transcranial Electrical Stimulation (tES)
Applications and past decade advances

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PhD in Health Psychology

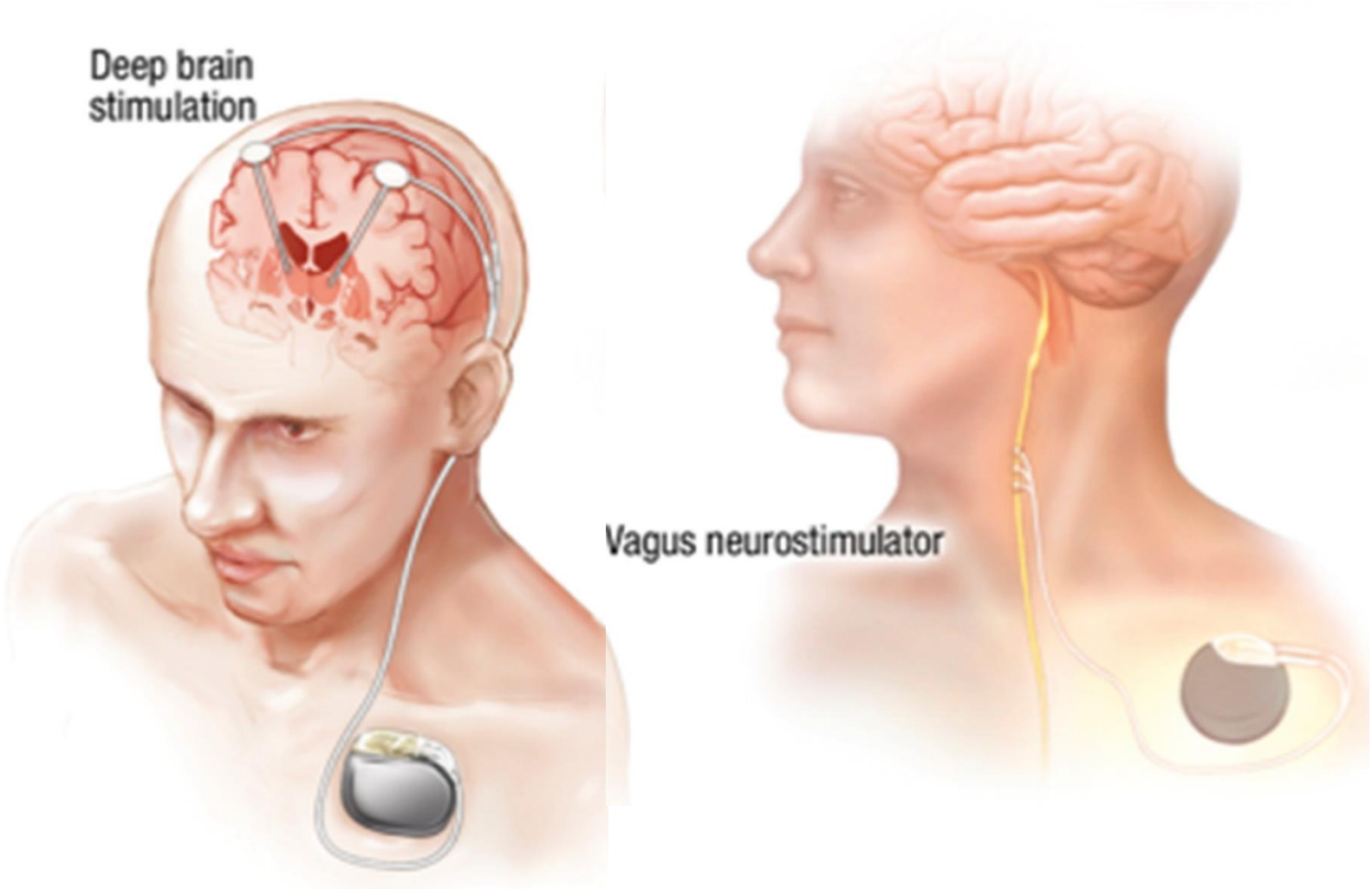
Introduction to tES

What is Neuromodulation

Neuromodulation, (defined by the International **Neuromodulation** Society) as "the alteration of nerve activity through targeted delivery of a stimulus, such as electrical stimulation or chemical agents, to specific neurological sites in the body," is carried out to normalize – or modulate – nervous tissue function.

تعدیل عصبی: ایجاد تغییر در فعالیت نورونی از طریق تحریک(از قبیل عوامل شیمیایی یا تحریک الکتریکی) با هدف بهبود، ارتقا یا بهنجار کردن فعالیت نورونها

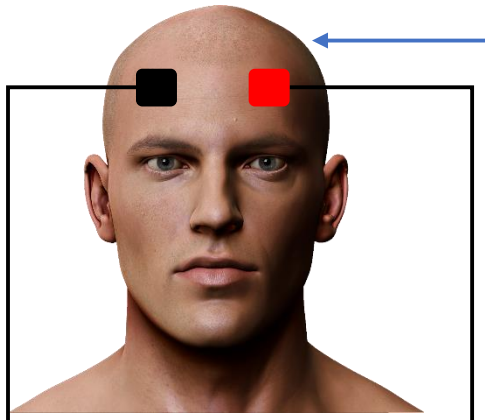
DBS and VNS



ElectroConvulsive Therapy (ECT)

ECT 800mA
tES 2mA

Simple technical features



$$V = I \times R$$

Voltage
Volt (V)

Current
Ampere (A, mA)

Resistance
Ohm (Ω)

Current= Up to 2mA

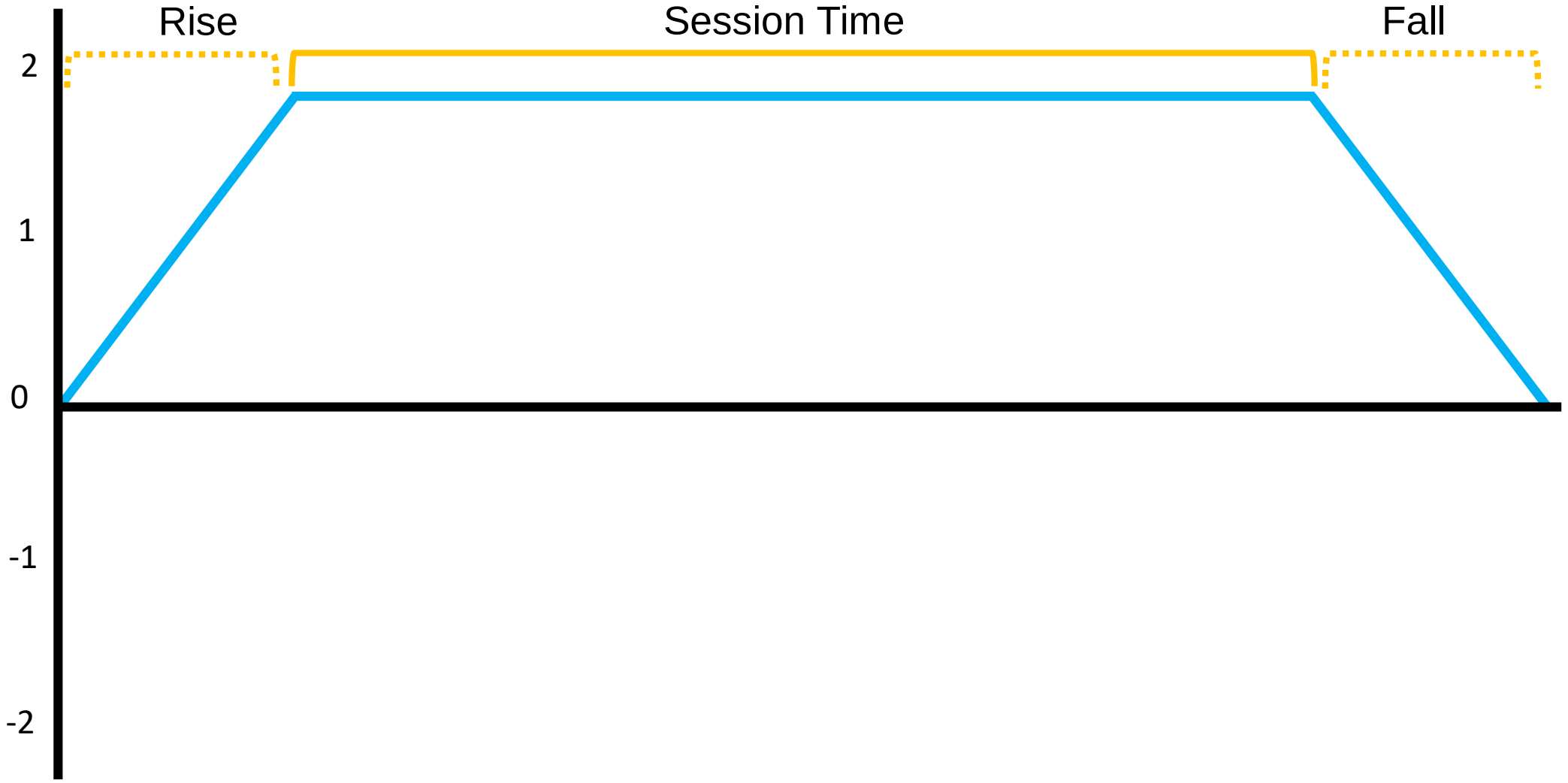
Definition

Red= Anode
Positive Pole

White= Cathode
Negative Pole

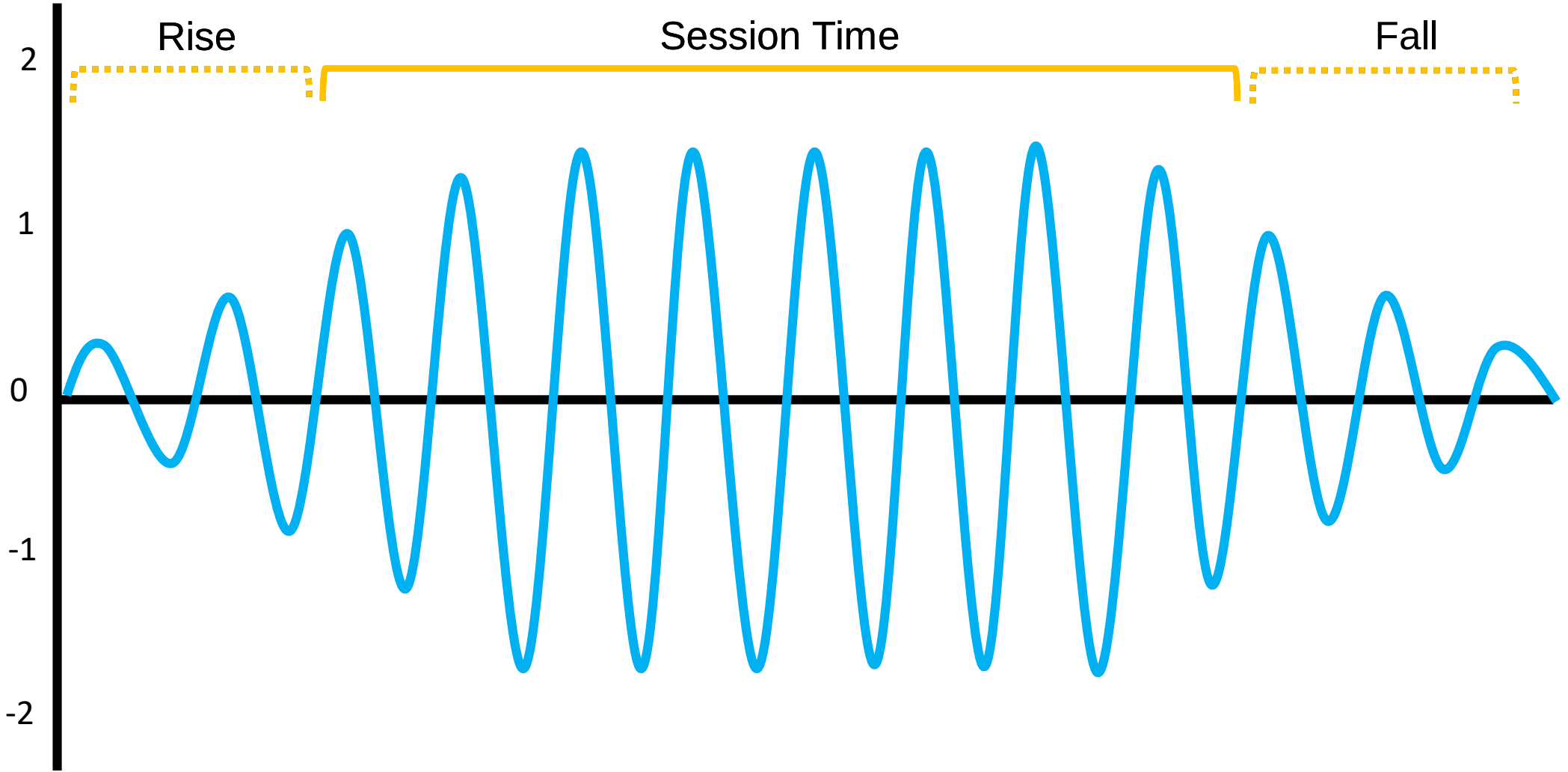
Types of tES

Transcranial Direct Current Stimulation

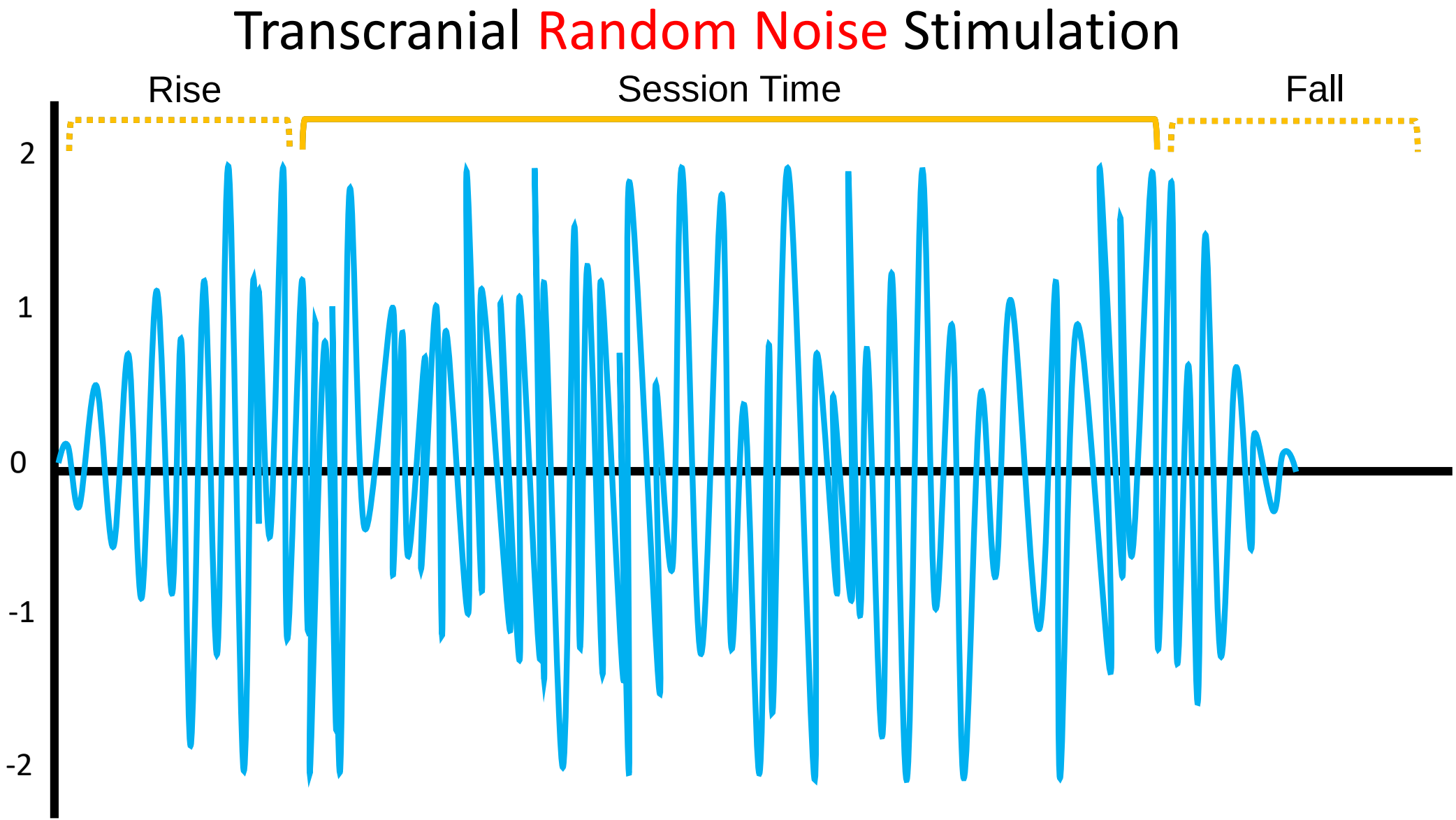


Types of tES

Transcranial Alternating Current Stimulation

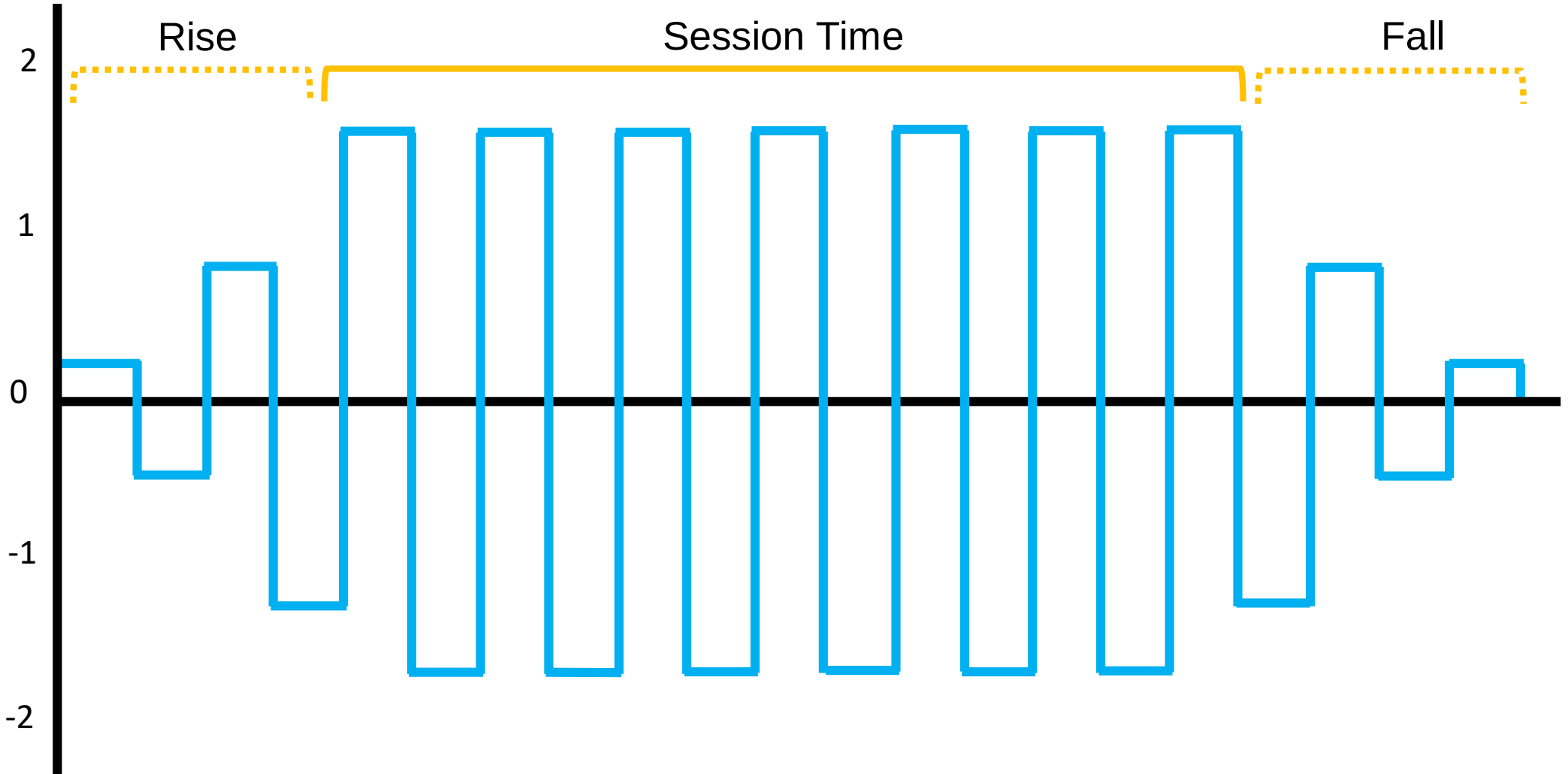


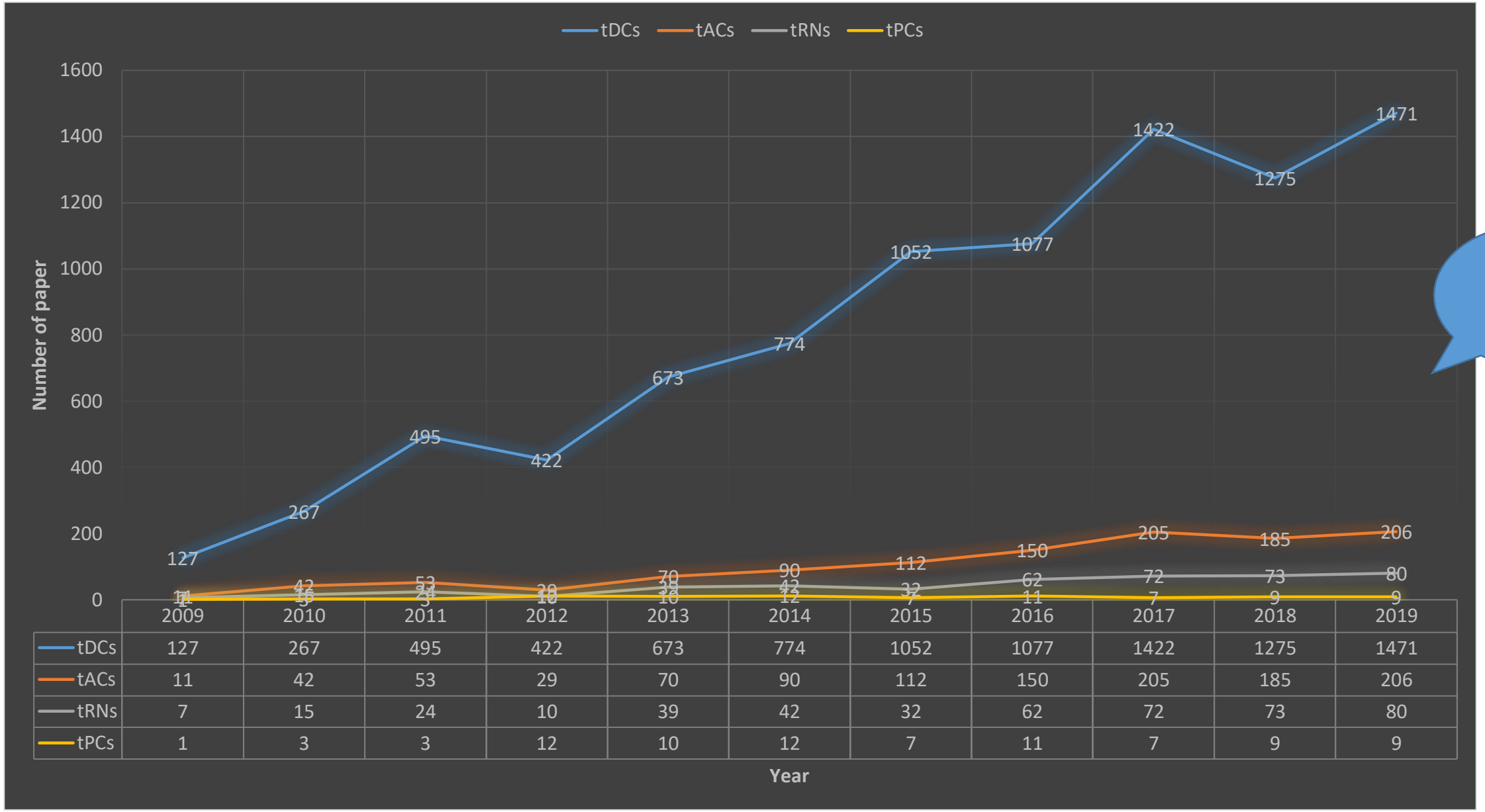
Types of tES


Transcranial Random Noise Stimulation
Rise
Session Time
Fall
2
1
0
-1
-2

Types of tES

Transcranial Pulsed Current Stimulation

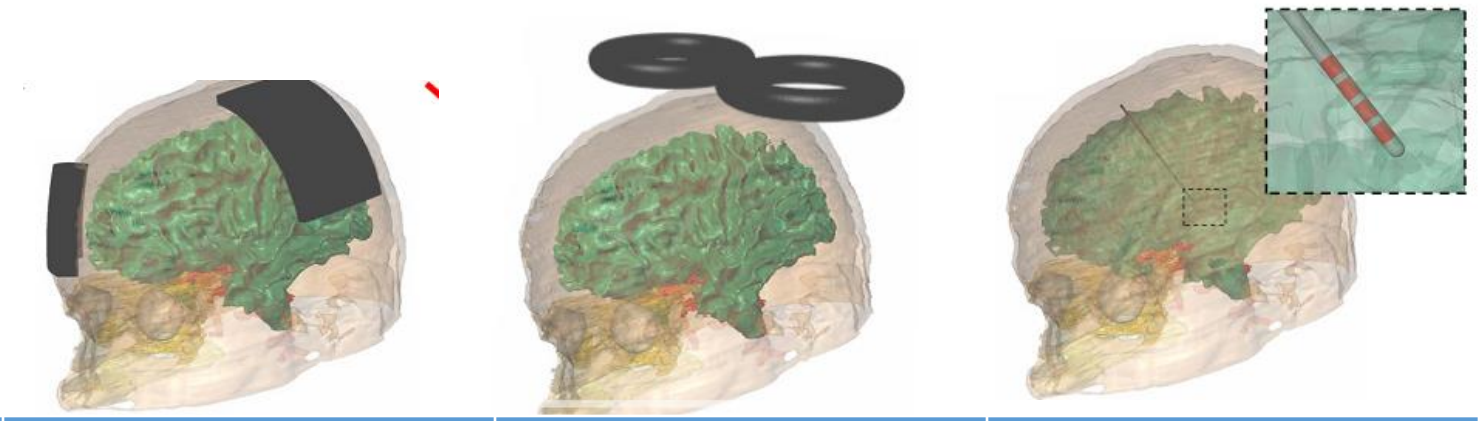




	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
tDCs	127	267	495	422	673	774	1052	1077	1422	1275	1471
tACs	11	42	53	29	70	90	112	150	205	185	206
tRNs	7	15	24	10	39	42	32	62	72	73	80
tPCs	1	3	3	12	10	12	7	11	7	9	9

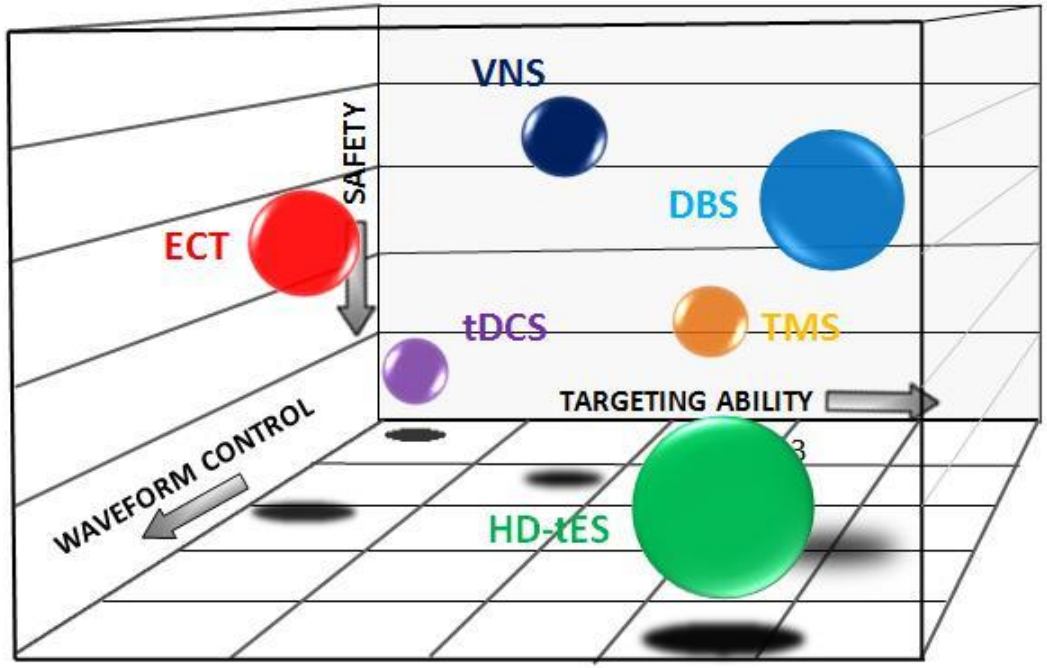
Totally: 10748

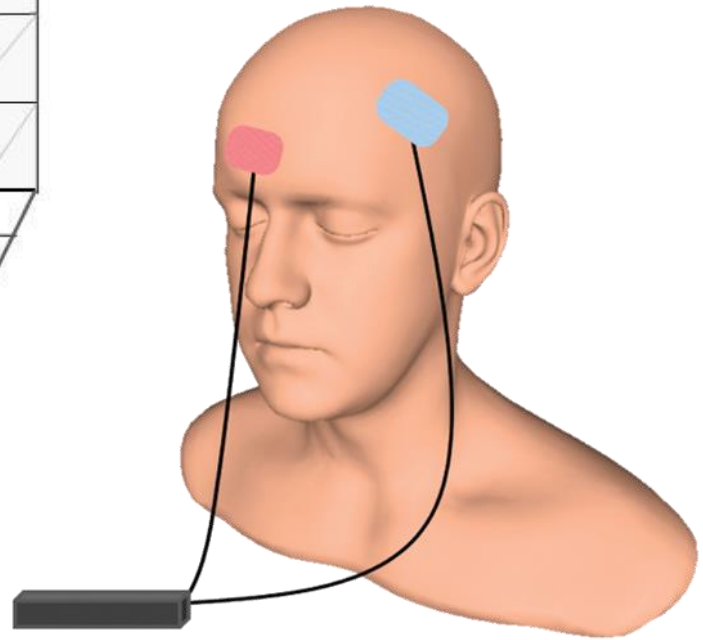
Efficacy, Safety and Flexibility

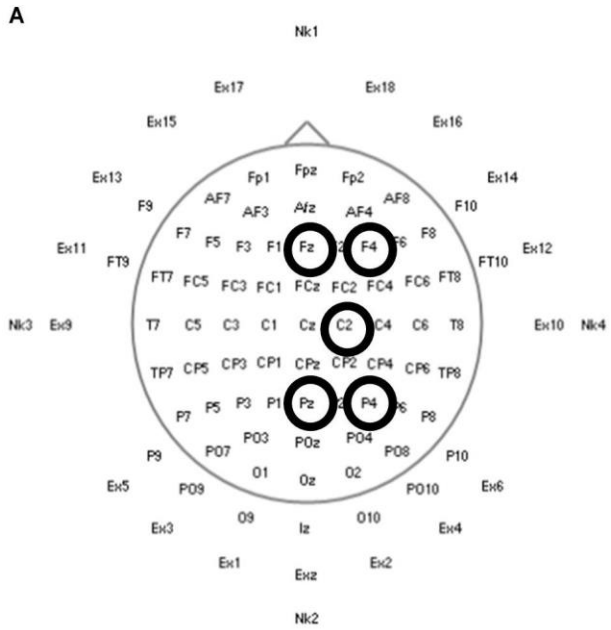


Feature	tES	TMS	DBS
Safety			
Targeting Ability			
Depth of effect			
Non-Invasive			
Waveform control			

Efficacy, Safety and Flexibility






A
Nk1
Ex17
Ex18
Ex15
Ex16
Ex13
Fp1
Fpz
Fp2
Ex14
AF7
AF3
Afz
AF4
AF8
F9
F10
F7
F5
F3
F1
Fz
F4
F8
Ex11
FT9
FT10
Ex12
FT7
FC5
FC3
FC1
FCz
FC2
FC4
FC6
FT8
Nk3
Ex9
T7
C5
C3
C1
Cz
C2
C4
C6
T8
Ex10
Nk4
TP7
CP5
CP3
CP1
CPz
CP2
CP4
CP6
TP8
P7
P5
P3
P1
Pz
P4
P8
P9
PO7
PO3
POz
PO4
PO8
P10
Ex5
O1
Oz
O2
Ex6
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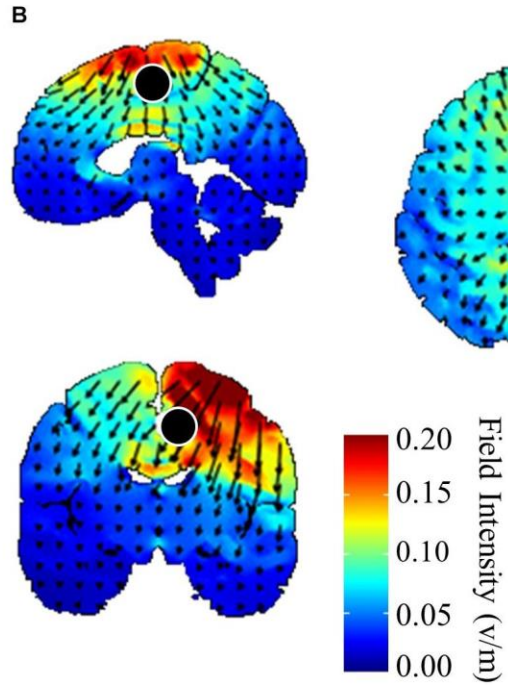
Iz
O10
Ex4
Ex1
Exz
Ex2
Nk2

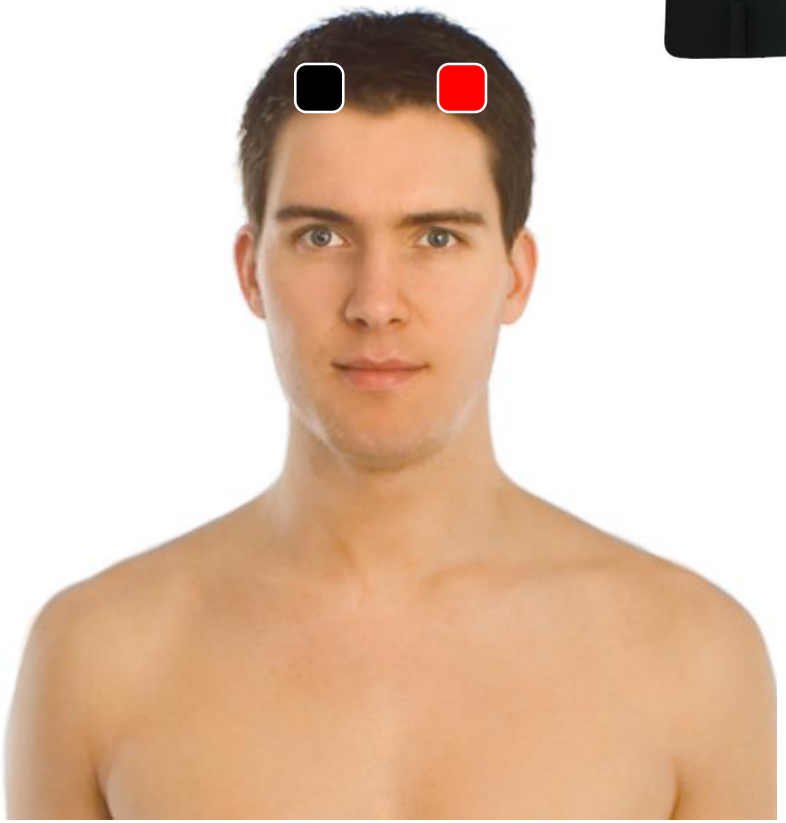

B

0.20
0.15
0.10
0.05
0.00
Field Intensity (v/m)

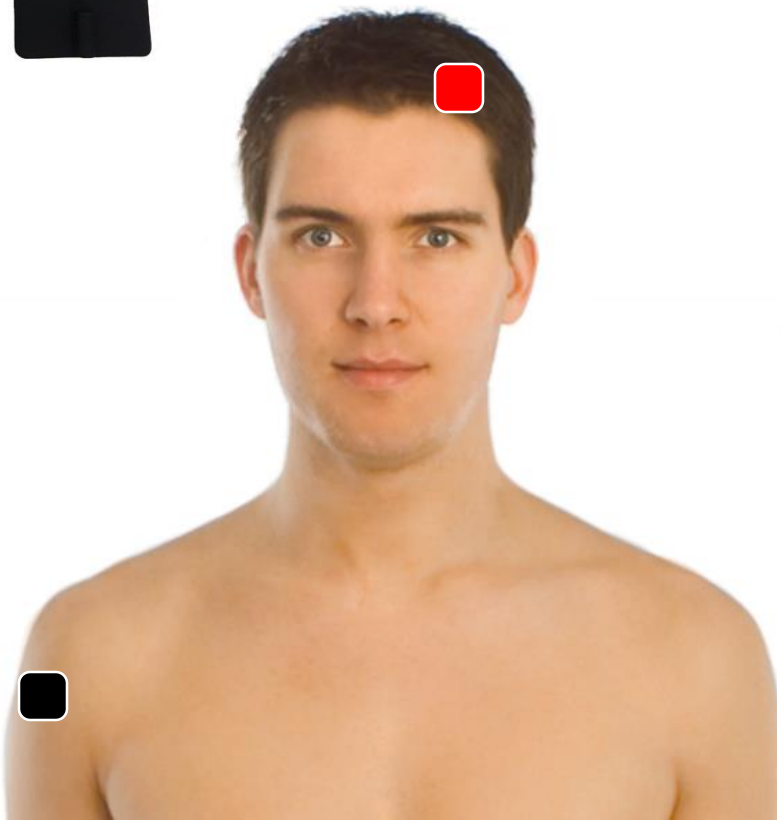
Technical aspects tES

Montage

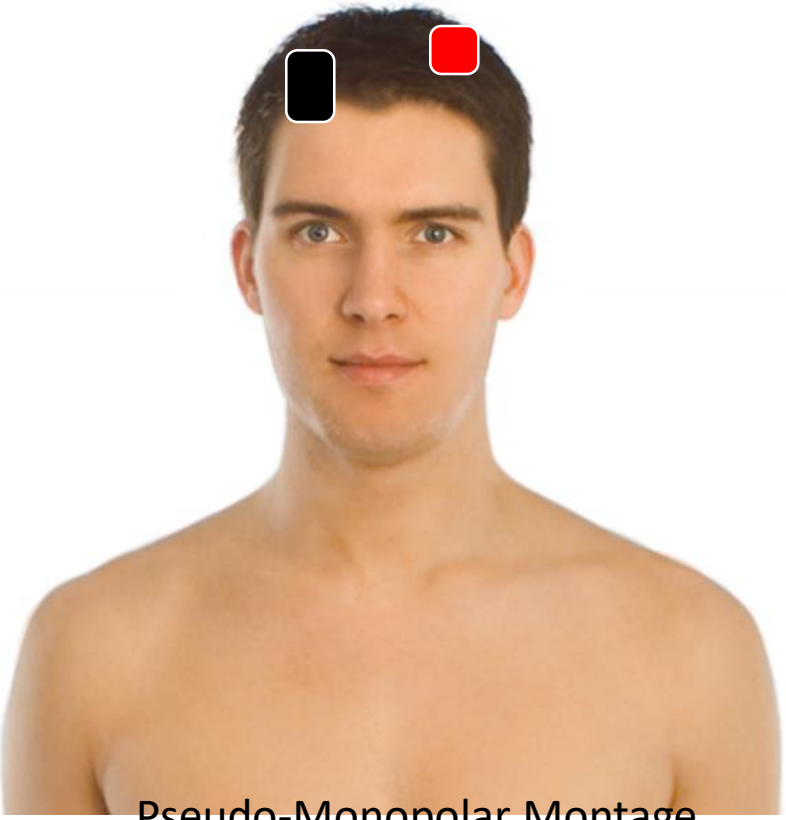
Anode
Cathode



Bipolar Montage



Monopolar Montage



Pseudo-Monopolar Montage

Current Density

Acceptable current= 80 uA/cm^2

1mA=1000uA

$$\frac{x}{Cm^2} = 80$$

Pad Size= 5x5

$$\frac{x}{5 \times 5} = 80$$

X=25x80=2000uA

Pad Size= 10x10

$$\frac{x}{10 \times 10} = 80$$

X=100x80=8000uA

Best Stimulation Density

Targeting Ability ↑

Effective Current ↑

Impedance

- **High impedance**= Skin burning without electrical penetration
- All devices must control impedance before and during treatment time.

Impedance

$$V = I \times R$$

On-label Devices

Main Current= 2mA

$$V = I \times R$$

Current is fixed to 2mA

$$V = I \times R$$

In On-label devices voltage goes to 28V (Maximum)

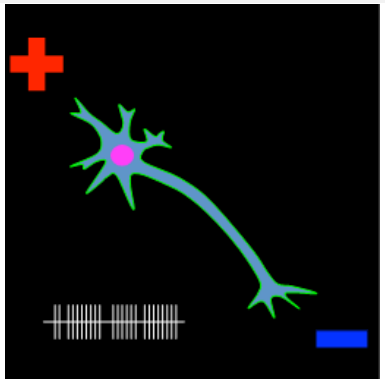
transcranial Direct Current Stimulation (tDCS)

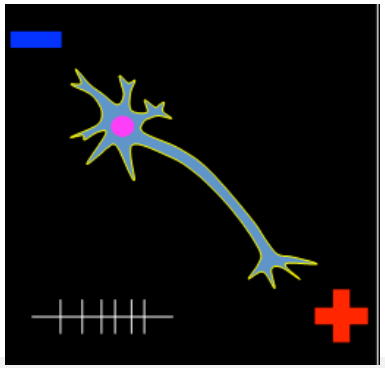
tDCS

Transcranial Direct Current Stimulation

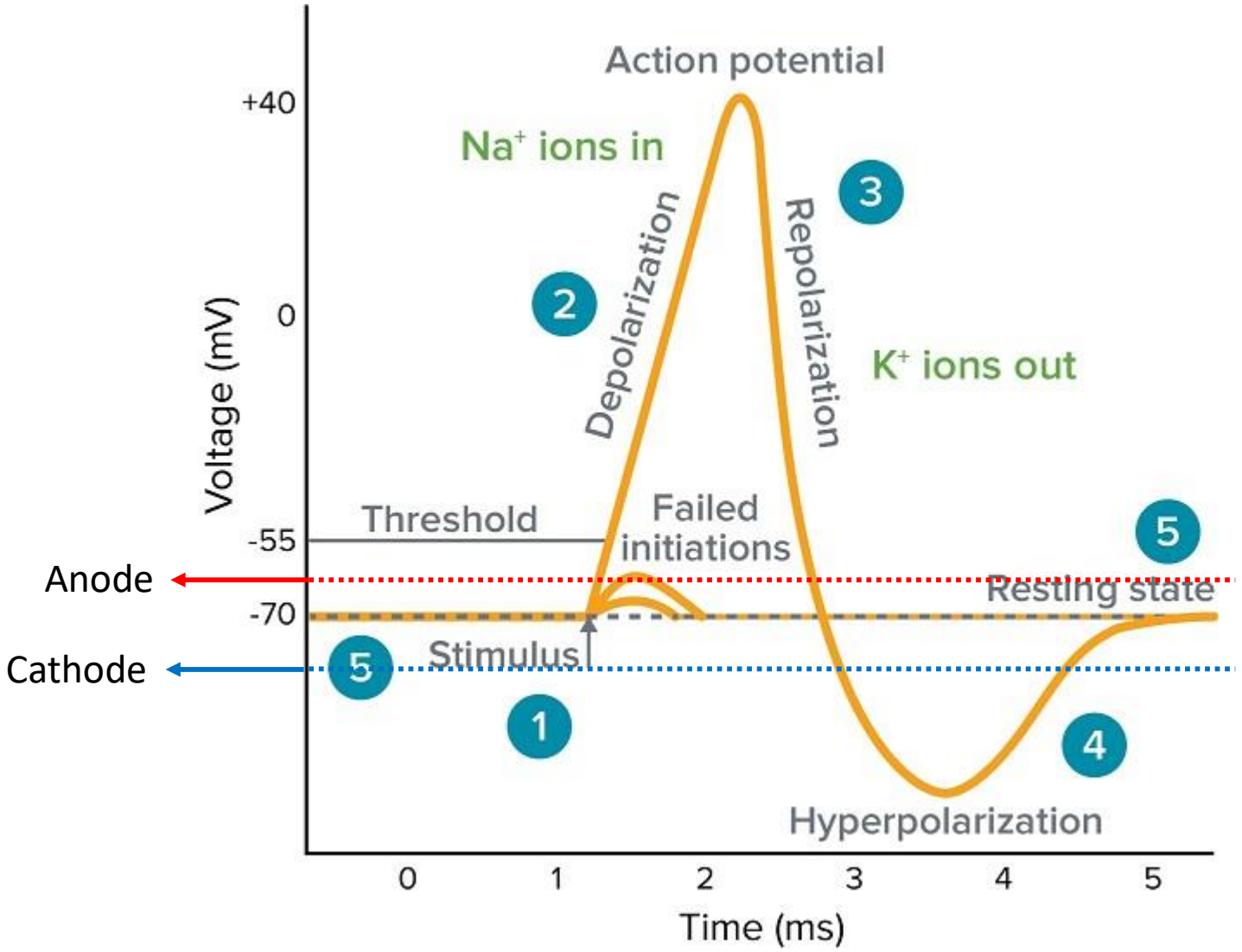
Mechanisms of tDCS

Under Anode:
Increase of positivity inside the axon





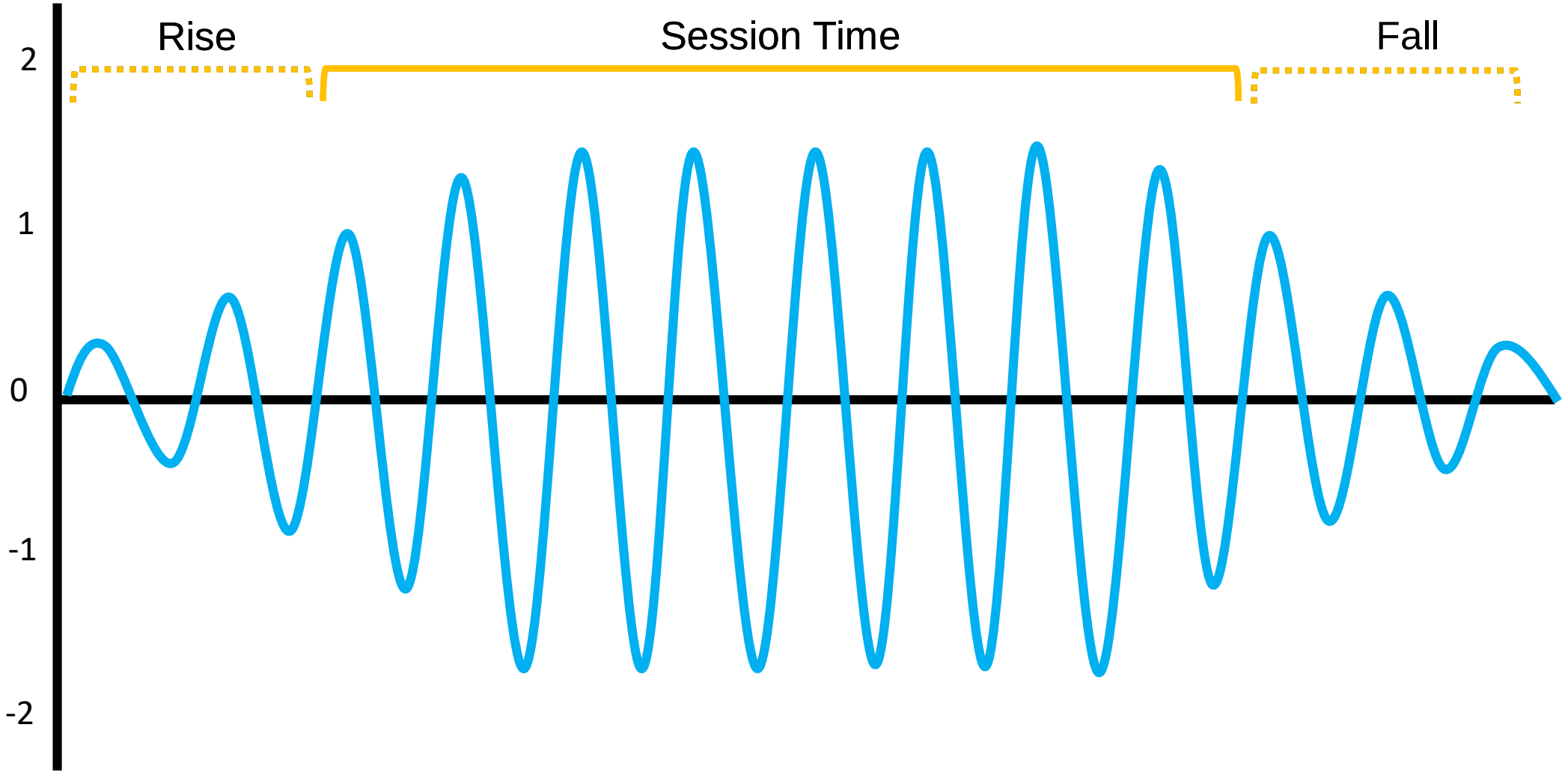
Under Cathode:
Increase of negativity inside the axon



transcranial Alternating Current Stimulation (tACS)

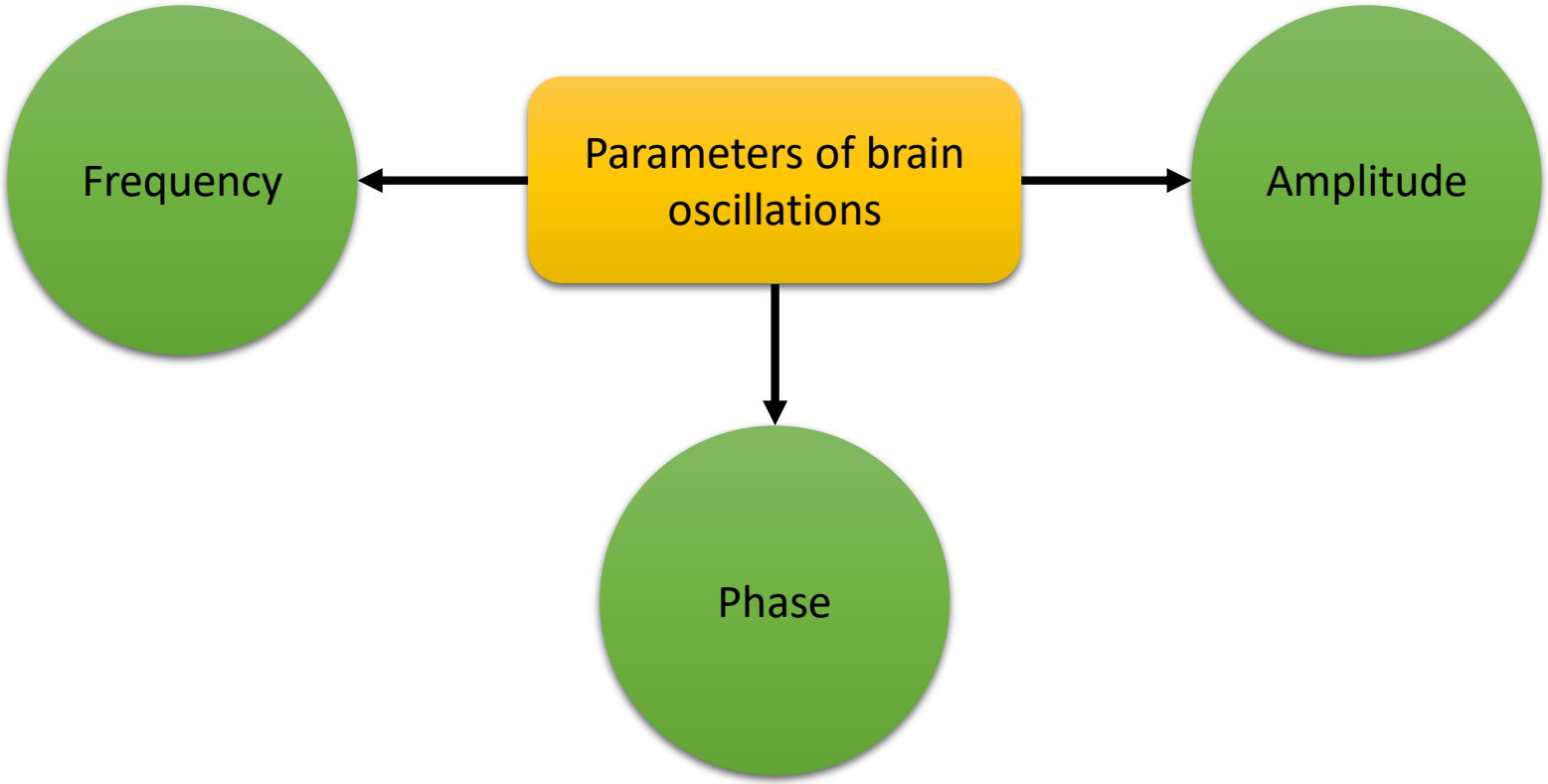
tACS

Transcranial Alternating Current Stimulation



Mechanisms of tACS

- Specific brain oscillations have been associated with cognitive and motor functions in healthy and clinical populations and that it is possible to restore disturbed oscillatory activity by applying alternating current externally to the brain.



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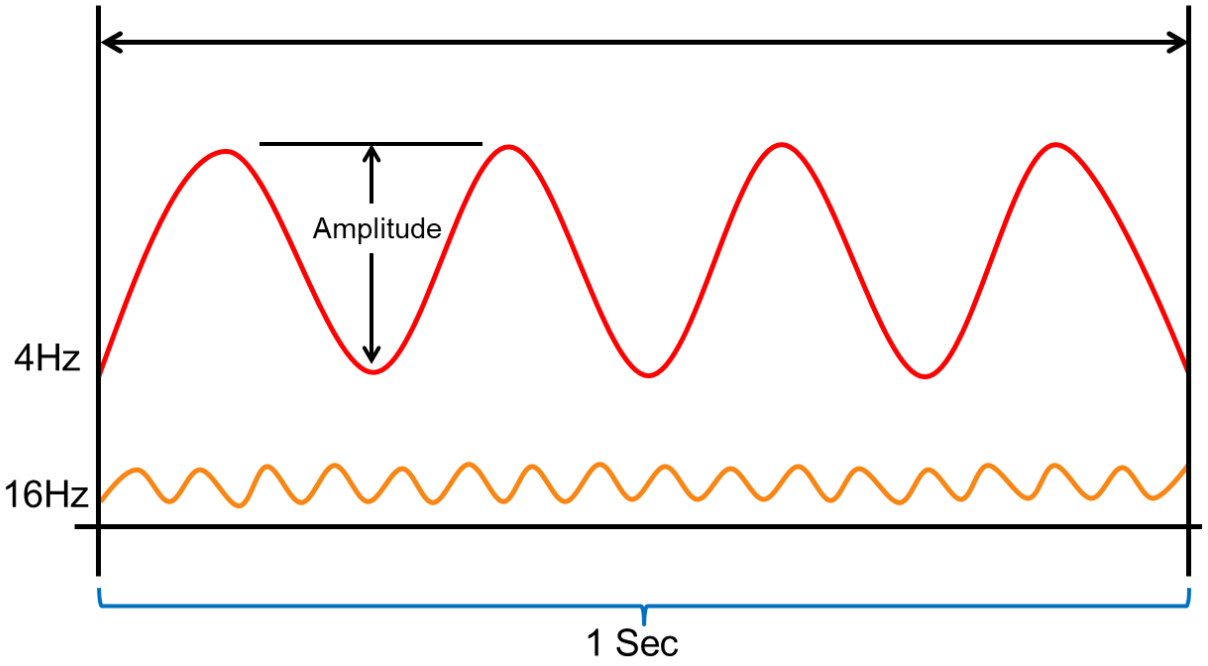
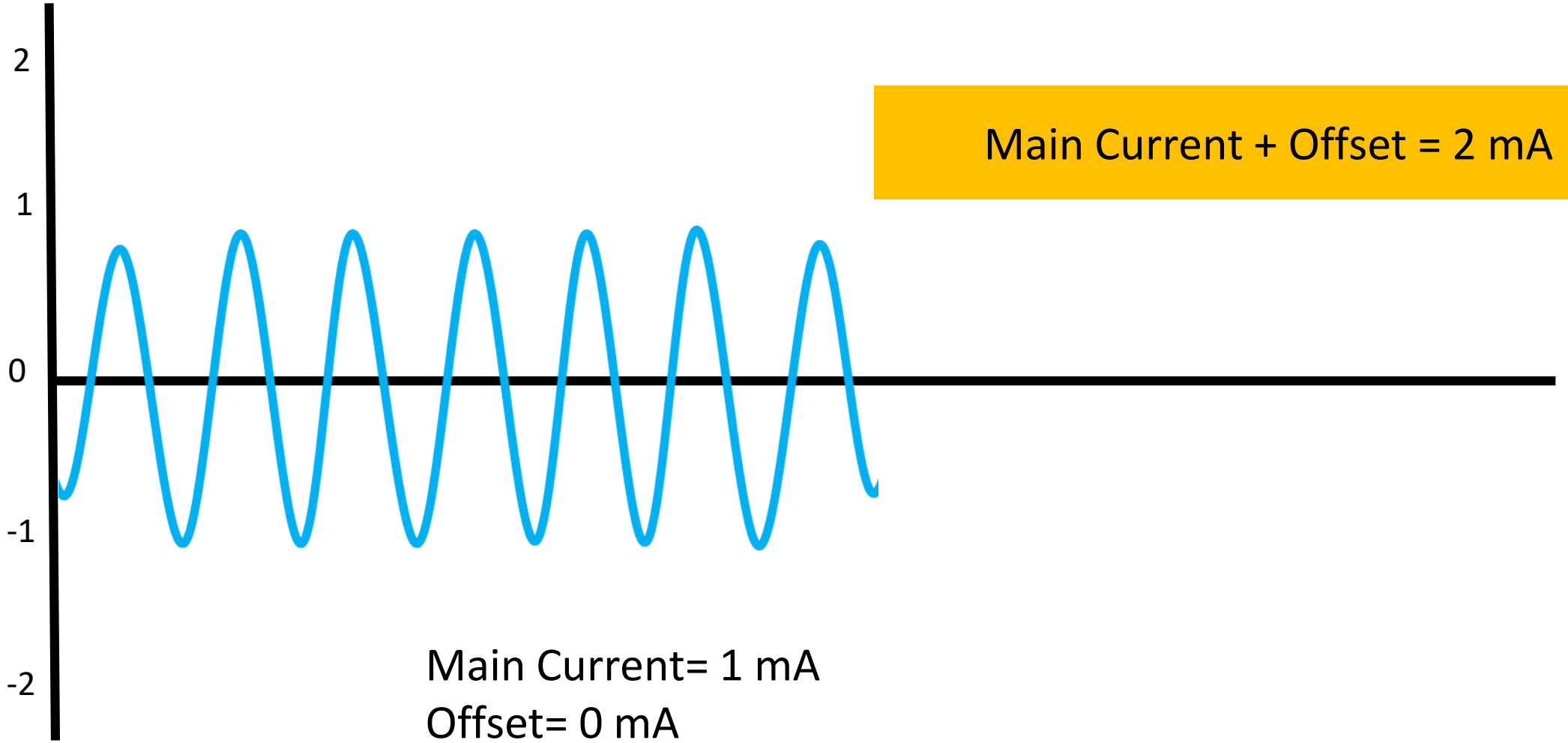


Delta (1-4Hz)
Theta (4-8Hz)
Alpha (8-12 Hz)
SMR (12-15Hz)
Beta 1(15-18Hz)
Gama (+40 Hz)

Mechanisms of tACS

- Usually currents induced by tACS do not affect cortical membrane excitability over sustained intervals of time; however, its effects during the brief phases of depolarization and hyperpolarization on each half cycle may induce online effects through entrainment. This entrainment process refers to the fact that synchronous activity from several cortical neurons adjust to the periodical signaling of external stimuli, such a repeating lights or sounds.
- TACS is useful in modulating subcortical neural circuits and as a tool for enhancing **motor skills and cognitive function**

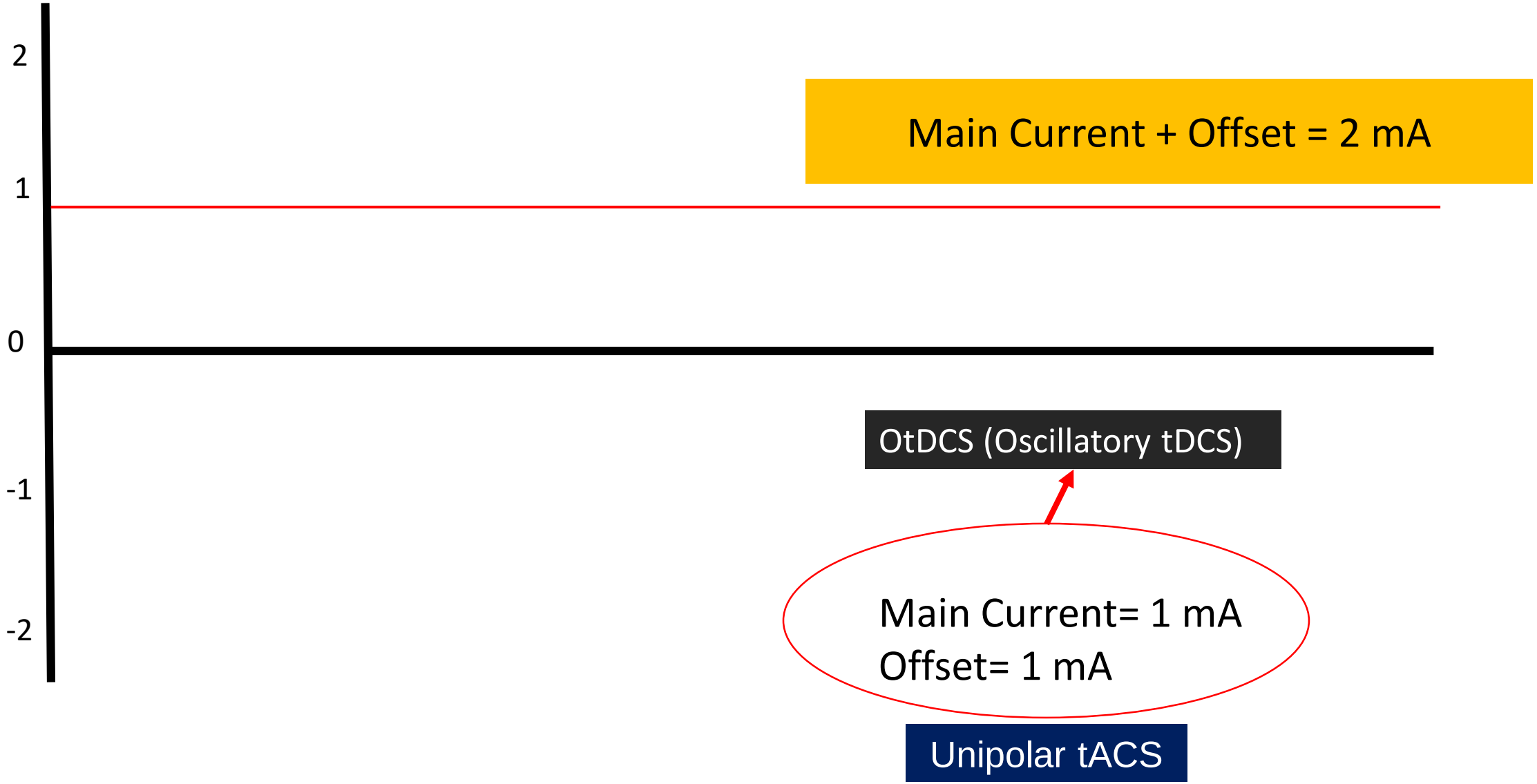
Practical notes of tACS- Offset



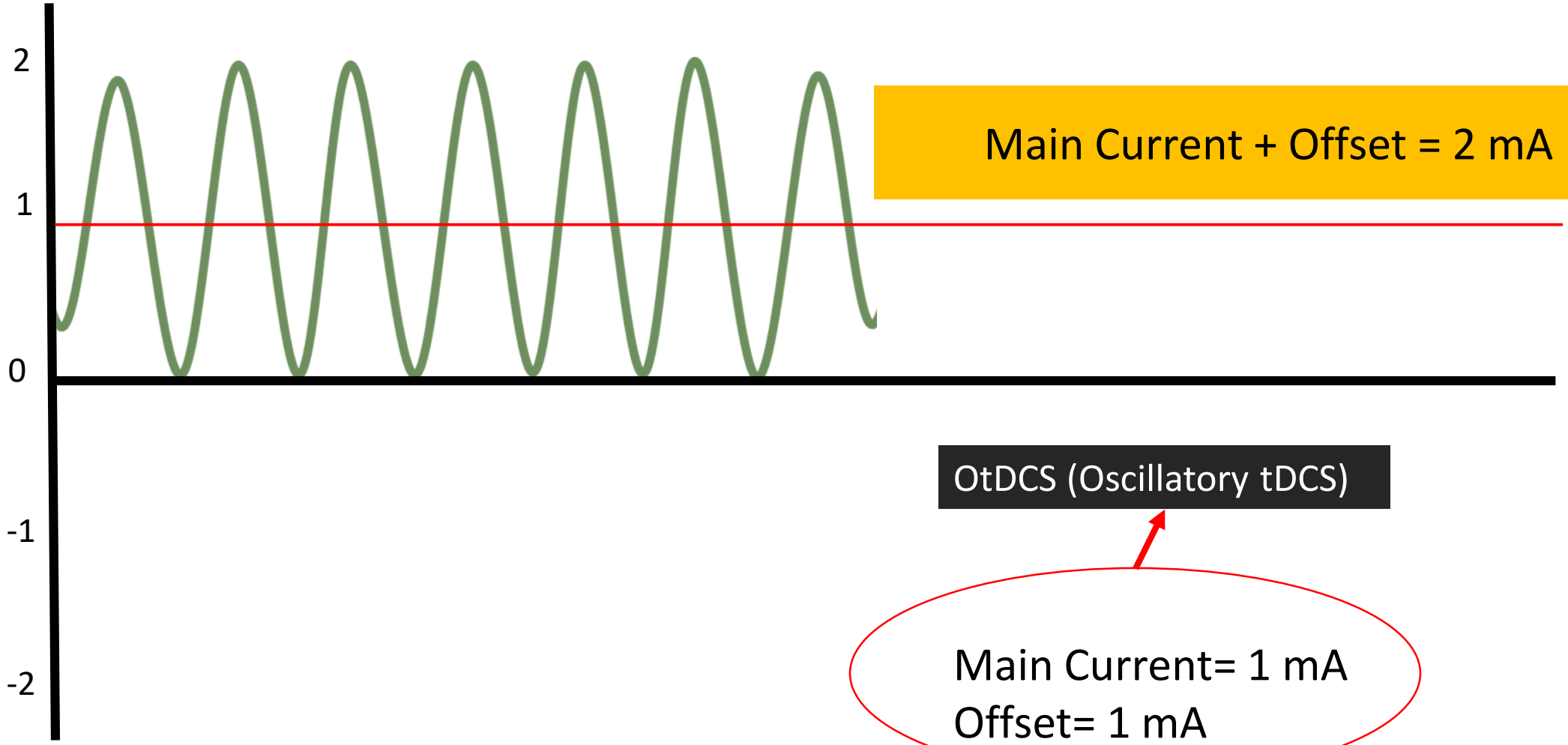
Main Current + Offset = 2 mA

Main Current= 1 mA
Offset= 0 mA

Practical notes of tACS- Offset



Practical notes of tACS- Offset



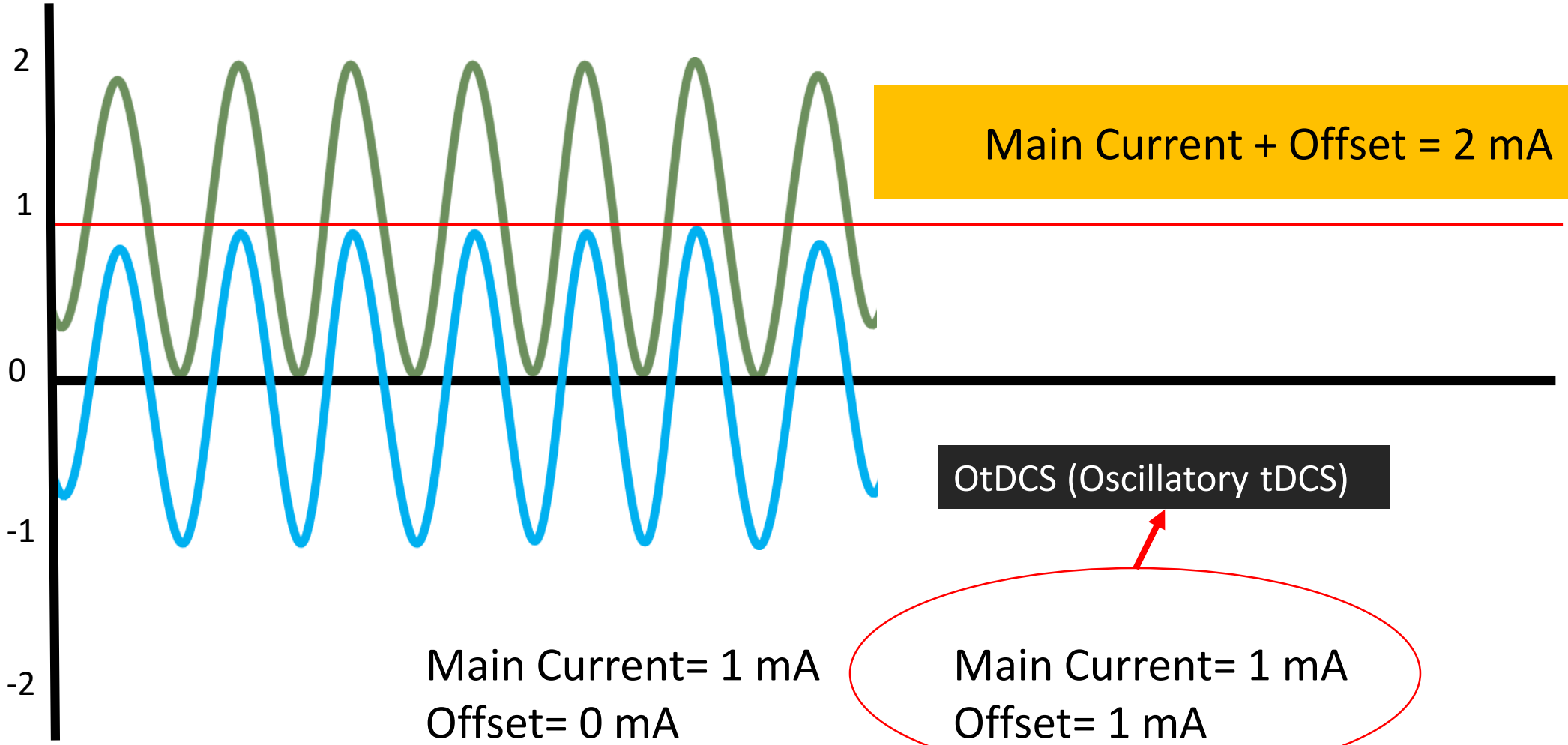
Main Current + Offset = 2 mA

OtDCS (Oscillatory tDCS)

Main Current= 1 mA
Offset= 1 mA

Unipolar tACS

Practical notes of tACS- Offset



Main Current + Offset = 2 mA

OtDCS (Oscillatory tDCS)

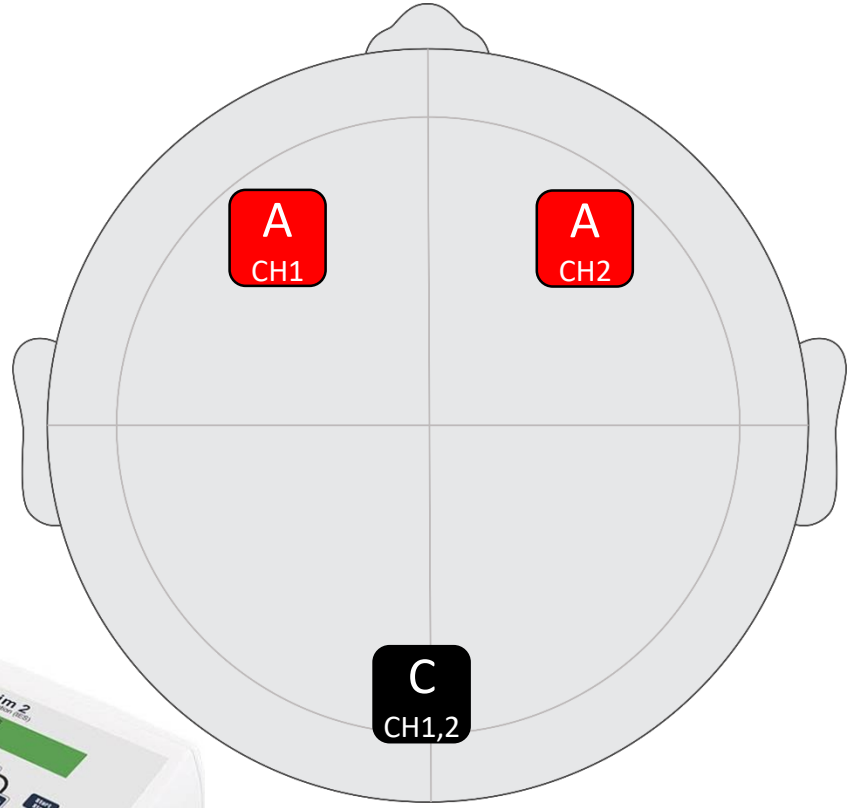
Main Current= 1 mA
Offset= 0 mA

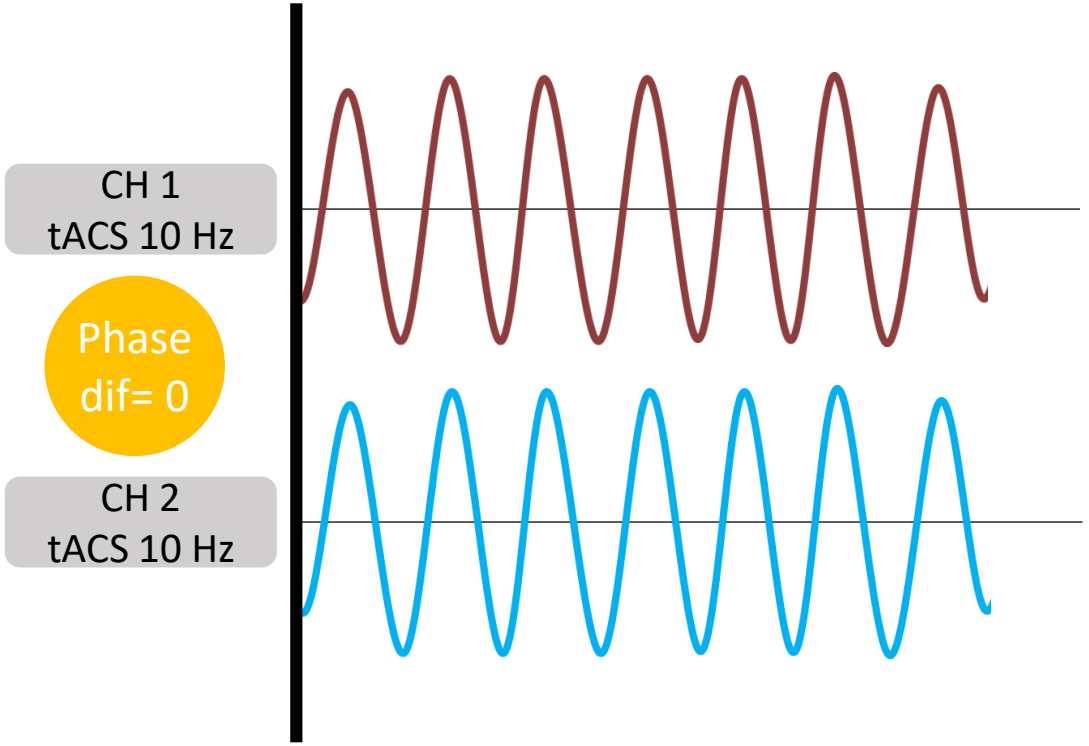
Bipolar tACS

Main Current= 1 mA
Offset= 1 mA

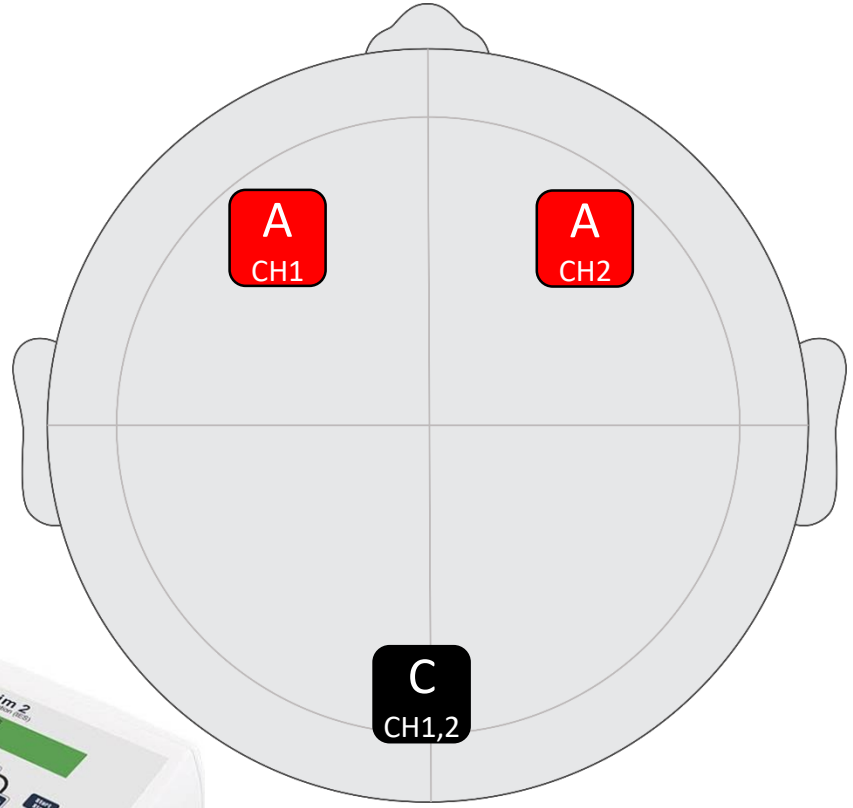
Unipolar tACS

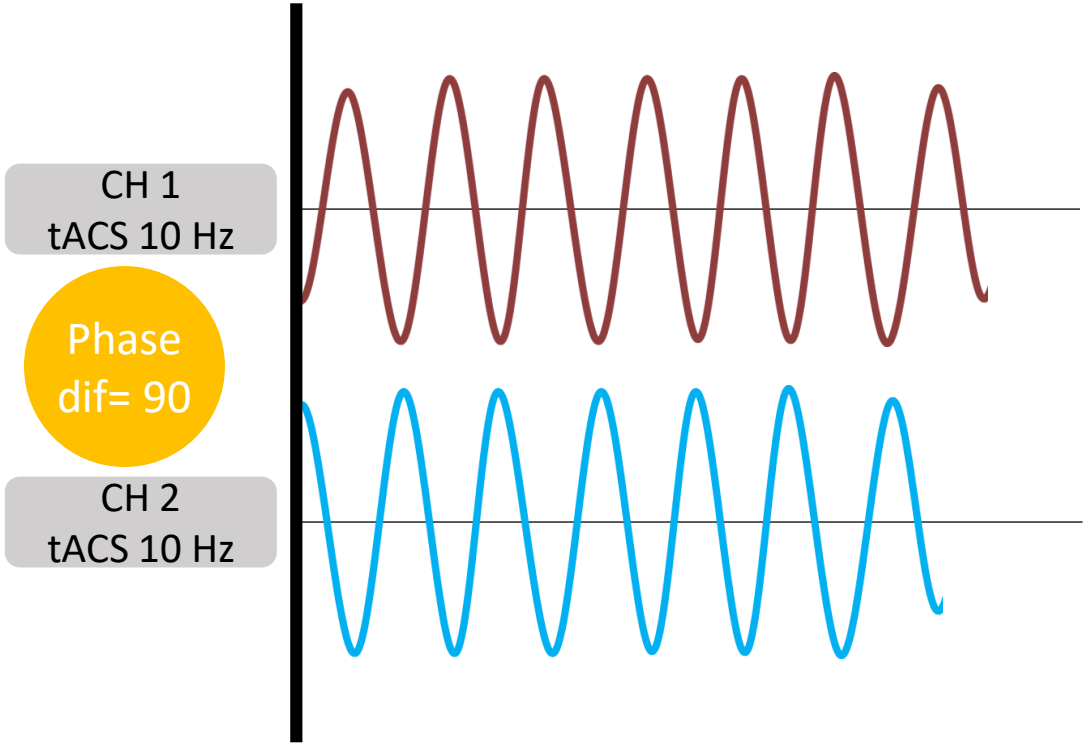
Practical notes of tACS- Phase

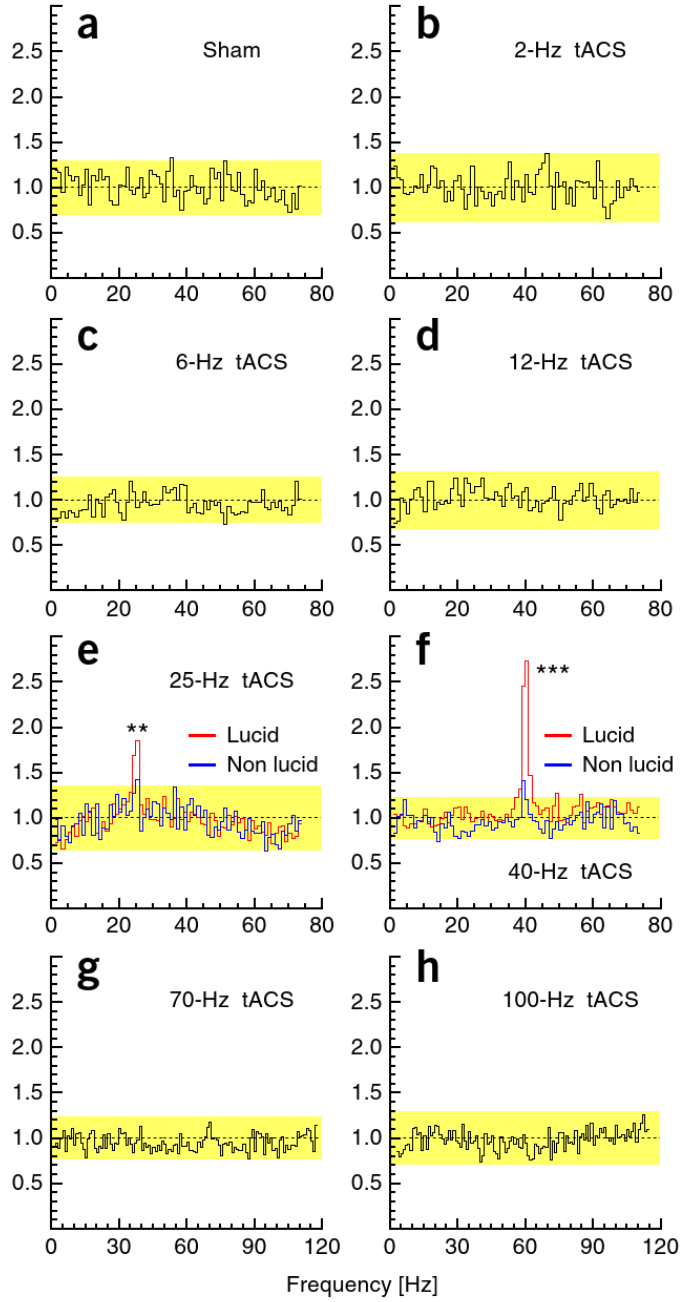


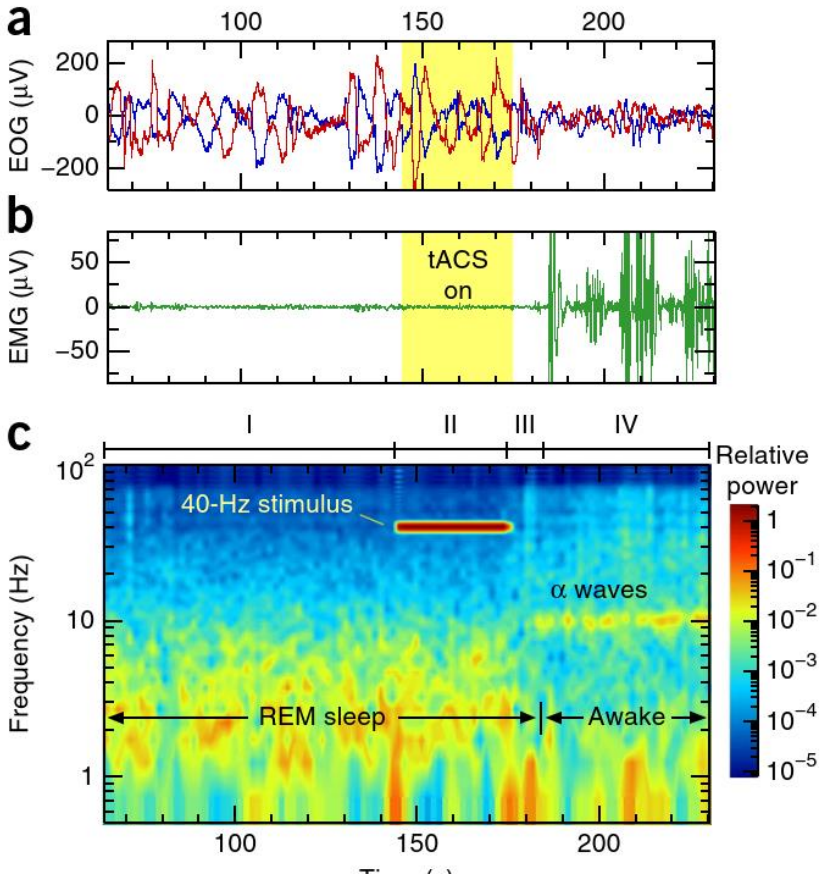


Practical notes of tACS- Phase

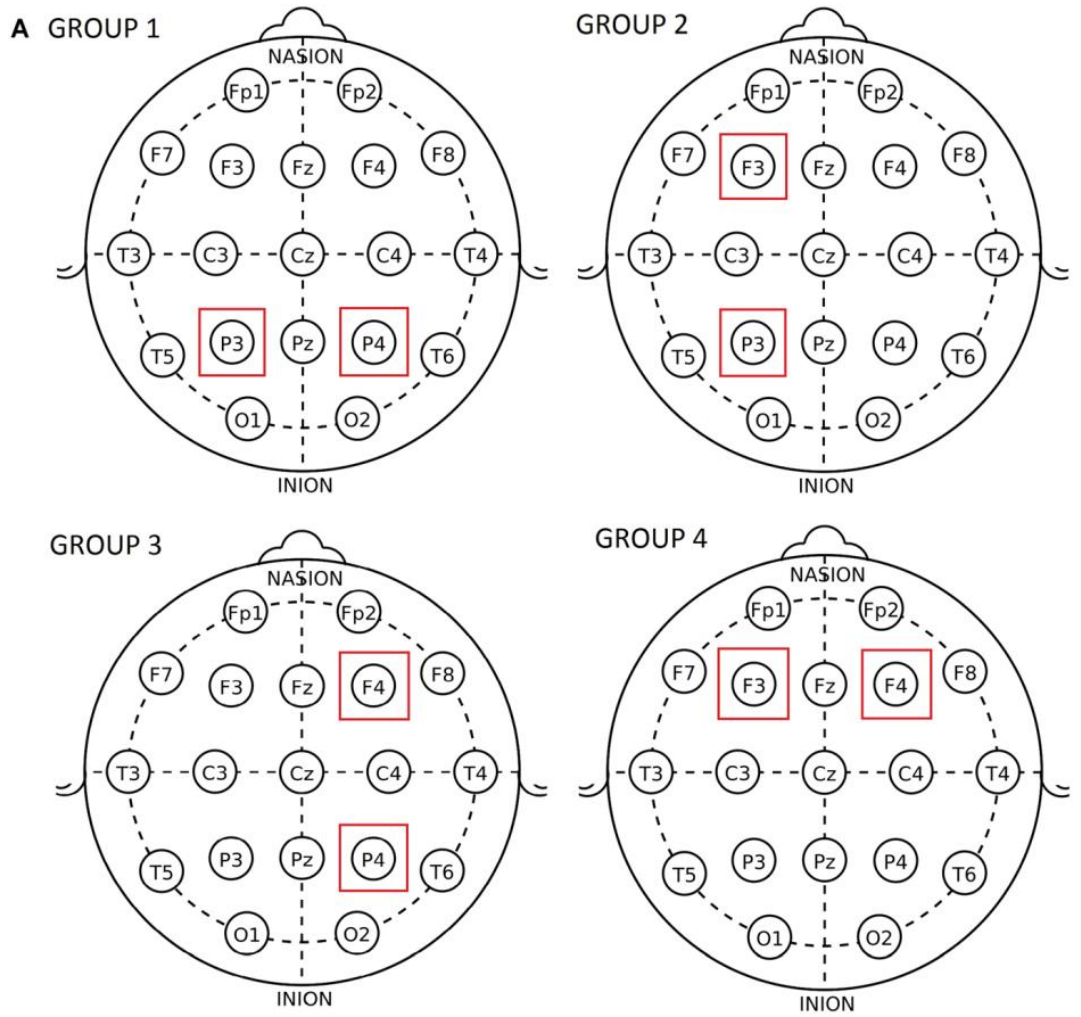




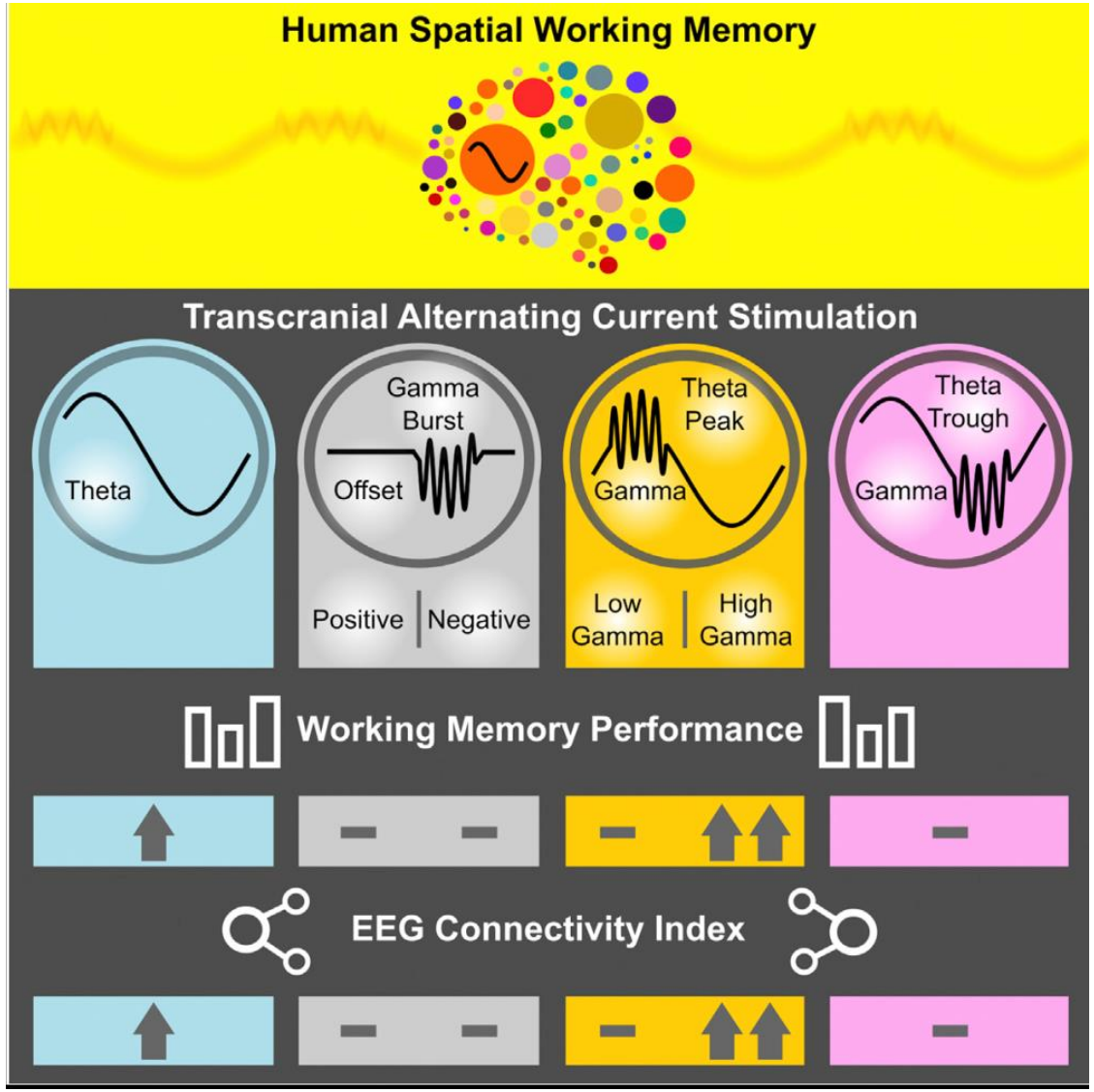




Voss, U., Holzmann, R., Hobson, A., Paulus, W., Koppehele-Gossel, J., Klimke, A., & Nitsche, M. A. (2014). *Induction of self awareness in dreams through frontal low current stimulation of gamma activity. Nature Neuroscience, 17(6), 810–812.* doi:10.1038/nn.3719

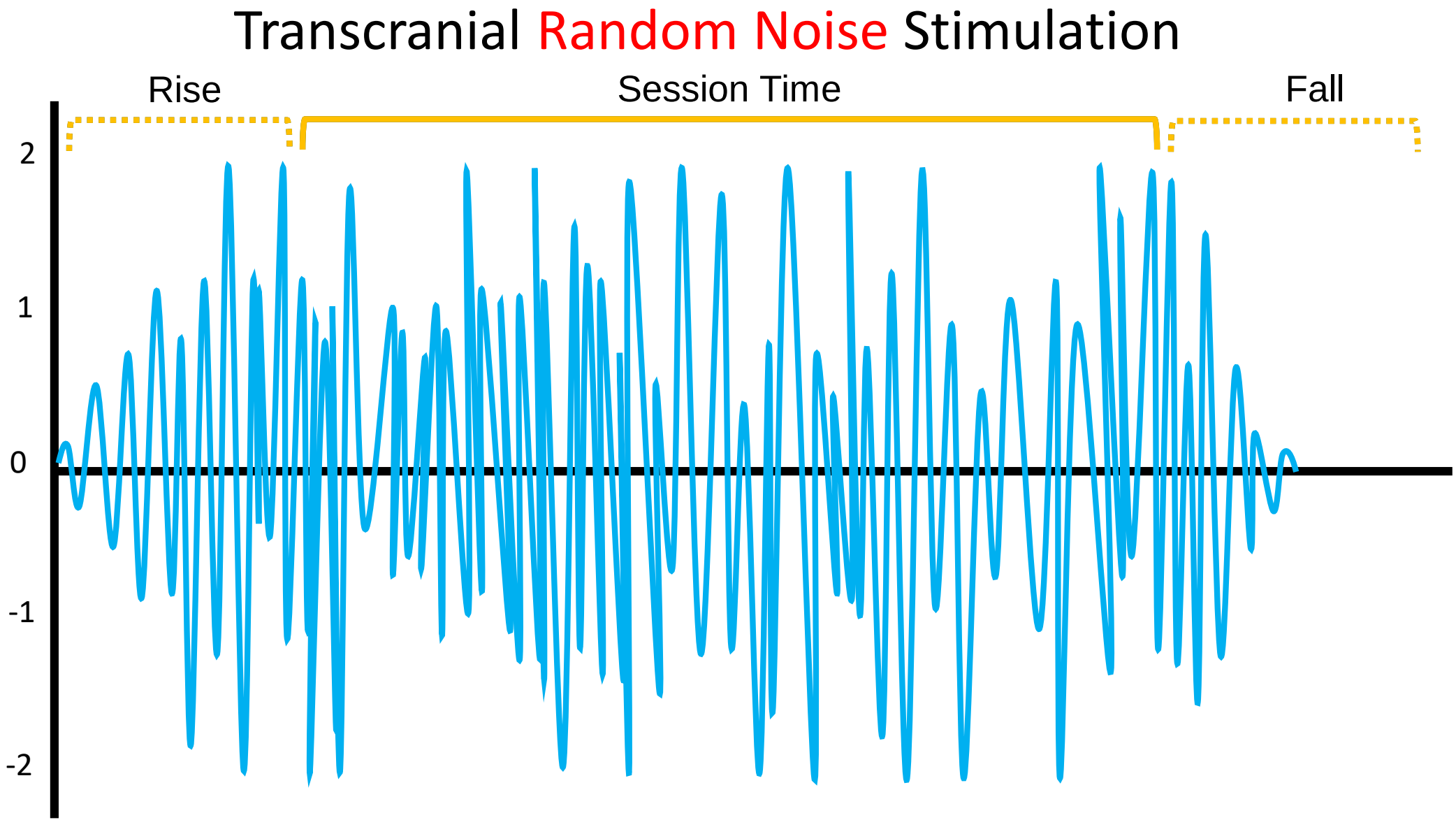


Pahor, A., & Jaušovec, N. (2018). The Effects of Theta and Gamma tACS on Working Memory and Electrophysiology. Frontiers in Human Neuroscience, 11. doi:10.3389/fnhum.2017.00651



Alekseichuk, I., Turi, Z., de Lara, G. A., Antal, A., & Paulus, W. (2016). Spatial working memory in humans depends on theta and high gamma synchronization in the prefrontal cortex. *Current Biology*, *26*(12), 1513-1521.

Types of tES


Transcranial Random Noise Stimulation
Rise
Session Time
Fall
2
1
0
-1
-2

- Transcranial random noise stimulation (tRNS) is a neuromodulatory technique that involves the delivery of a bi-directional, randomly oscillating current. Introduction of a positive DC offset to the stimulation can produce a polarity-specific randomly oscillating current that produces effects similar to that of transcranial direct current stimulation (tDCS). It is thought that tRNS modulates cortical excitability by interfering with the ongoing neural oscillations in the cortex. In contrast to using a direct current, tRNS may avoid the homeostatic neural mechanisms associated with repeated stimulation sessions. This may be an advantage in clinical treatment protocols which seek to induce cumulative neuroplastic changes over multiple sessions. To date, there has only been one reported use of tRNS with a positive DC offset for the treatment of depression. Findings were promising, suggesting therapeutic potential for this form of stimulation (Chan et al. (2012)).

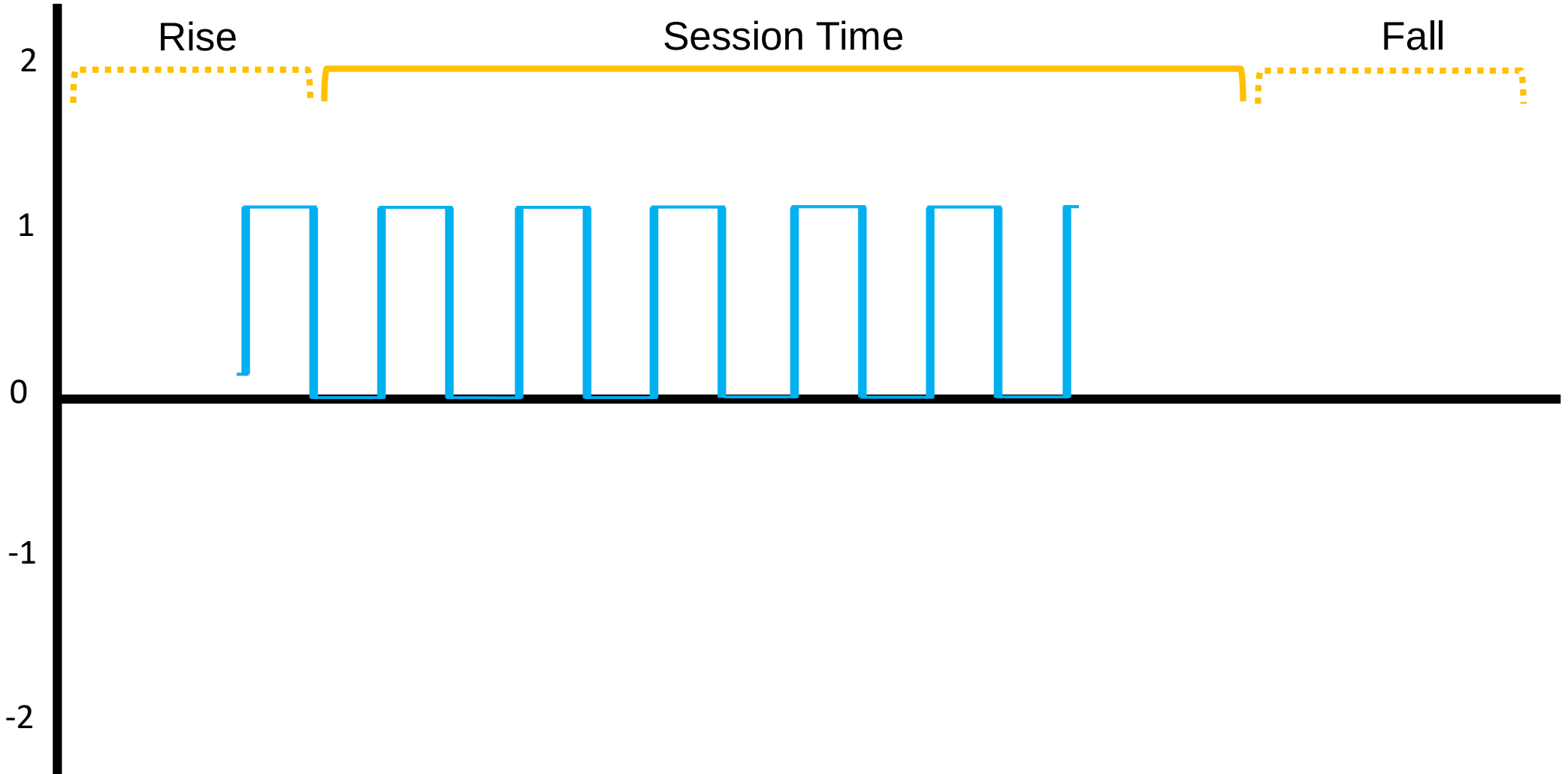
Low Signal

Low Signal
+
Weak Noise

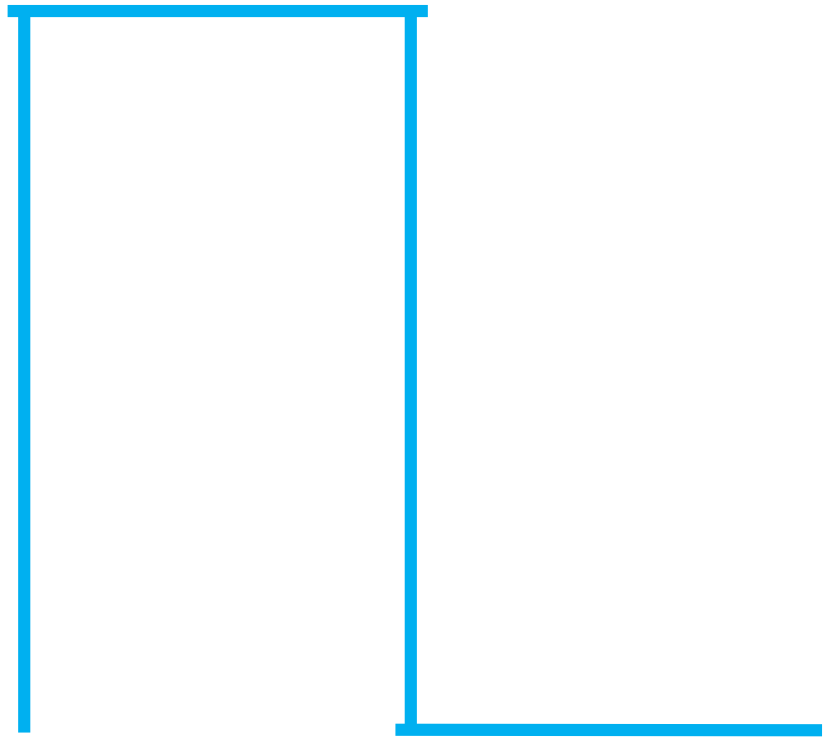
Low Signal
+
High Noise

tPCS

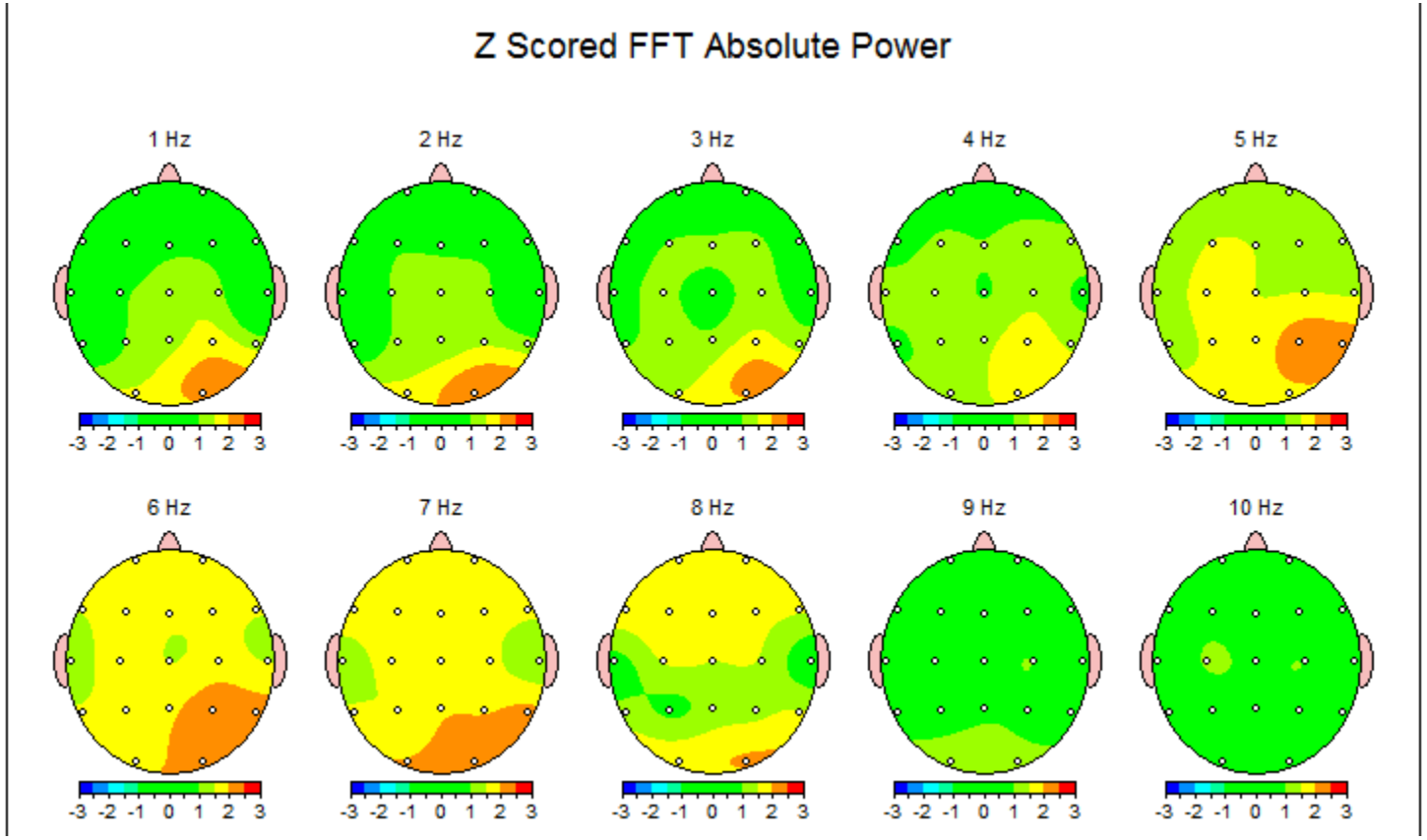
Transcranial Pulsed Current Stimulation



tPCS



- QEEG-Guided tES



- **Cranio Electro Stimulation (CES)**

- It has been suggested that the current results in an increase of the brain's levels of serotonin, norepinephrine, and dopamine, and a decrease in levels of cortisol. After a CES treatment, users are in an "alert, yet relaxed" state, characterized by increased alpha and decreased delta brain waves as seen on EEG

- **Then the main application of CES is Alpha wave**

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

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

Review article

Transcranial electrical and magnetic stimulation (tES and TMS) for addiction medicine: A consensus paper on the present state of the science and the road ahead

Hamed Ekhtiari[a,*], Hosna Tavakoli[b,c], Giovanni Addolorato[d,e], Chris Baeken[f], Antonello Bonci[g,h,i], Salvatore Campanella[j], Luis Castelo-Branco[k], Gaëlle Challet-Bouju[l], Vincent P. Clark[m,n], Eric Claus[n], Pinhas N. Dannon[o], Alessandra Del Felice[p,q], Tess den Uyl[r], Marco Diana[s], Massimo di Giannantonio[t], John R. Fedota[u], Paul Fitzgerald[v], Luigi Gallimberti[w], Marie Grall-Bronnec[l], Sarah C. Herremans[f], Martin J. Herrmann[x], Asif Jamil[y], Eman Khedr[z], Christos Kouimtsidis[A], Karolina Kozak[B,C], Evgeny Krupitsky[D,E], Claus Lamm[F], William V. Lechner[G], Graziella Madeo[g], Nastaran Malmir[c], Giovanni Martinotti[t], William M. McDonald[H], Chiara Montemitro[g,t], Ester M. Nakamura-Palacios[I], Mohammad Nasehi[J], Xavier Noël[j], Masoud Nosratabadi[K], Martin Paulus[a], Mauro Pettorruso[t], Basant Pradhan[L], Samir K. Praharaj[M], Haley Rafferty[k], Gregory Sahlem[N], Betty jo Salmeron[g], Anne Sauvaget[O,P], Renée S. Schluter[a,b], Carmen Sergiou[Q], Alireza Shahbabaie[y], Christine Sheffer[R], Primavera A. Spagnolo[S], Vaughn R. Steele[u], Ti-fei Yuan[T], Josanne D.M. van Dongen[Q], Vincent Van Waes[U], Ganesan Venkatasubramanian[V], Antonio Verdejo-García[W], Ilse Verveer[Q], Justine W. Welsh[H], Michael J. Wesley[X], Katie Witkiewitz[n], Fateme Yavari[y], Mohammad-Reza Zarrindast[Y], Laurie Zawertailo[B,C], Xiaochu Zhang[Z], Yoon-Hee Cha[a], Tony P. George[B,C], Flavio Frohlich[aa], Anna E. Goudriaan[ab,ac], Shirley Fecteau[ad], Stacey B. Daughters[aa], Elliot A. Stein[u], Felipe Fregni[k], Michael A. Nitsche[y,ae], Abraham Zangen[af], Marom Bikson[ag], Colleen A. Hanlon[N]

Learn more about Neuromodulation, NYC Neuromodulation Conference 2020

Completed Updates on Transcranial Direct Current Stimulation (tDCS) : Applications and Mechanisms

Starts: Monday, April 20th 2020 | 9 AM (EDT) / 14:00 (GMT+1)
Duration: 3 hours

Session Chair:

Marom Bikson, (The City College of New York)

Session Speakers:

Marom Bikson: Opening Remarks
(9:02) Michael Nitsche: Updates on tDCS dosing: Polarity, Intensity, and Interval.
(9:27) Lucas Parra: Updates and perspective on tDCS mechanisms: tDCS is Hebb.
(9:52) Bernadette Gillick: Controversies, Vulnerabilities and Possibilities: New Frontiers for Neuromodulation in Early Injury to the Pediatric Brain

https://neuromodec.com/nyc-neuromodulation-online-2020/event-list.html