

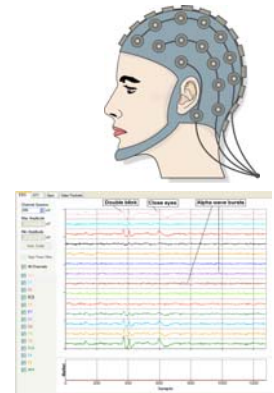
EEG-based Brain Computer Interface

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Biomedical Engineering



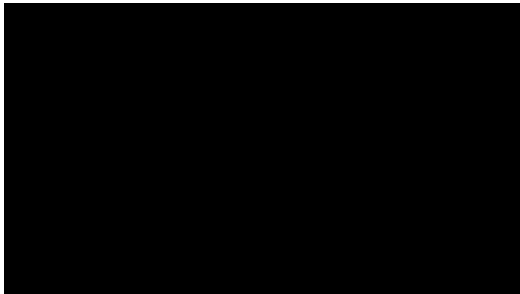
What is EEG

EEG monitors electrical signals in the brain using electrodes placed on the scalp. EEG wave patterns characterize emotion, cognition, diseases, imagination, intention, and body kinematics.



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Mind-controlled Robotics



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EEG Amplitude

- EEG signal voltage amplitudes range from about 1 to 100 μ V at frequencies (0.5 to 100Hz) at the cranial surface.
- At the surface of the cerebrum, signals may be 10 times stronger.
- Weak EEG signals require input preamplifiers (differential type) that have high gain and internal or external noise rejection.

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EEG Frequency Bands

- Higher frequencies: active processing, relatively de-synchronized activity (alert wakefulness, dream sleep).
- Lower frequencies: strongly synchronized activity (dreamless sleep, coma).

Name	Frequency (Hz)	Activity
Delta	<4	Deep sleep state/physical defects present
Theta	4-7	Emotional tensions, stress, frustration, disappointment
Alpha	8-15	Brought out by closing the eyes and by relaxation.
Beta	16-31	Brain is active, thinking, focusing
Gamma	>32	Conscious perception
Mu	8-12	Released with spontaneous nature of the brain like motor activities

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EEG recording techniques

- EEG measurements employ recording system consisting of:
 - Electrodes with conductive media - read signals from the head surface
 - Amplifiers with filters - signal is amplified and noise is removed
 - A/D converter - converts analog signal to digital format
 - Recording device - computer stores and displays the obtained data



• M. Teplan, 2002, FUNDAMENTALS OF EEG MEASUREMENT

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Types of recording electrodes

- ❑ Disposable (gel-less, and pre-gelled) types - comes in peel-and-stick form
- ❑ Reusable disc electrodes (gold, silver, stainless steel or tin)
- ❑ Headbands and electrode caps - conducting gel required make contact with the scalp
- ❑ Subdermal needles - used for long recordings and invasively inserted under the scalp



M. Teplan. 2002. FUNDAMENTALS OF EEG MEASUREMENT

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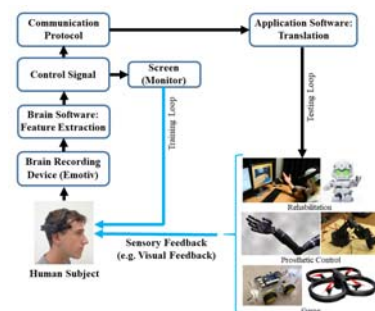


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Brain Computer Interface (BCI)



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Detecting Brain Disorders

	NC	MCI	AD
Number	15	16	17
Age (std)	75.7 (5.5)	74.6 (8.8)	76.7 (5.2)
Gender	Male=6, Female=9	Male=12, Female=4	Male=7, Female=10
MMSE	n=14	n=16	n=15
Median(range)	30 (28, 30)	27.8 (23, 30)	24.5 (19, 28)
Logic Memory I	n=14	n=15	n=12
Median (range)	13.5 (9, 18)	9.5 (2, 39)	5 (1.5, 21)

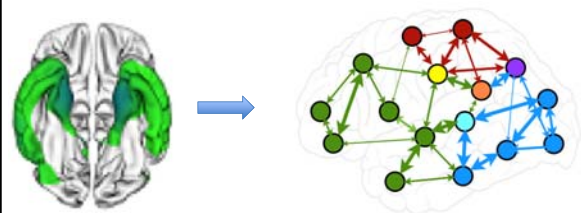
Note: std = standard deviation. MMSE = mini-mental state examination. Logic Memory I is from Wechsler Memory Scale.

NC=normal control
MCI=mild cognitive impairment
AD=Alzheimer's Disease

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Hypothesis

Brain thinning in early AD lead to functional change in EEG network.

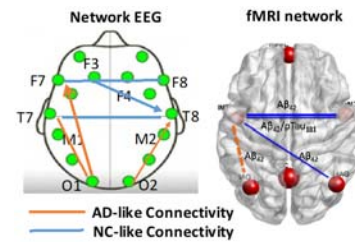


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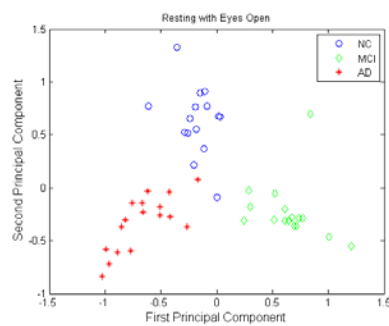
Analysis Process

- Step 1 – create EEG network model
- Step 2 – feature generation using causality estimation
- Step 3 – feature reduction
- Step 4 – classification

EEG Network



PCA: Resting Eyes Open

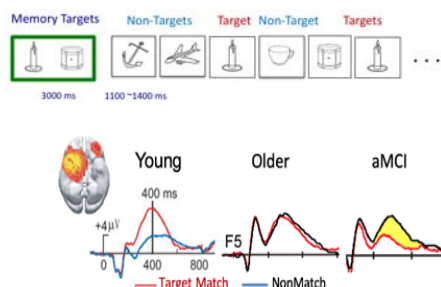


Results: Resting Eyes Open

Confusion Table of 3-Way SVM Discrimination for Resting Eyes Open

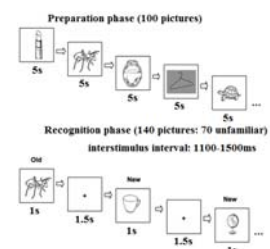
		Predicted Classes			
True Classes		NC	MCI	AD	
	NC	14	1	0	93.3%
	MCI	1	15	0	93.8%
	AD	0	0	17	100%
		93.3%	93.8%	100%	Overall Acc.: 95.8%

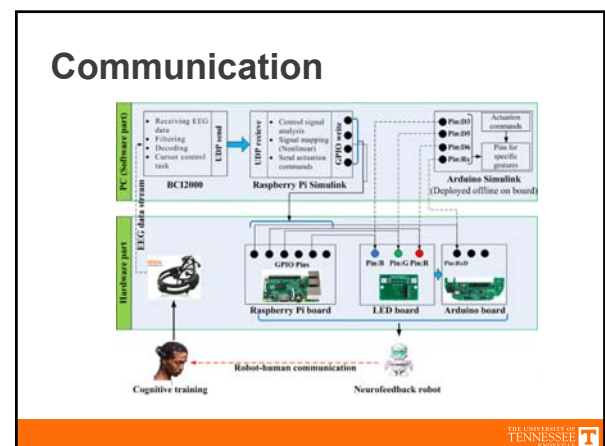
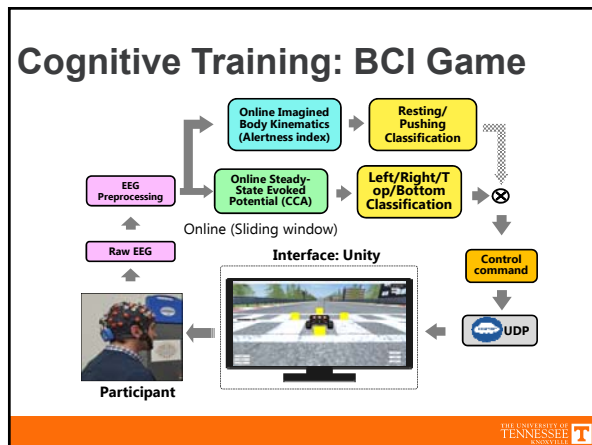
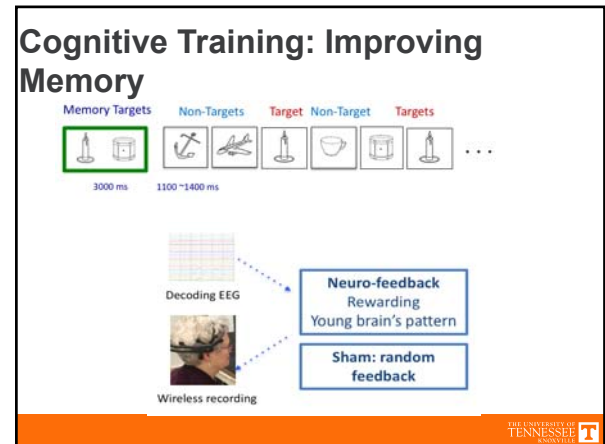
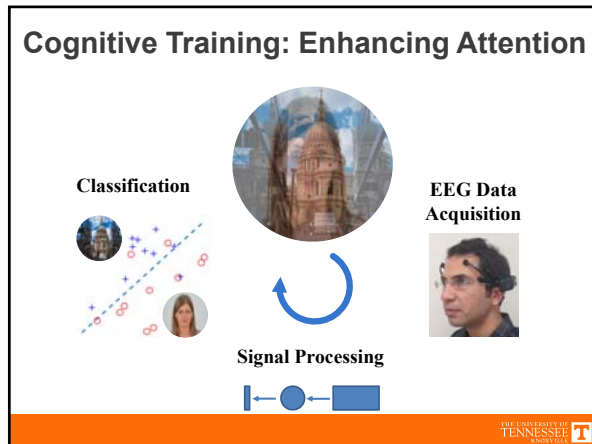
Detecting Early AD: Working Memory Protocol



Detecting Traumatic Brain Injury

- EEG recorded during working memory (WM) task
 - N=30 (15 NC, 15 TBI)
 - Avg. 13 yr (SD 7 yr) post-injury
 - Moderate/severe TBI
 - Well matched (age, extraneous factors)
 - 25 channels (32-chnl cap, some excluded)

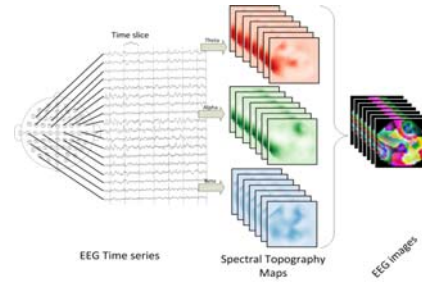




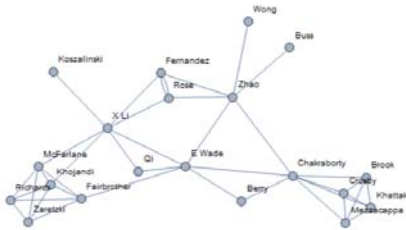
Drone Control



Machine Learning



BCI Community of Scholars



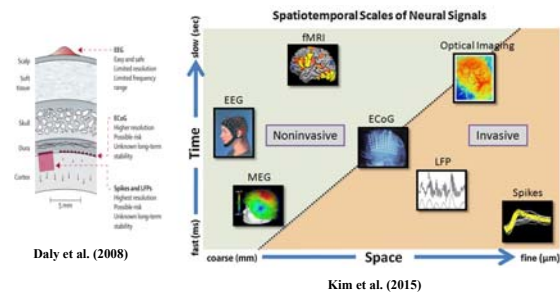
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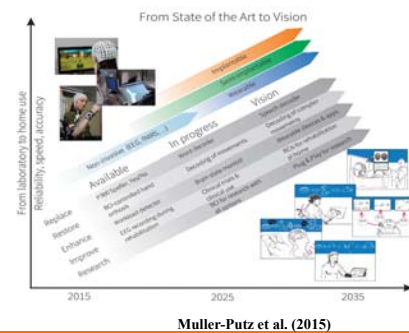
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- Rehab for stroke and Parkinson patients
- Sleep monitoring
- Special education
- Smart cities
- Deep learning
- ...

Brain Imaging Technologies



Paradigms and Applications





Take-home Message

EEG-based BCI enables enhanced communication between brain and the external world, providing new methods for neurorehabilitation and neuroprosthetics.



Acknowledgement

- | | |
|----------------|--------------------------------|
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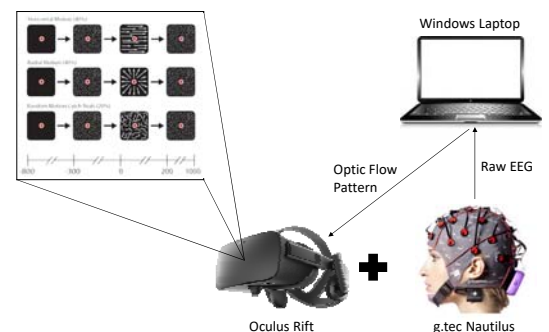
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THANK YOU



BCI Diagnosis in VR



Drone Control

