

# BCIs that Stimulate

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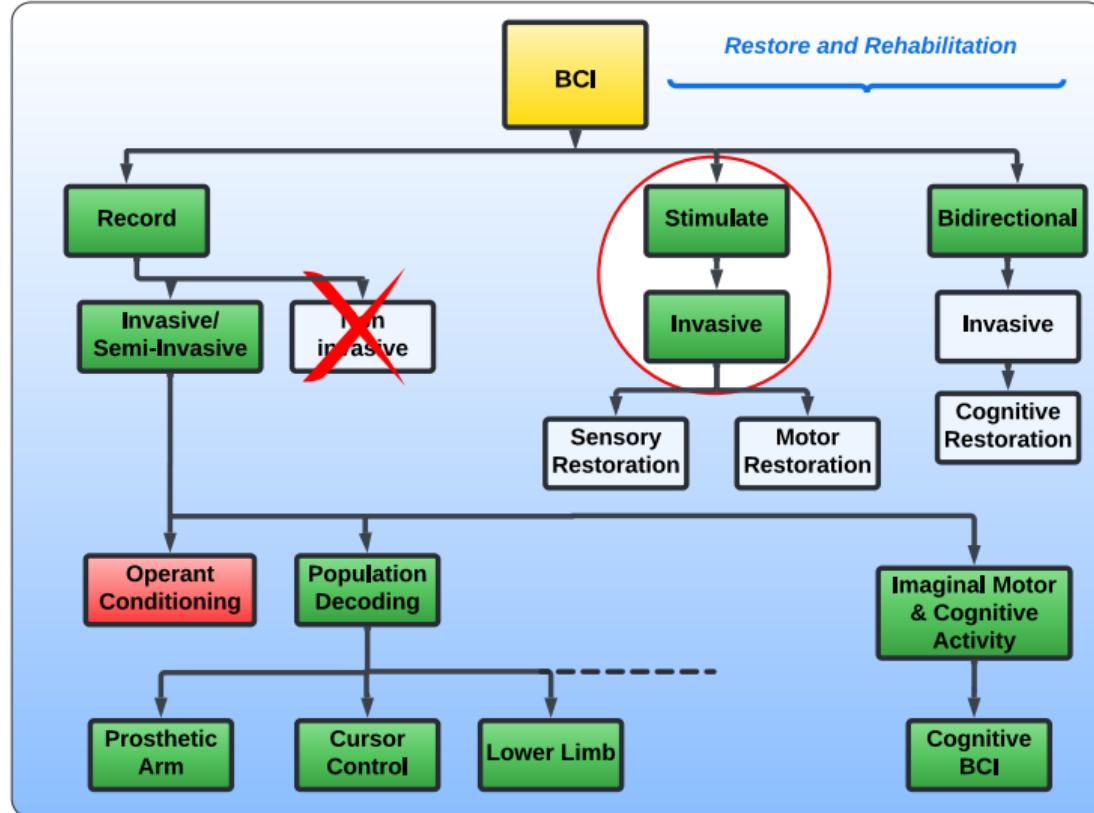
Department of  
Electronic  
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Engineering



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# Probable Applications of BCI



# Brief History (Luigi Galvani, 1780)

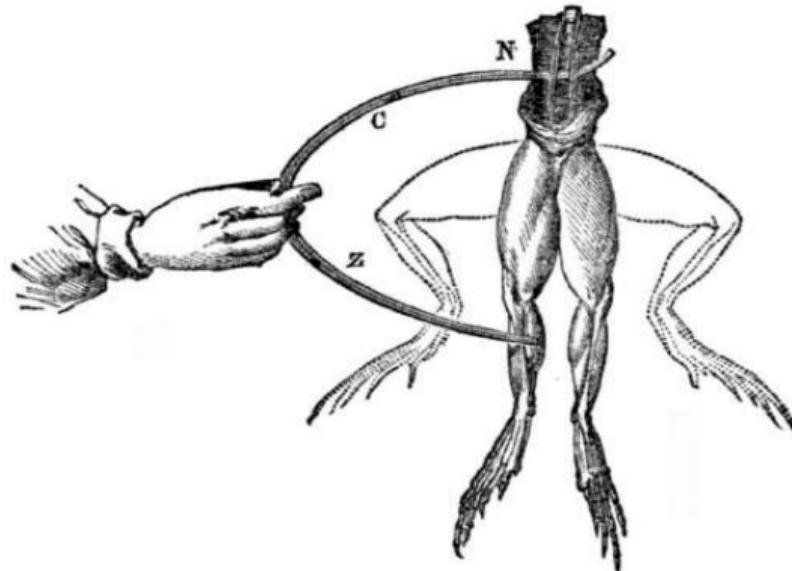
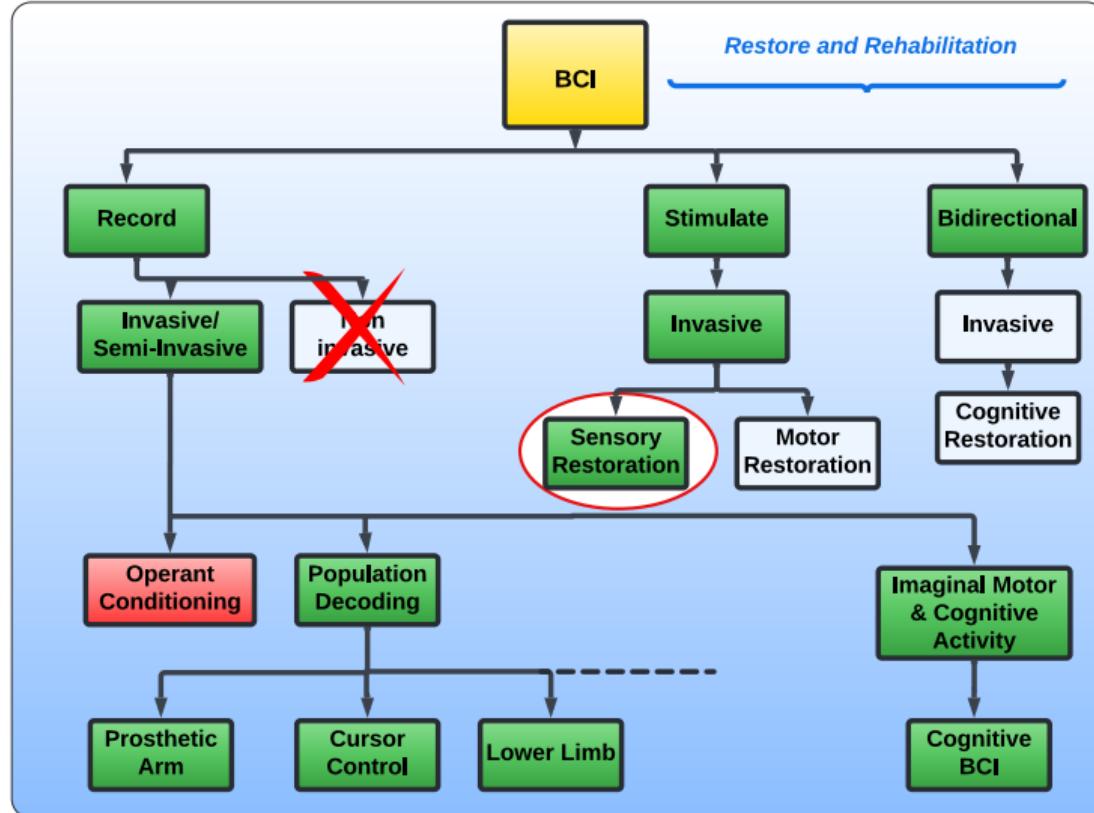


Figure: A Classic experiment of electrical stimulation, an electric current delivered to a spinal nerve by a Leyden jar caused the contraction of the leg muscles of a dissected frog.

<https://www.youtube.com/watch?v=xG6W8A3JYFA>

# Sensory Restoration



# A. Cochlear Implants

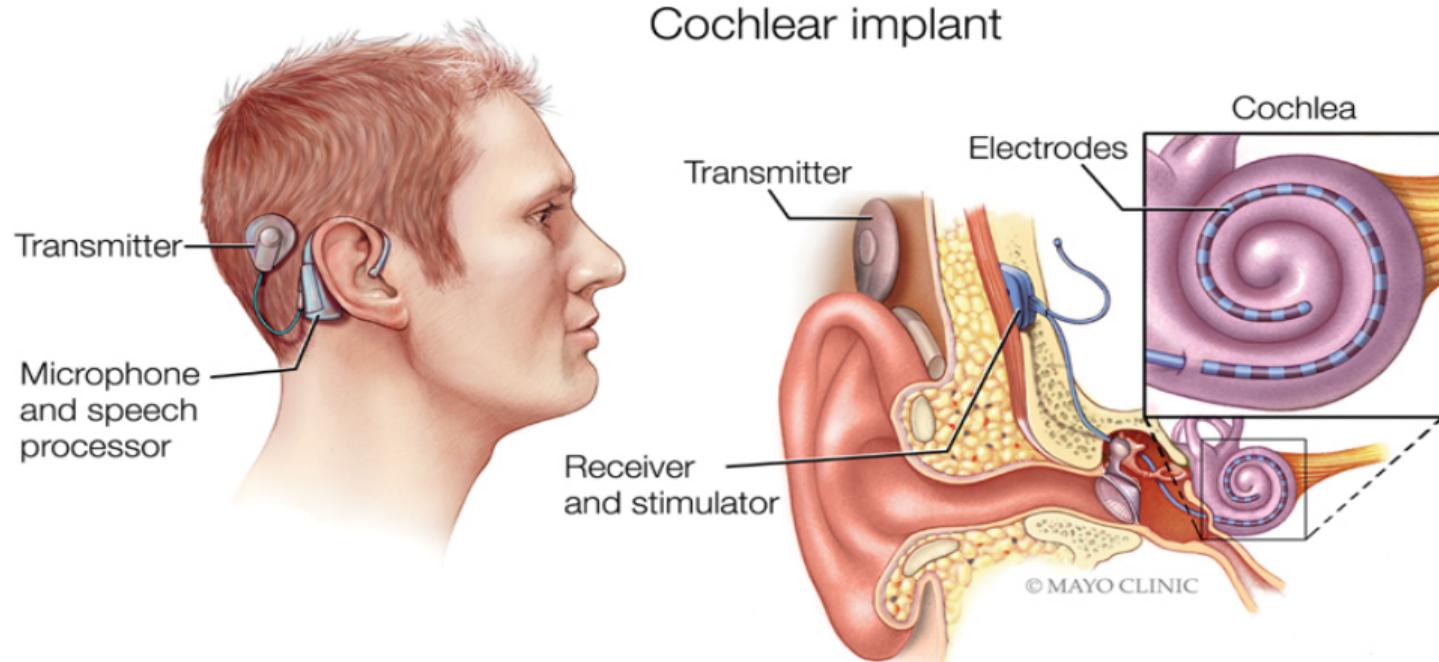


Figure: Components of Cochlear Implant system

## B. Retinal Implants(1978)

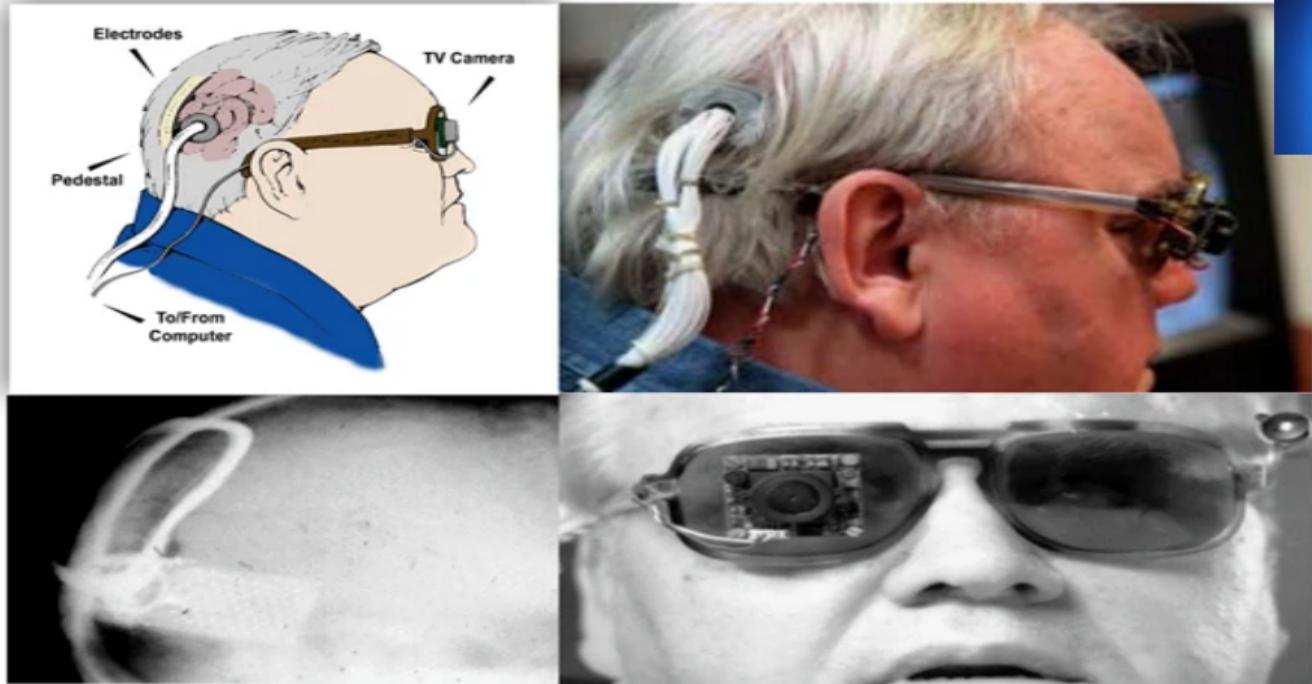


Figure: Stimulation of the **visual cortex** of hemianopic patients during neurovascular operations. [2]

# Future of Retinal Implants

4 Neuralink ✨ @neuralink · Sep 18

We have received Breakthrough Device Designation from the FDA for Blindsight.

Join us in our quest to bring back sight to those who have lost it. Apply to our Patient Registry and openings on our career page [neuralink.com](https://neuralink.com)



12:40 AM · Sep 18, 2024 · 59.5M Views



Elon Musk ✅  
@elonmusk

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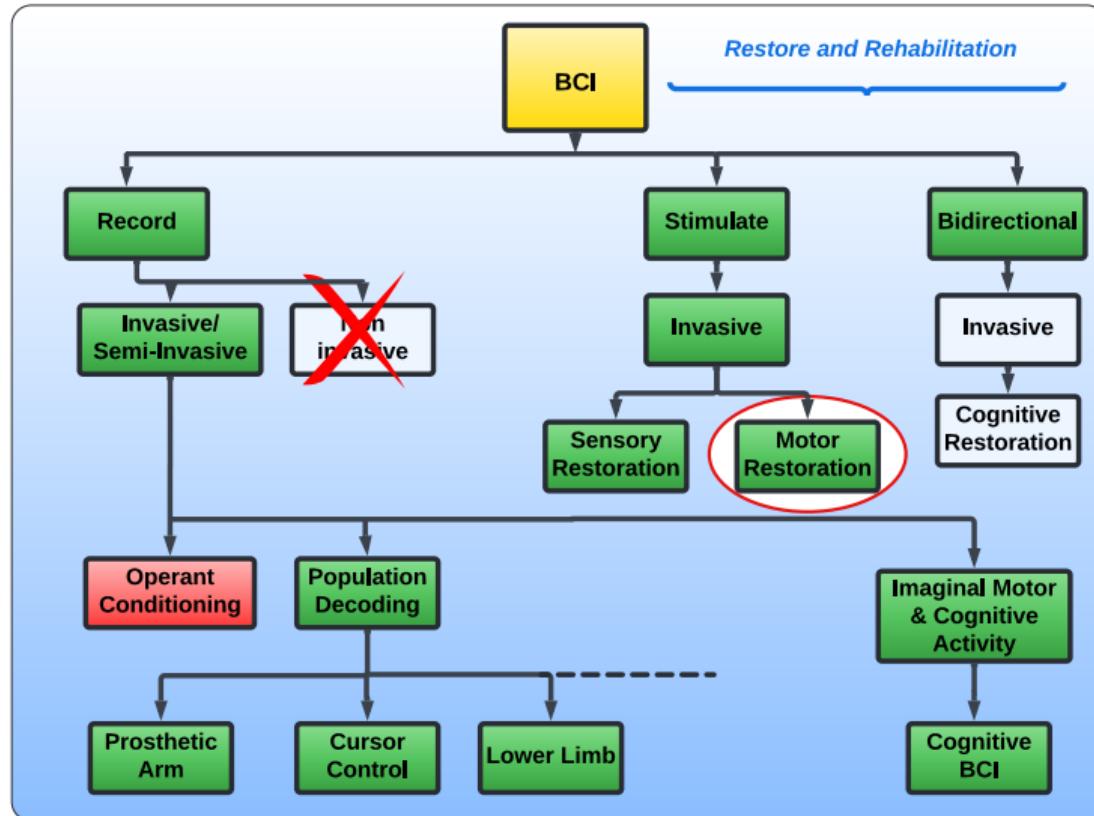
The Blindsight device from Neuralink will enable even those who have lost both eyes and their optic nerve to see.

Provided the visual cortex is intact, it will even enable those who have been blind from birth to see for the first time.

To set expectations correctly, the vision will be at first be low resolution, like Atari graphics, but eventually it has the potential be better than natural vision and enable you to see in infrared, ultraviolet or even radar wavelengths, like Geordi La Forge.

Much appreciated, [@US\\_FDA](#)!

# Motor Restoration



# DBS for Parkinson's Disease: Issue



Cut section of the midbrain where a portion of the substantia nigra is visible

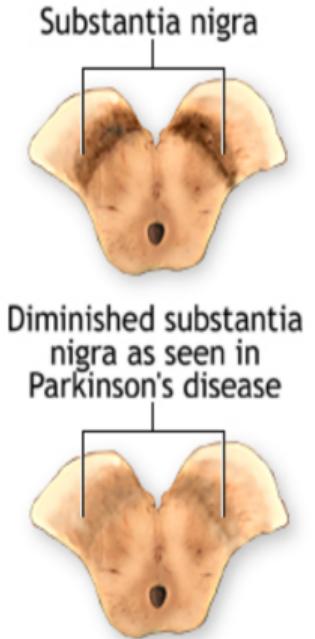


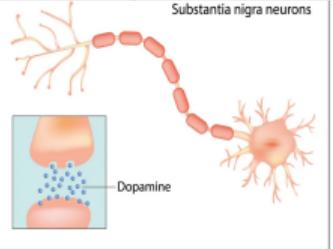
Figure: Substantia nigra from basal ganglia(Mid-brain) helps control movement.



Parkinson's disease (PD)



Healthy Substantia Nigra

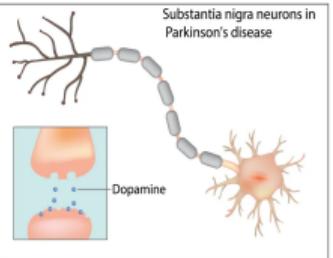


Substantia nigra neurons

Dopamine



Depreciated Substantia Nigra



Substantia nigra neurons in Parkinson's disease

Dopamine

Figure: Reward function i.e. dopamine release.

# DBS for Parkinson's Disease: Remedy

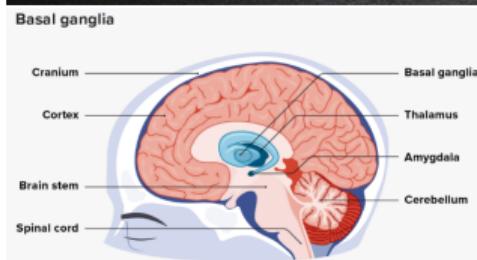
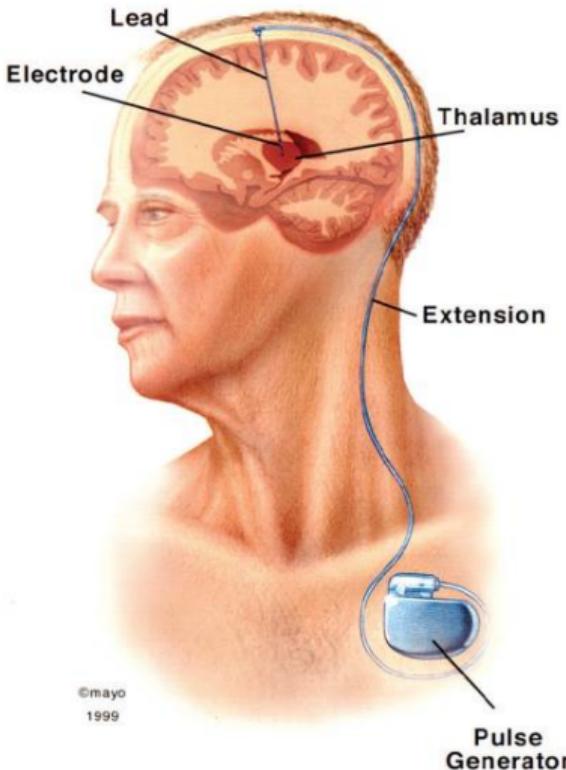
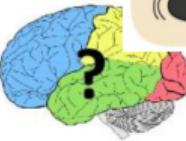
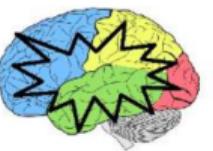
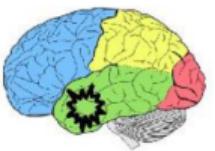


Figure: "Brain Pacemaker" for rehabilitation of parkinsons disease

# DBS for Epilepsy Disease: Issue



## Focal Onset

Classified to either:

- Aware
- Impaired awareness

### Motor Onset

### Non-motor Onset

May progress to:

### Focal to bilateral tonic-clonic

## Generalised Onset

Classified to either

- Motor**
  - Tonic clonic
  - Other motor
- Non-motor**  
(Absence seizures)

## Unknown Onset

Classified to either

- Motor**
  - Tonic clonic
  - Other motor
- Non-motor**

### Unclassified

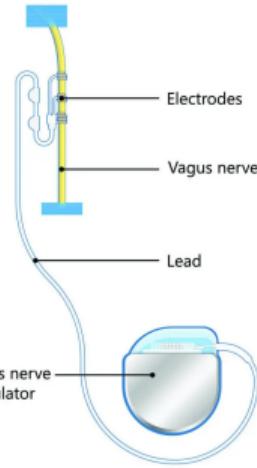
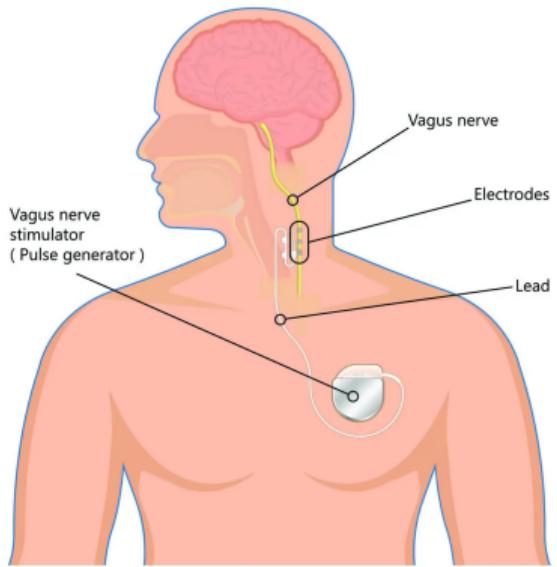
*Aware = Awareness during the seizure, knowledge of self and environment, consciousness is intact.*

*Motor = Movement or motion*

*Unclassified = Seizures with patterns that do not fit into the other categories or there is insufficient information to classify the seizure*

Figure: Seizure Types and classification [Ref.]

# DBS for Epilepsy Disease: Remedy



Vagus Nerve Stimulation  
( VNS )

Figure: Vagus nerve Stimulation for Depression and anxiety

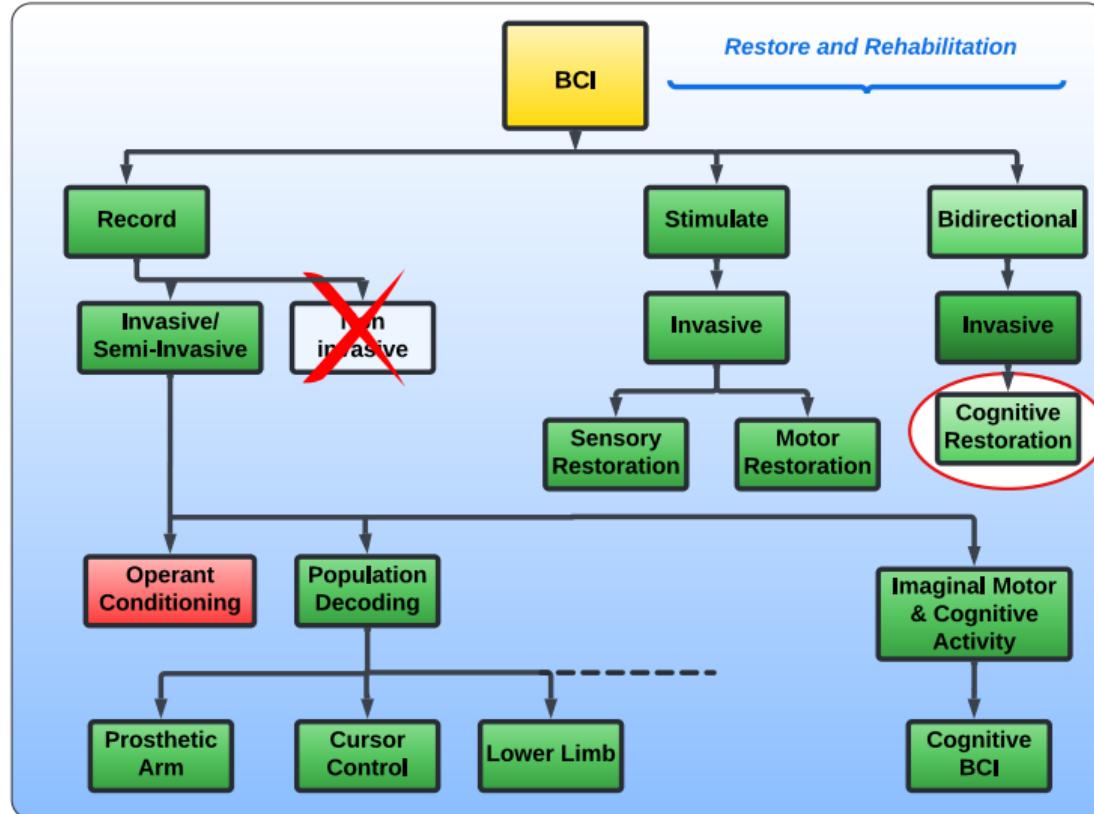
It is also used for Epilepsy treatment

# Motivation for Bidirectional BCI

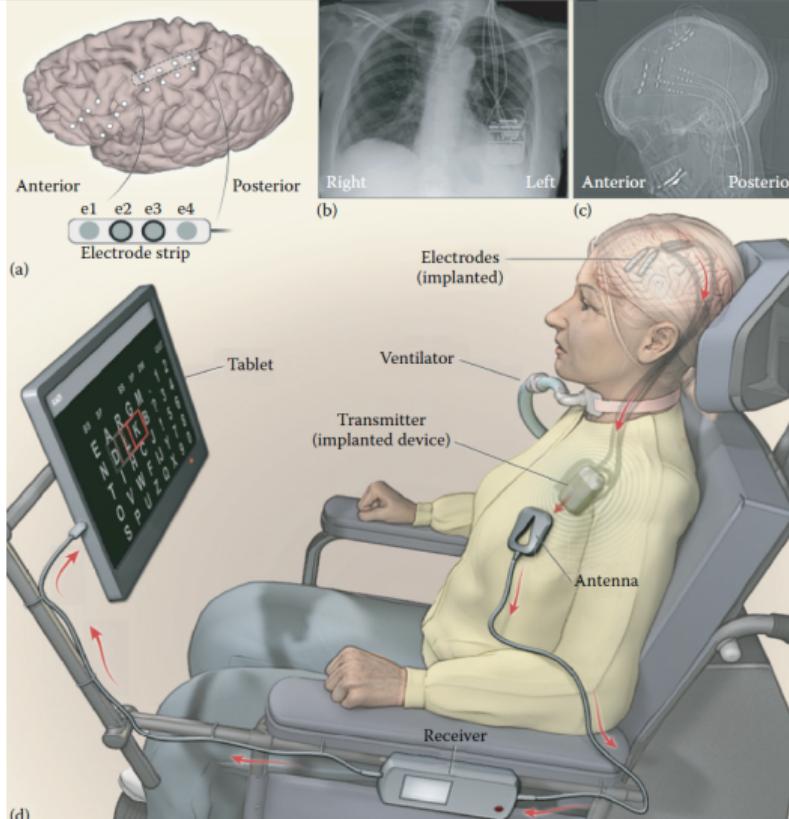
Disorder	Circuit	Postulated circuit dysfunction	Deep brain stimulation target(s) being studied or that could be considered	Stage of study
Parkinson disease, essential tremor or dystonia	Motor	<ul style="list-style-type: none"> <li>• Beta and theta oscillations</li> <li>• GPi overactivity</li> <li>• STN overactivity</li> <li>• Neuronal bursting</li> </ul>	STN, GPi, GPe, VL thalamus, PPN and spinal cord	Standard of care
Major depression	Limbic	<ul style="list-style-type: none"> <li>• Increased activity in OFC, SCC, amygdala and VS</li> <li>• Failure to downregulate amygdalar activation</li> </ul>	SCC, NAcc, habenula and medial forebrain bundle	Phase III
Obsessive-compulsive disorder	Motor and limbic	<ul style="list-style-type: none"> <li>• OFC hyperactivity</li> <li>• Failure of VS-mediated thalamofrontal inhibition</li> </ul>	NAcc, BNST, ITP, ALIC and STN	Phase II/III
Tinnitus	Auditory	<ul style="list-style-type: none"> <li>• Sensory deafferentation</li> <li>• Thalamocortical dysrhythmia</li> </ul>	Auditory pathways and caudate nucleus	Phase I
Tourette syndrome	Motor and limbic	<ul style="list-style-type: none"> <li>• Overactive direct pathway</li> <li>• Failure of thalamocortical inhibition</li> </ul>	GPi and CM-Pf	Phase I
Schizophrenia—positive symptoms	Executive function, cognition and reward	<ul style="list-style-type: none"> <li>• Thalamocortical dysrhythmia</li> <li>• Failure of saliency networks</li> </ul>	Temporal cortex and NAcc	Preclinical
Schizophrenia—negative symptoms	Motivation, reward, cognition and mood	<ul style="list-style-type: none"> <li>• Mesolimbic and mesocortical dysfunction</li> <li>• Failure to engage anticipatory hedonic system</li> </ul>	NAcc, VTA and SCC	Preclinical
Alzheimer disease	Cognitive and memory circuits	<ul style="list-style-type: none"> <li>• Amyloid-<math>\beta</math> plaques throughout the brain</li> <li>• Default mode network dysfunction</li> <li>• Cholinergic degeneration</li> <li>• Entorhinal cortex and hippocampal atrophy</li> </ul>	Fornix, entorhinal cortex, hippocampus, cingulate, precuneus, frontal cortex and nucleus basalis	Phase II/III
Pain (phantom pain, deafferentation pain, central pain and nociceptive pain)	Sensory systems and interoceptive awareness	<ul style="list-style-type: none"> <li>• Sensory deafferentation</li> <li>• Abnormal neuronal spontaneous bursting behaviour</li> </ul>	Sensory pathways, periventricular and periaqueductal areas, cingulate and insula	Phase I/II
Addiction	Reward	NAcc sensitivity to reward	NAcc	Phase I/II
Anorexianervosa	Reward and mood	<ul style="list-style-type: none"> <li>• Frontoparietal disconnection</li> <li>• Parietal hypometabolism</li> <li>• Insular abnormality</li> <li>• SCC overactivity</li> </ul>	SCC and NAcc	Phase II
Epilepsy	Various	Abnormal excitability and synchrony	CM thalamus, anterior thalamic nucleus, thalamus and seizure focus	Phase II/III

Figure: Disorder currently under investigation with deep brain stimulation. [1]

# Coming Up...



# Coming Up...



# References

- [1] Andres M. Lozano et al. "Deep brain stimulation: current challenges and future directions". In: *Nature Reviews Neurology* 2019 15:3 15.3 (Jan. 2019), pp. 148–160. ISSN: 1759-4766. DOI: 10.1038/s41582-018-0128-2. URL: <https://www.nature.com/articles/s41582-018-0128-2>.
- [2] J. O. Mills, A. Jalil, and P. E. Stanga. "Electronic retinal implants and artificial vision: journey and present". In: *Eye* 2017 31:10 31.10 (May 2017), pp. 1383–1398. ISSN: 1476-5454. DOI: 10.1038/eye.2017.65. URL: <https://www.nature.com/articles/eye201765>.

# Thank You!

# Bonus Content: World Wide Neural Diseases

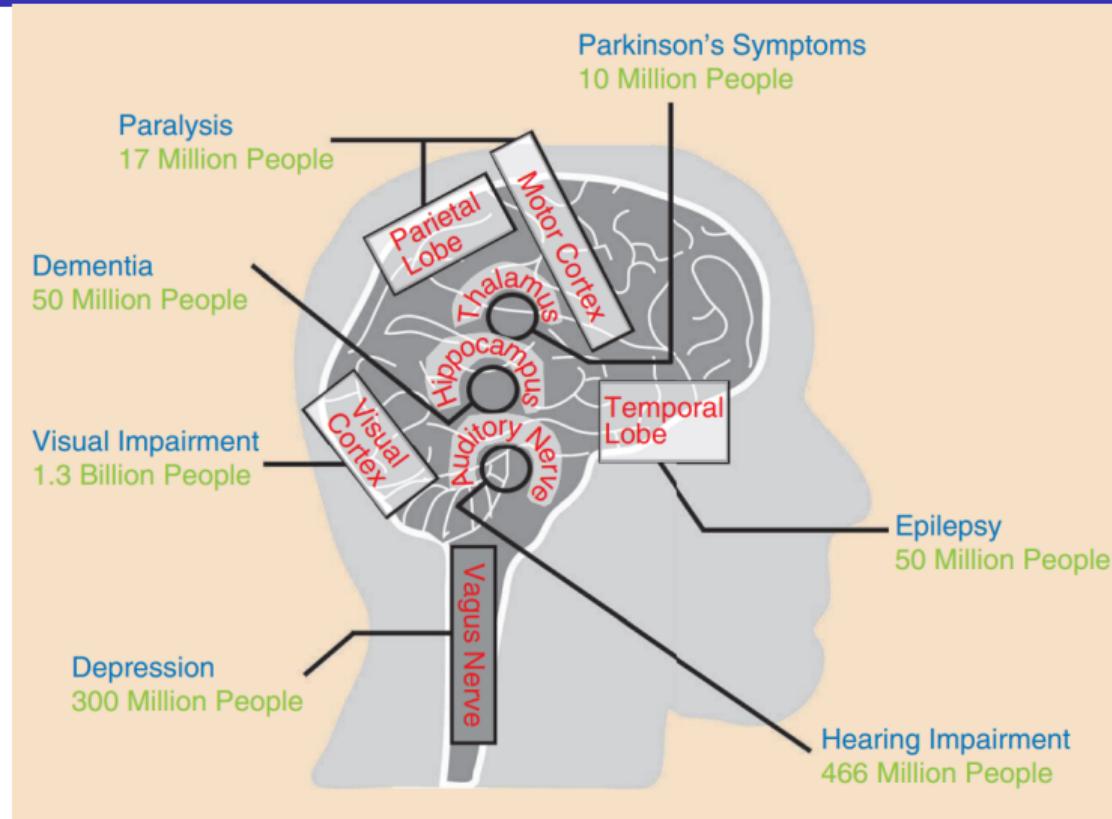


Figure: Worldwide facts about neural and other diseases affecting brain functions