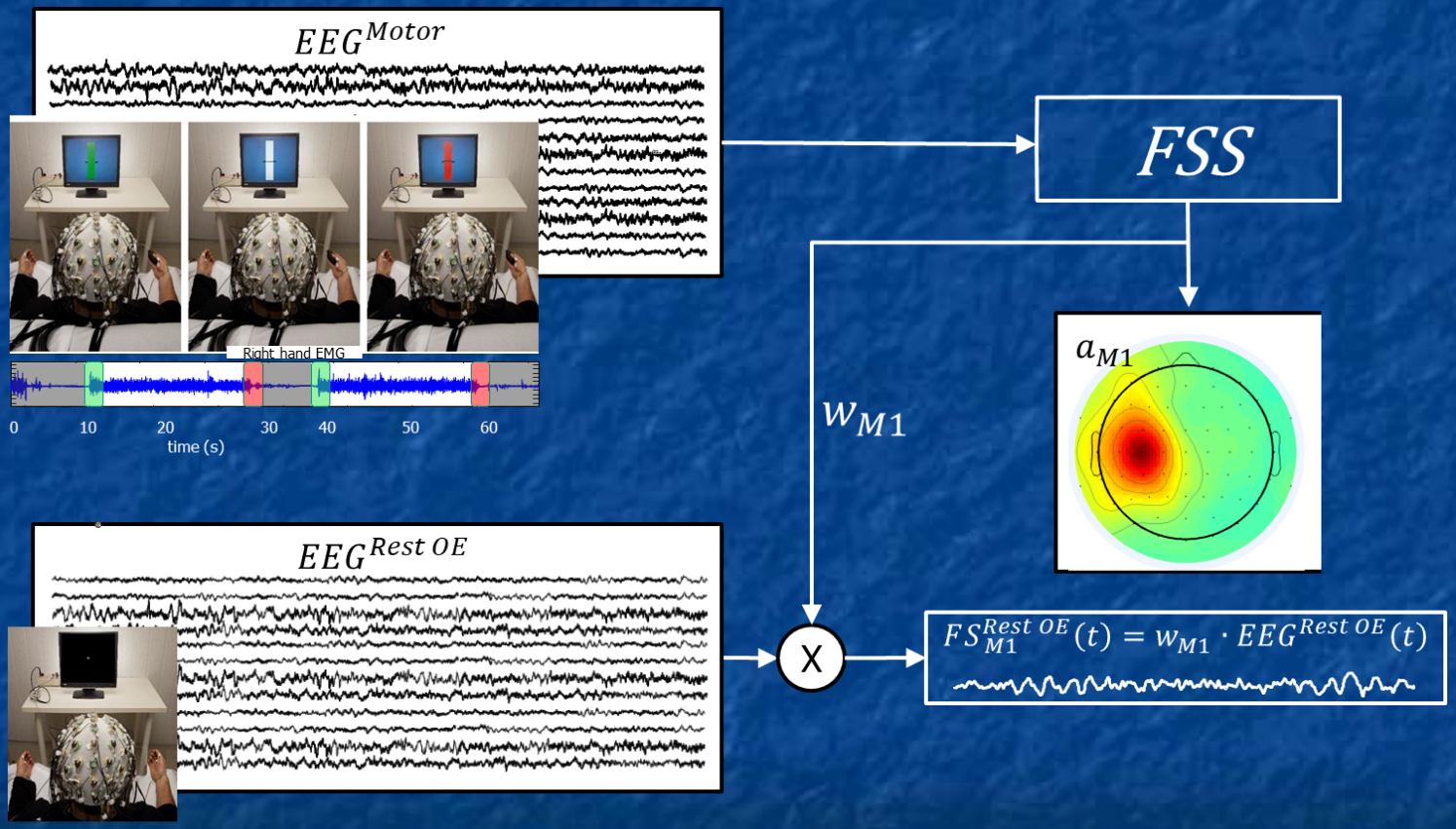
The cortical area speaks its 'typical' language.

When it hears a similar message, it tends to speak.



catching the 'typical' language

By FSS-equipped EEG
we identified the M1 activity (neurodynamics)
of each person at rest.



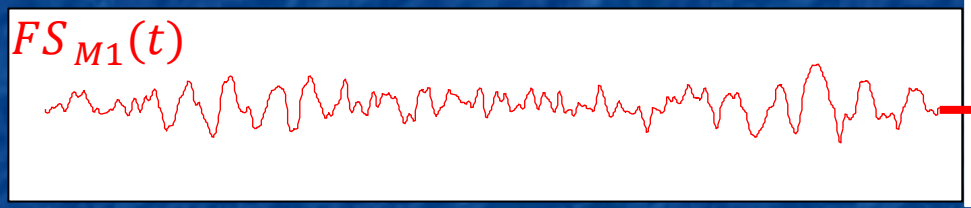
Cottone et al JN 2019,
11 + 5 healthy people

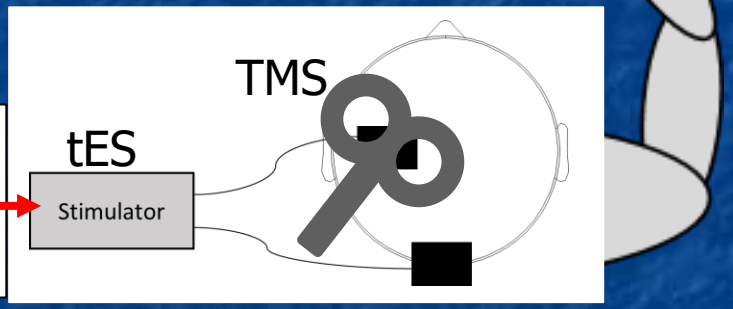
Individual neuroDynamics tES (tIDS)

tIDS
to speak to nodes

We called the novel stimulation:
transcranial Individual neuroDynamics Stimulation (tIDS)

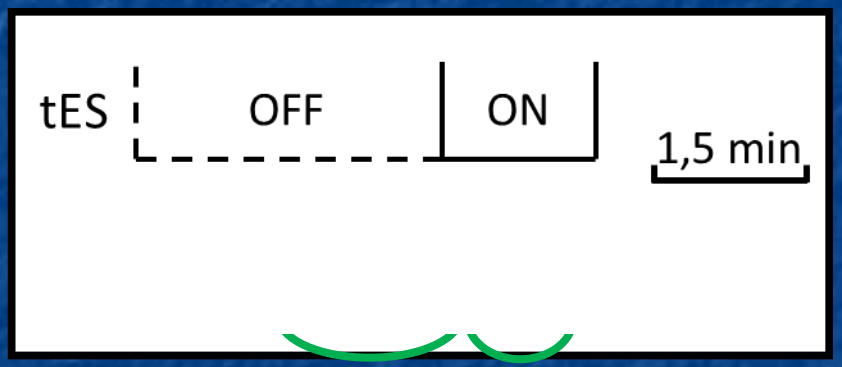
Cottone et al JN in press,
11 + 5 healthy people





Key question:
Does tIDS neuromodulate?

neuromodulate=: change the target excitability

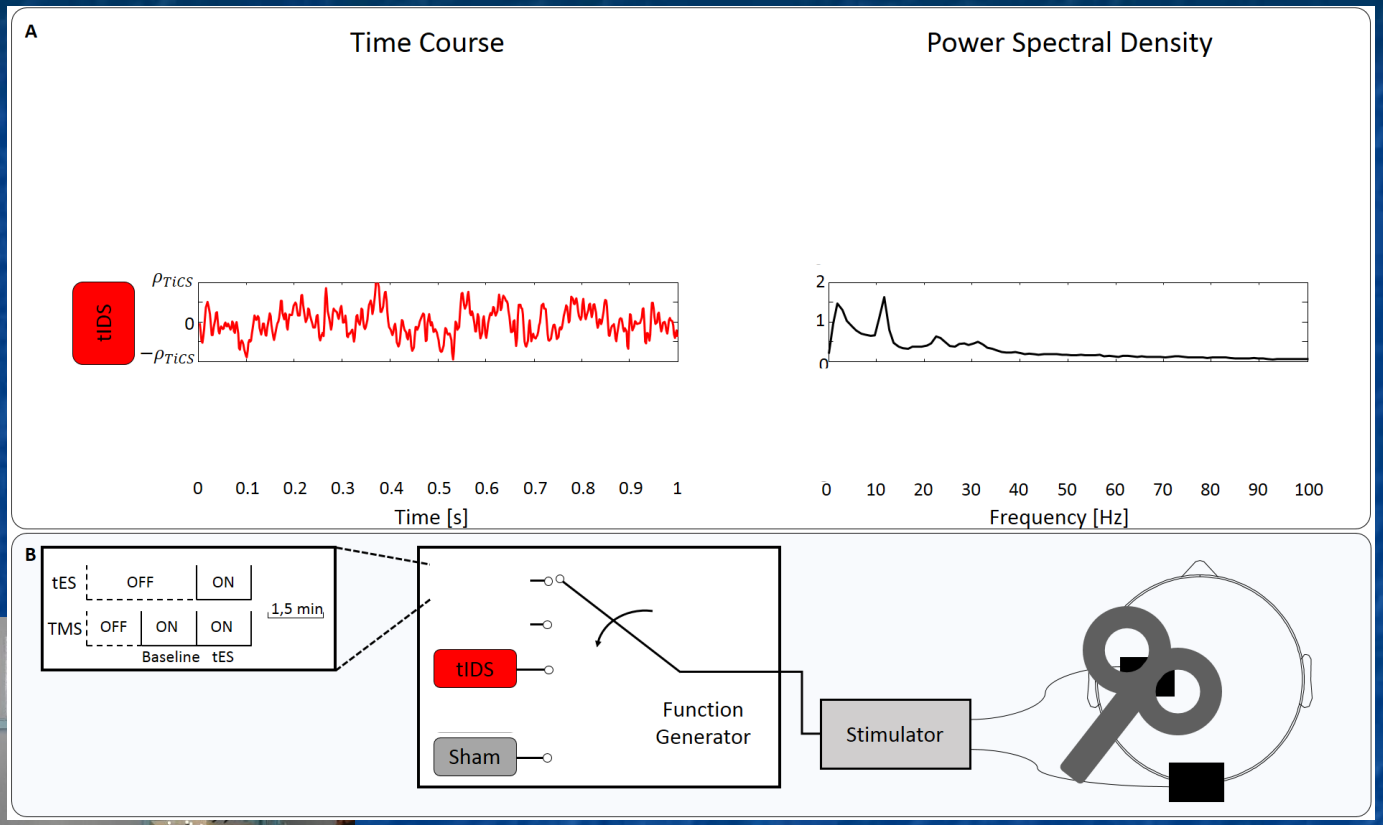


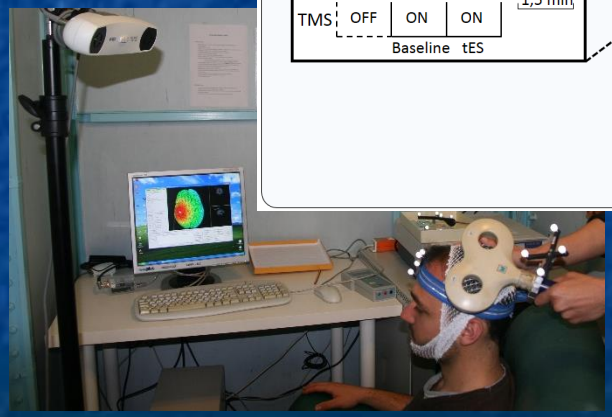
M1 excitability probed via TMS-MEP amplitude

We tested whether the **M1 excitability** during **tIDS**, is higher than in **baseline**
(18 MEP tES ON *vs.* 18 MEP tES OFF)

Individual neuroDynamics tES (tIDS)

tES to 'speak' to nodes





Feurra et al JN 2011, JN 2013

Cottone et al JN 2019, 11 + 5 healthy people

tIDS *vs.* **Sham**

tIDS vs. the most efficient method up to now (20Hz transcranial Alternating Current Stimulation, **tACS**).

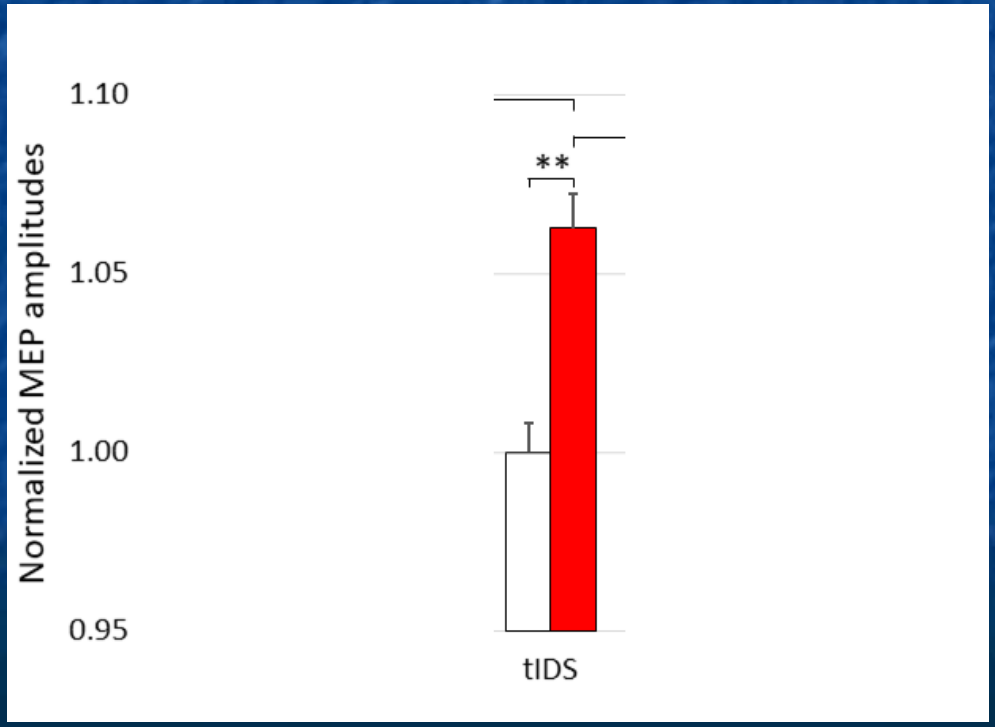
Control condition: **tIDS** vs. was the transcranial random noise stimulation (**tRNS**) in the same frequency range as tIDS (1-250 Hz).

Individual neuroDynamics tES (tIDS)

tIDS
to speak to nodes

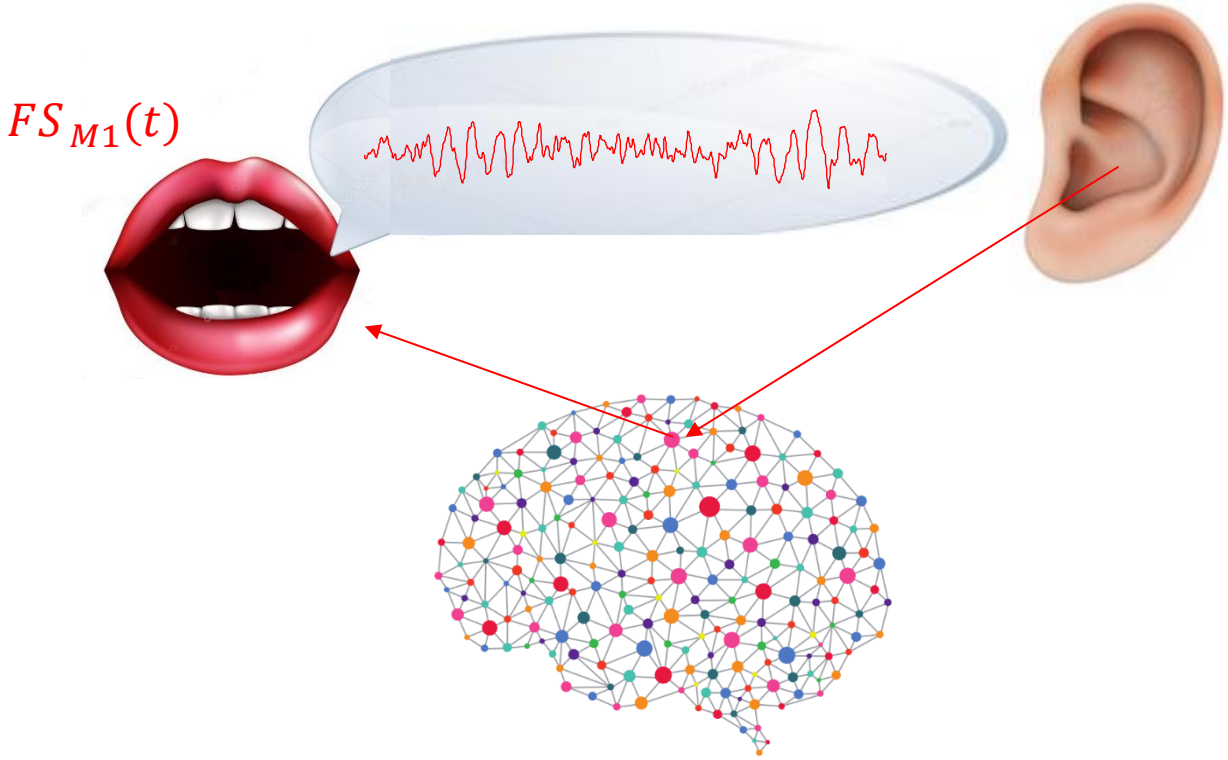
At group level,
tIDS neuromodulation (**34%**),
> **tACS** (**13%**, paired comparison p<.001)

tRNS and **Sham** induced no effect (p>.400).



Diverse symptoms Electroceuticals Personalization

We aim at speaking to cortical areas with their 'typical' language.



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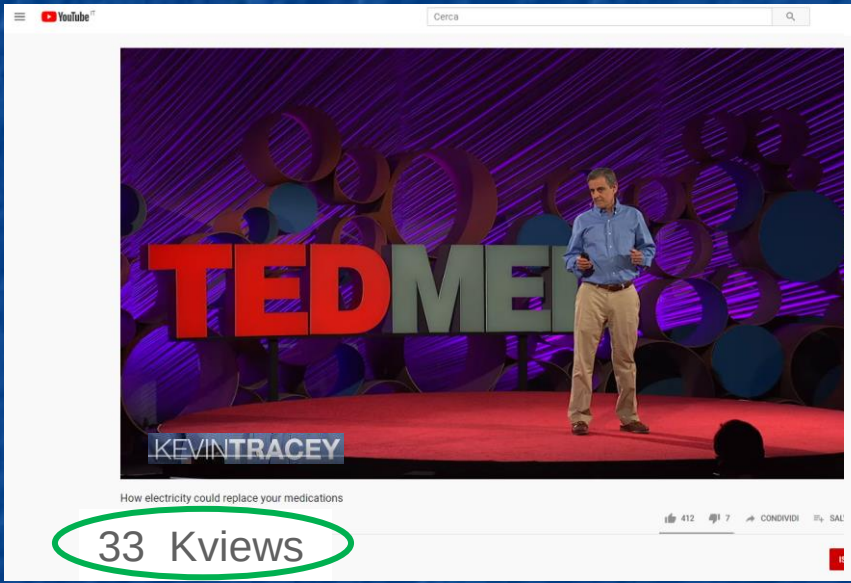
Electroceuticals

Kevin Tracey (World Economic Forum)
TEDMED 2016



Franca Tecchio (FaReMuS)
TEDx 2016

LET'S

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Electroceuticals

neuromodulation via neurodynamics knowledge

Individual neurodynamics & personalized neuromodulation

population-based & individual-based

Medical physics & Electroceuticals

A new profession?

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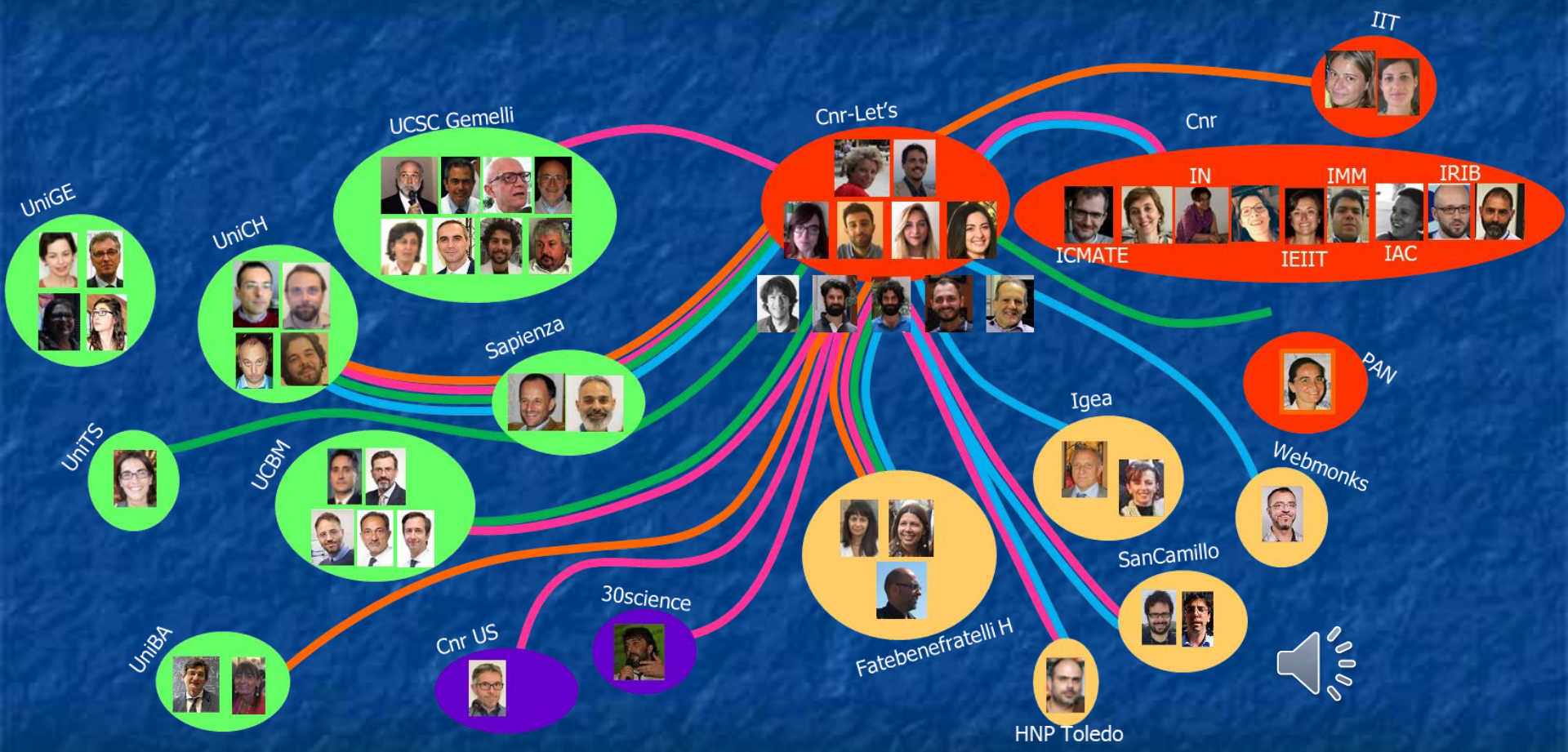
Electroceuticals Thank you Team & Parners



Legend

Writing | Laboratory | Governance | Projecting

Media | Enterprises & Hospitals | Reasech institution | Universities