Brain Robot Augmented INtelligence

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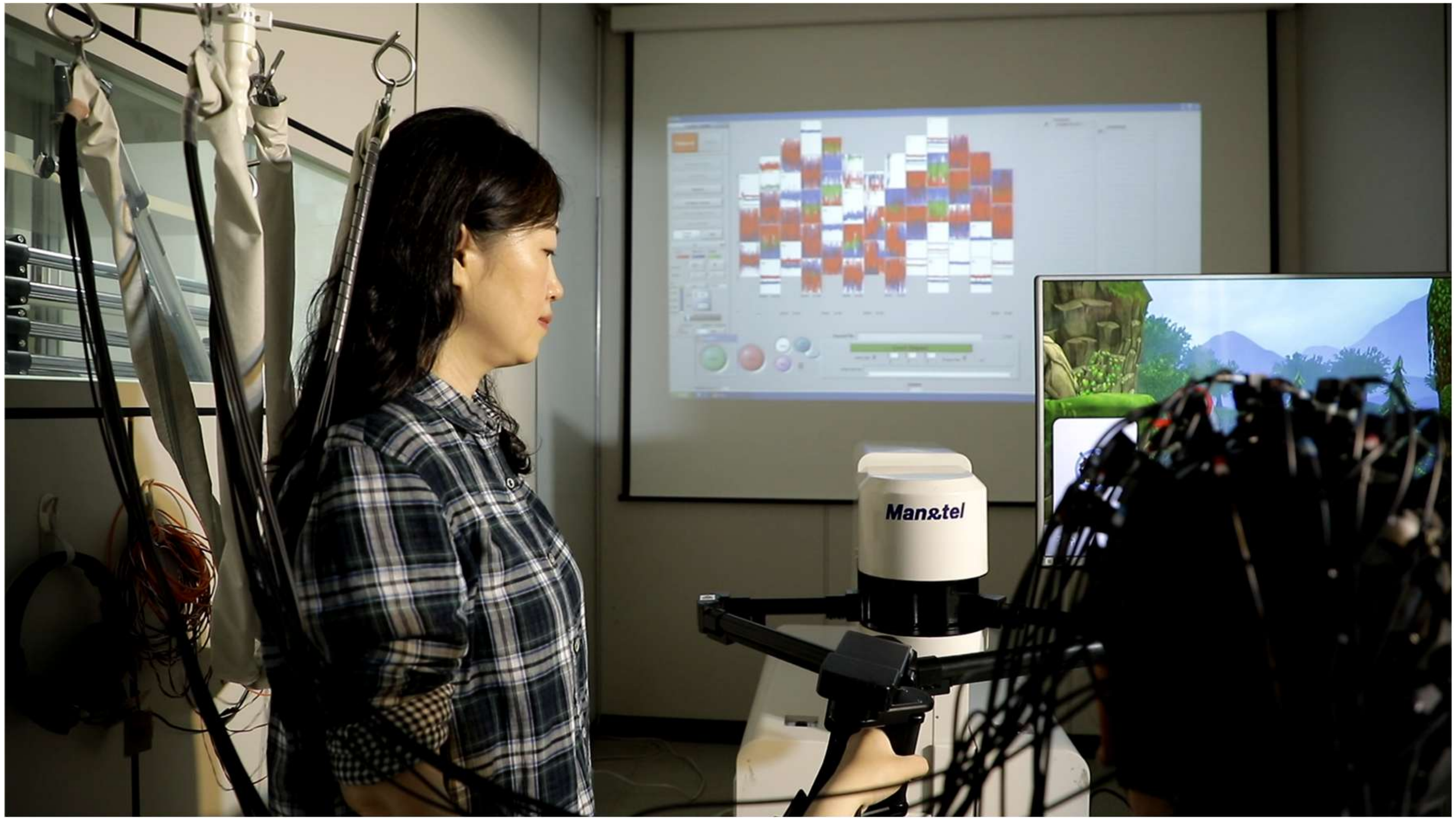
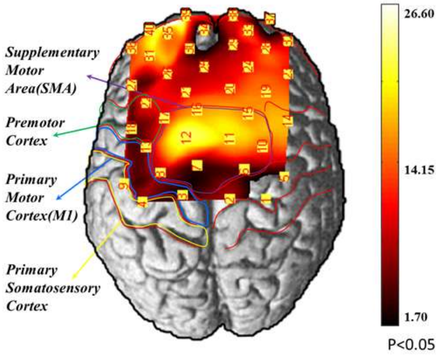
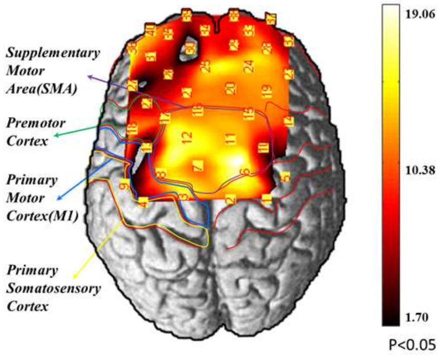
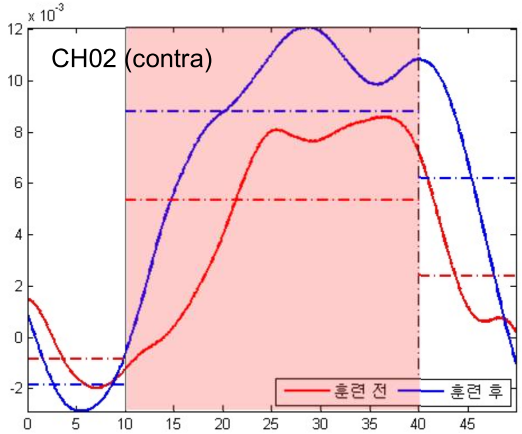


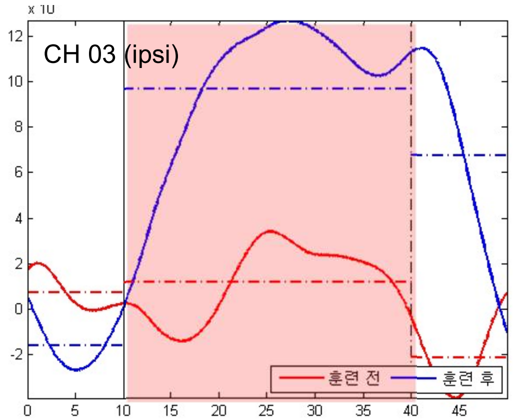
Brain Drives Action

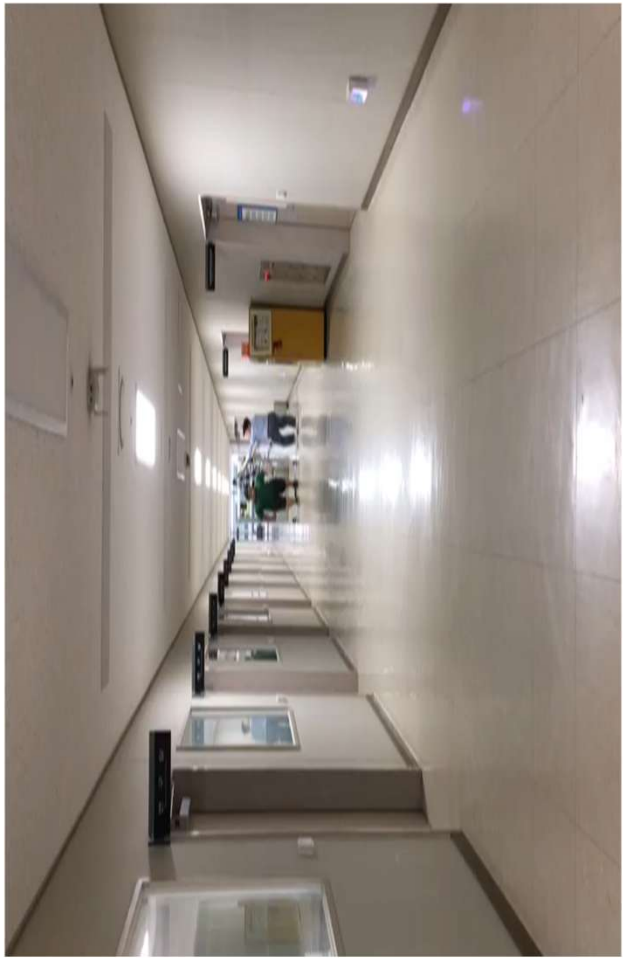
Brain-Robot Augments Gait Restoration of Stroke

Brain-Robot Augments Gait Restoration of Stroke

SPM Results	
Before	
After	

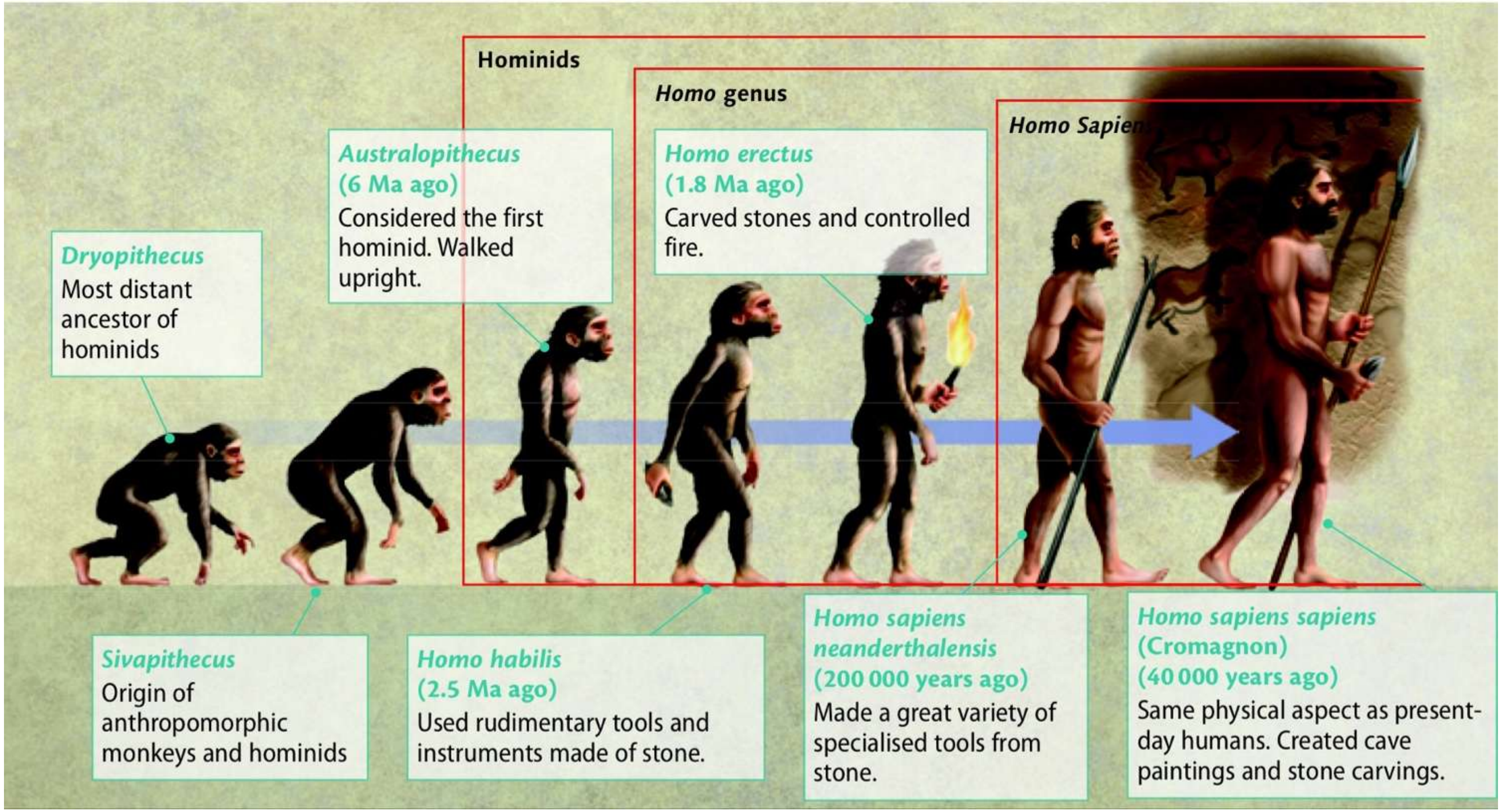






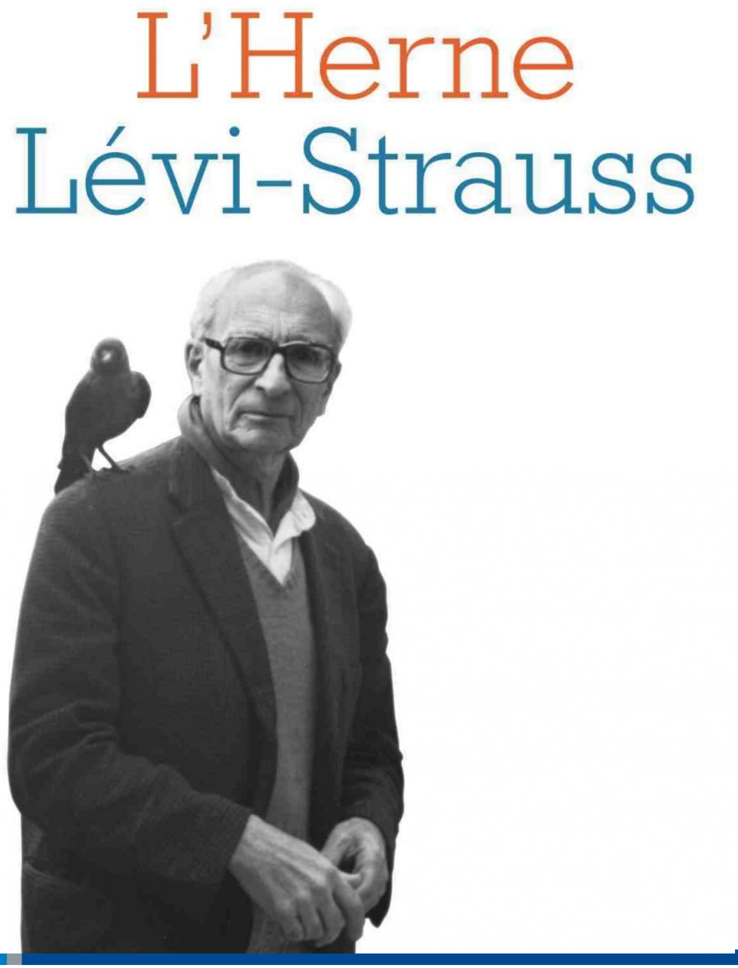
2. When Brain Meets AI

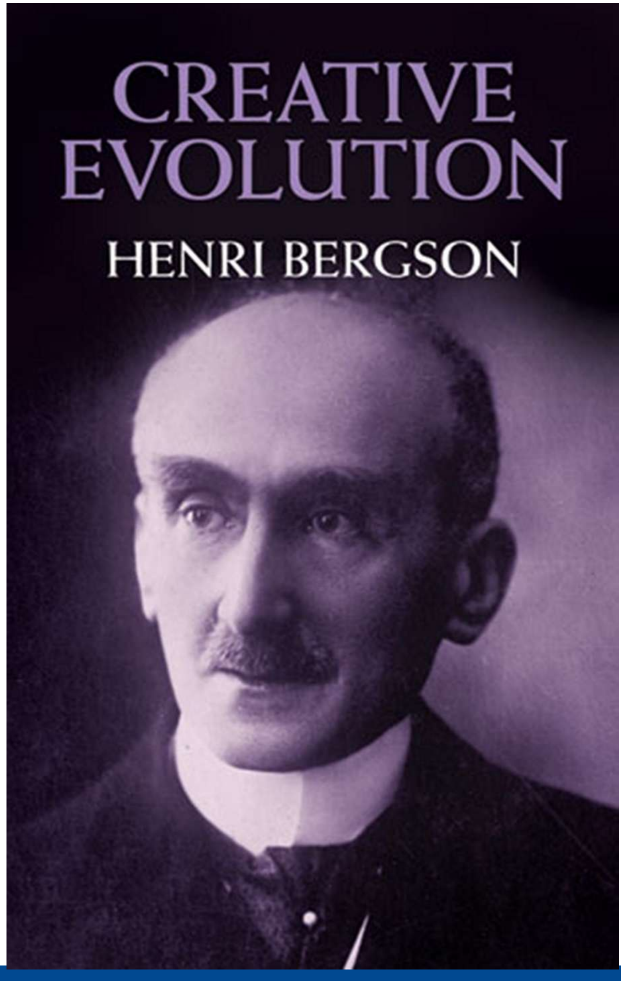
Evolution from Maker to Speaker



Language & Skill

Homo Loquens? Homo Faber?

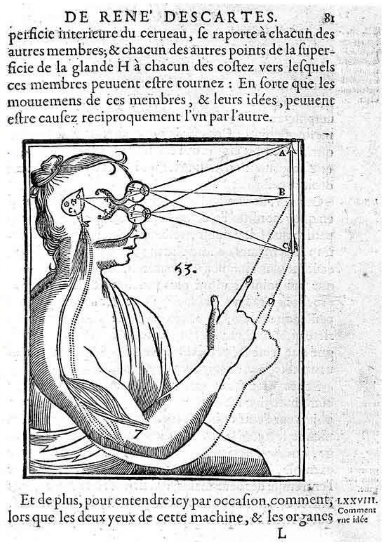




Nature? Nurture?

Nature? Nurture?

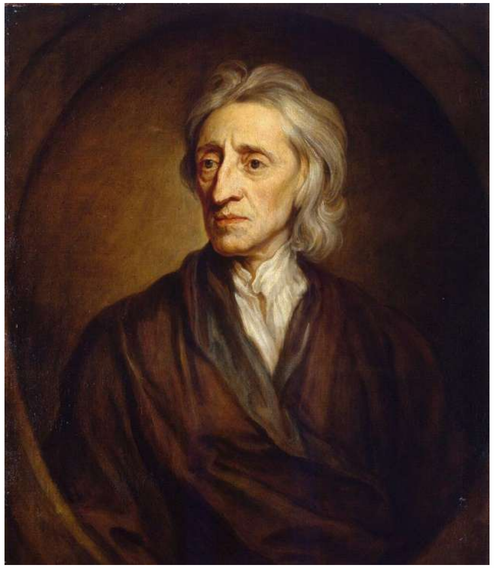
Nature? Nurture?

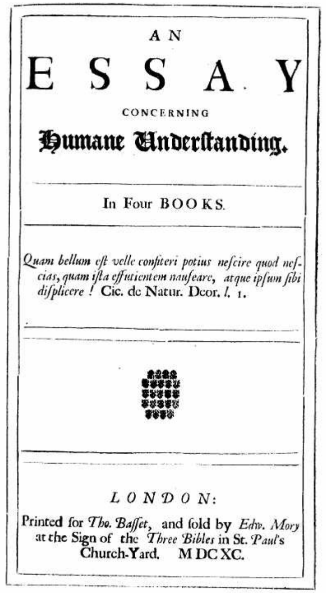

DE RENE' DESCARTES. 81

perficie interieure du cerueau, ſe raporte à chacun des autres membres; & chacun des autres points de la ſuperficie de la glande H à chacun des coſtez vers leſquels ces membres peuuent eſtre tournez : En ſorte que les mouuemens de ces membres, & leurs idées, peuuent eſtre cauſez reciproquement l'vn par l'autre.

Et de plus, pour entendre icy par occaſion, comment, lors que les deux yeux de cette machine, & les organes LXXVIII. Comment vne idée

L




AN

ESSAY

CONCERNING

Humane Understanding.

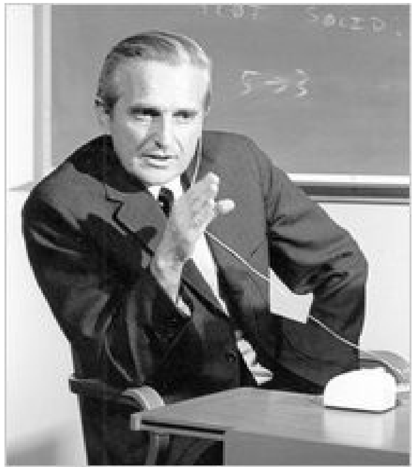
In Four BOOKS.

Quam bellum est velle confiteri potius nescire quod nescias, quam ista effutientem nauseare, atque ipsum sibi displicere! Cic. de Natur. Deor. *l.* 1.

LONDON:

Printed for *Tho. Basset*, and sold by *Edw. Mory* at the Sign of the *Three Bibles* in St. *Paul's* Church-Yard. MDCXC.

Intelligence Augmentation? Artificial Intelligence?



Courtesy: Stanford Univ.

Douglas C. Engelbart

Courtesy: Stanford Univ.

John McCarthy

Augmentation? Autonomy?

Courtesy: Lockheed Martin HULC

Courtesy: Boston Dynamics ATLAS

BCI? Generative AI?

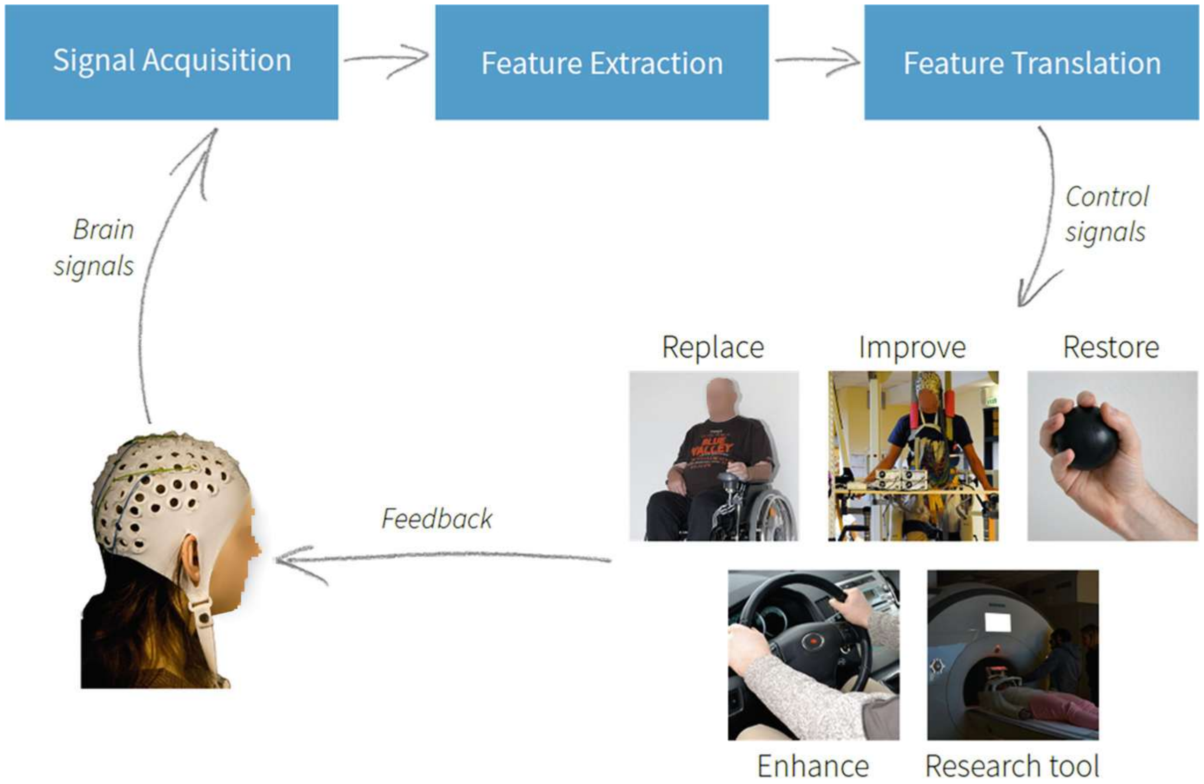
NEURALINK

ChatGPT

Claude

Gemini

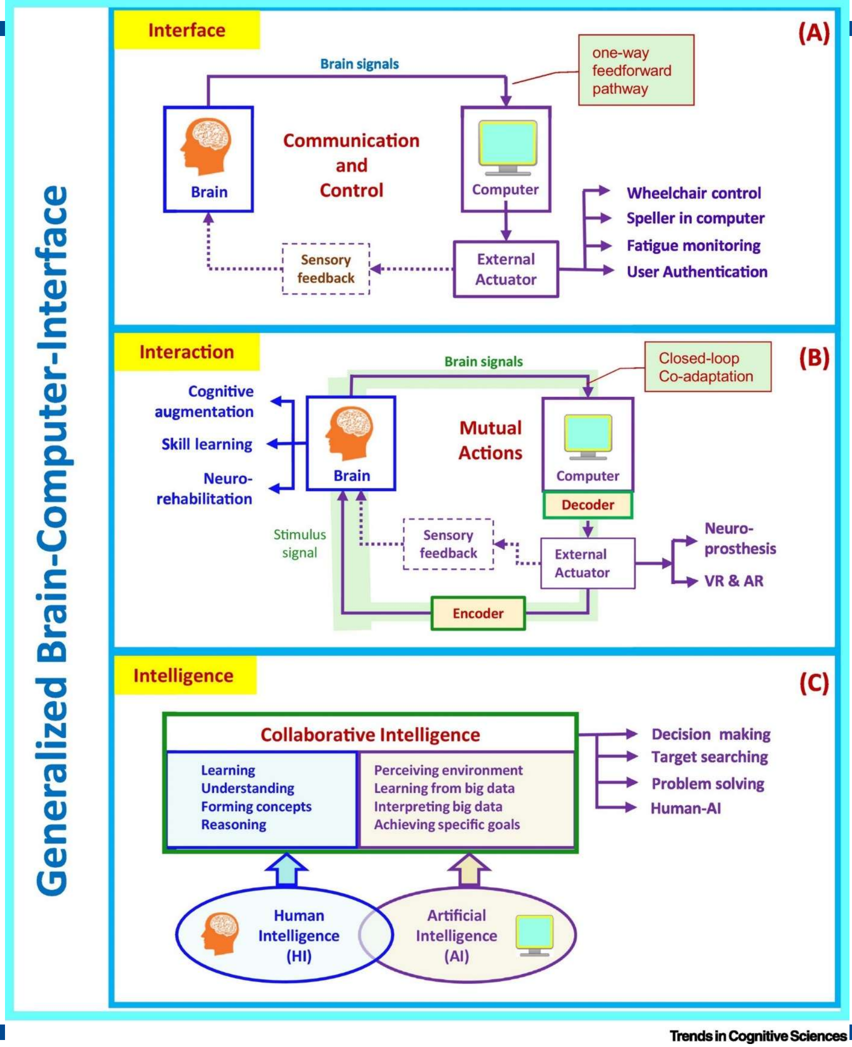
BCI



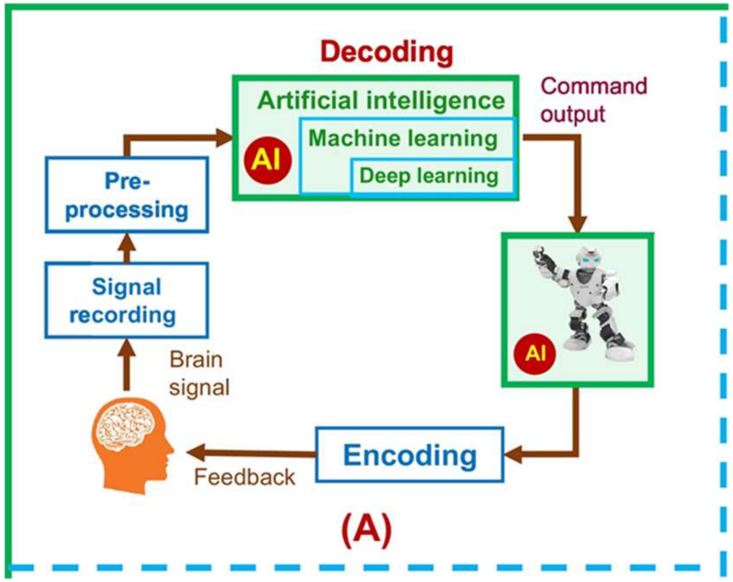
Signal Acquisition
Feature Extraction
Feature Translation
Brain signals
Control signals
Replace
Improve
Restore
Feedback
Enhance
Research tool

Three Different Views of BCI

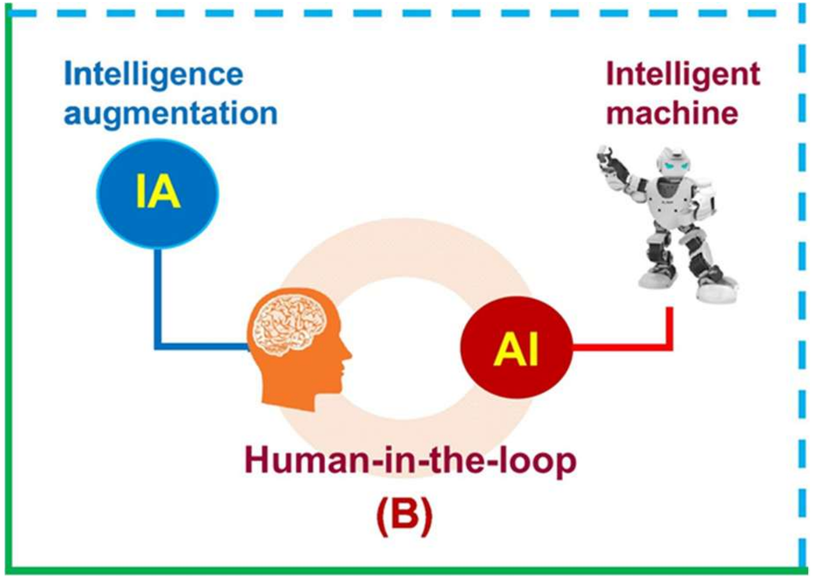
- (A) **Brain–computer interface**: This classical BCI could be thought as a one-way feedforward pathway. Communication and control are its major applications.
- (B) **Brain–computer interaction**: the interaction is based on a closed-loop feedback control system with brain-in-the-loop. The system integrates both decoding and encoding components in a loop forming a bidirectional BCI system. Through the mutual actions, the system will change the brain function as well as the status of devices.
- (C) **Brain–computer intelligence**: the system converges human intelligence (HI) and artificial intelligence (AI) components in a unified platform. The collaborative intelligence takes full advantage of the complementary nature of HI and AI systems. The performance of a resultant hybrid intelligence system will be superior to a single-modal HI or AI system.



AI in BCI



Decoding
Artificial intelligence
Machine learning
Deep learning
AI
Command output
Pre-processing
Signal recording
Brain signal
AI
Encoding
Feedback
(A)

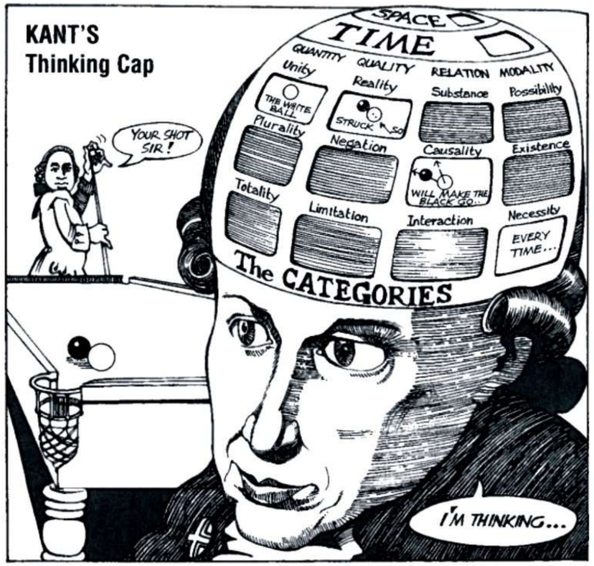


Intelligence augmentation
Intelligent machine
IA
AI
Human-in-the-loop
(B)

Nature + Nurture

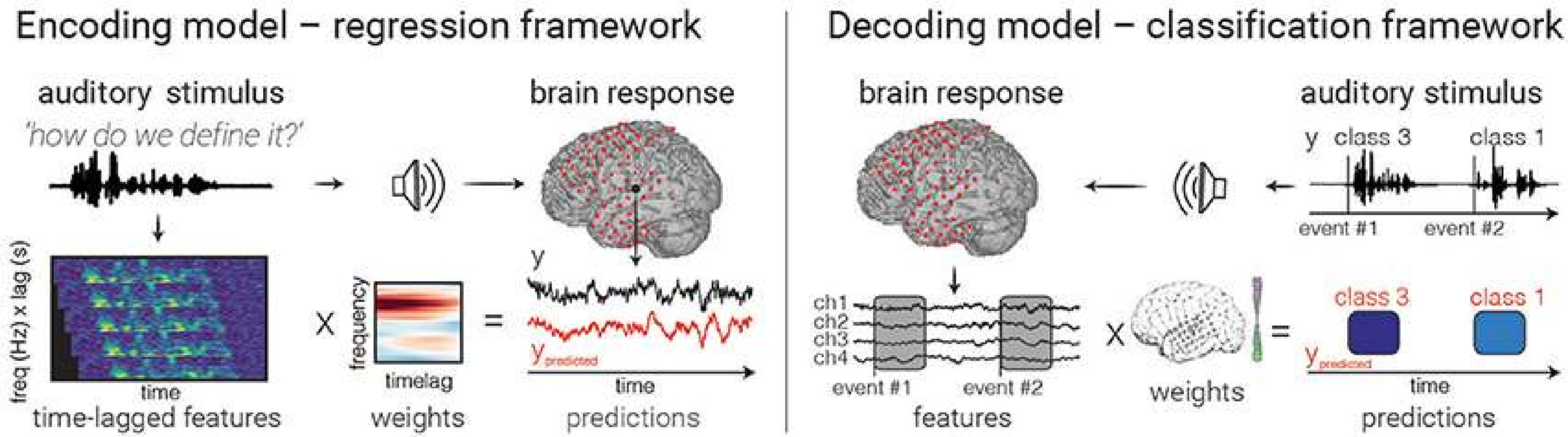
Critik
der
reinen Vernunft
von
Immanuel Kant
Professor in Königsberg.

Riga,
verlegts Johann Friedrich Hartknoch
1781.



Neural Decoding & Neural Encoding

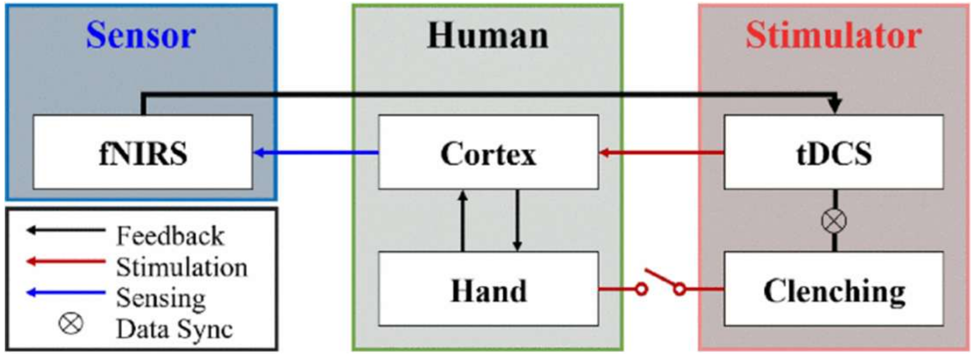
- Neural decoding models seek to predict the stimuli from neural activity.
- Neural encoding models seek to predict brain activity from stimuli.

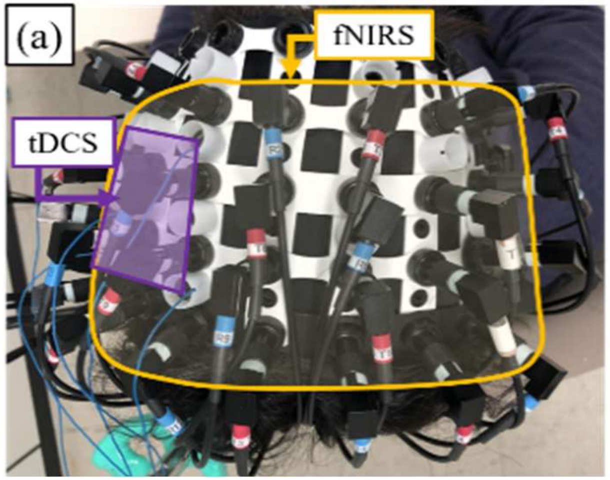


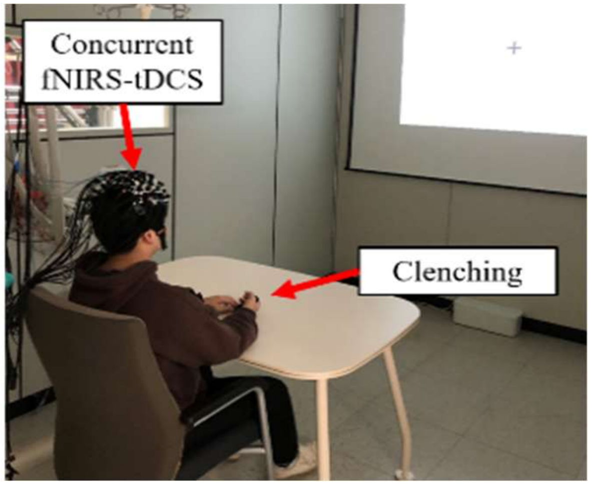
Decoding + Encoding

Lorach, H., Galvez, A., Spagnolo, V. *et al.* Walking naturally after spinal cord injury using a brain–spine interface. *Nature* **618**, 126–133 (2023)

Effect of tDCS on Cortical Motor Facilitation

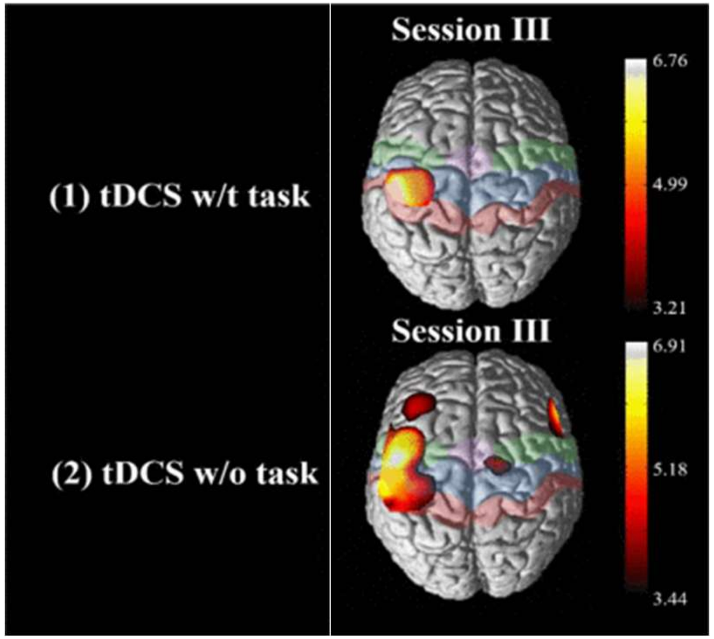


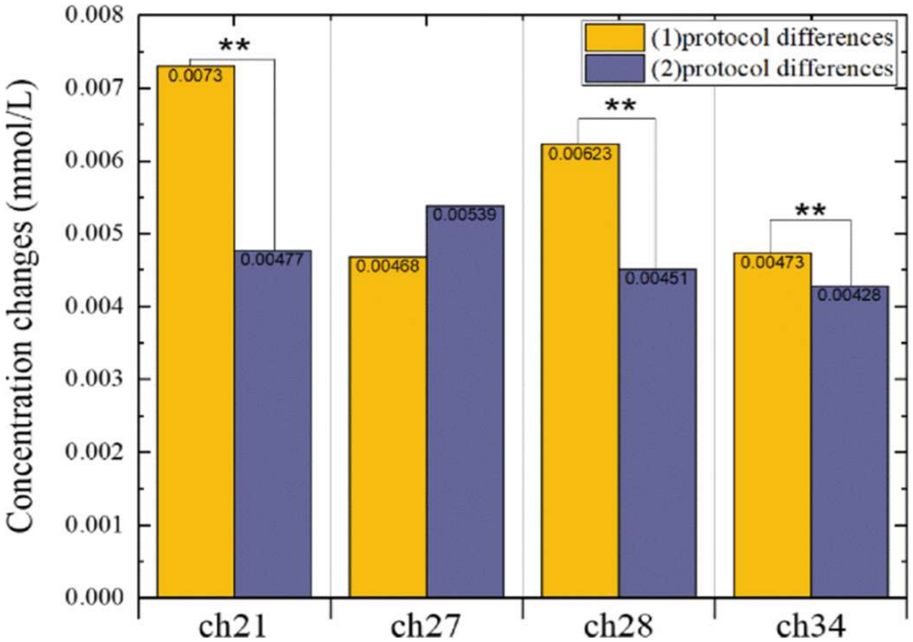




Effect of tDCS on Cortical Motor Facilitation

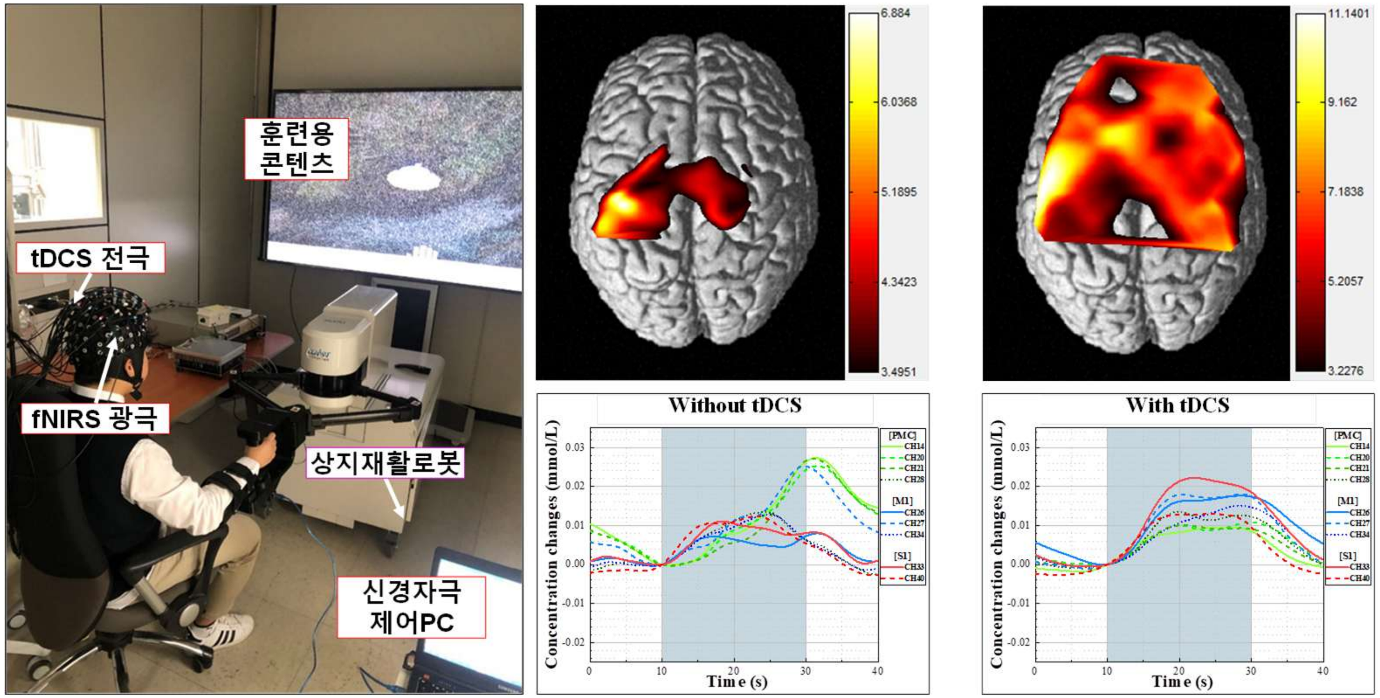
- Anode : ch 21(PMC), Cathode : Ch 7, 33(Temporal), 9(PMC) & 35(M1)
- Higher activation at Ch 21(PMC), 28(M1, hand), 34(S1, hand) for protocol (1)





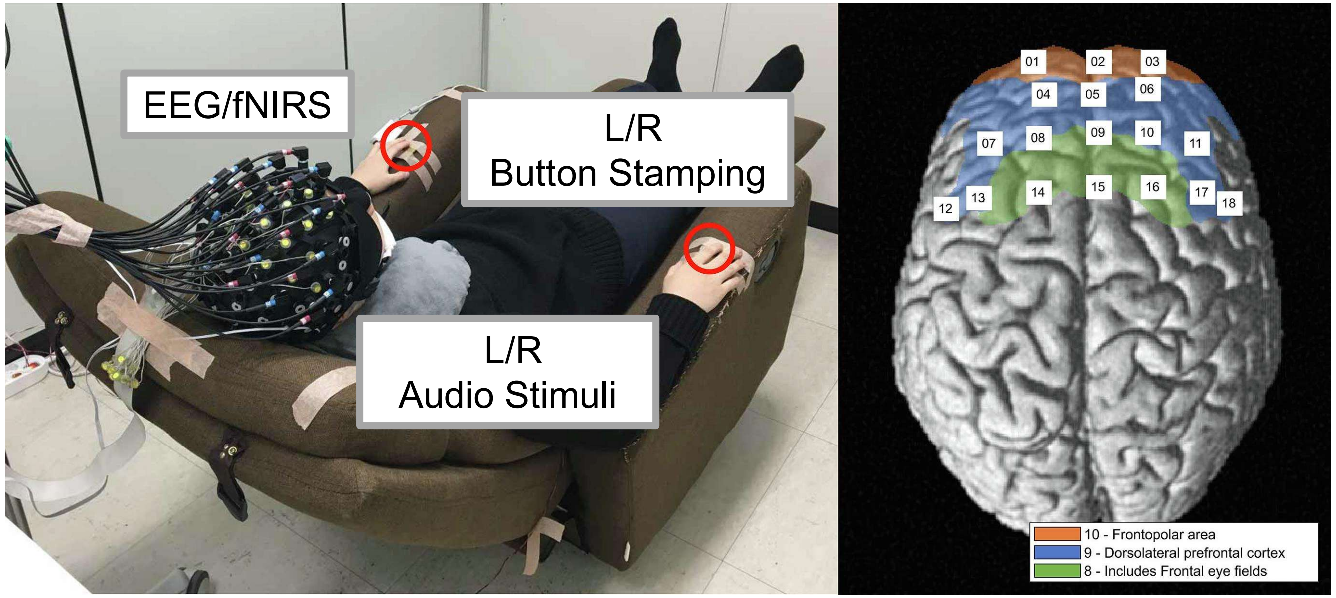
Rehabilitation Robot Task with tDCS

- Higher excitability in overall regions, especially at M1 & PMC



Multiple Consciousness States Decoding

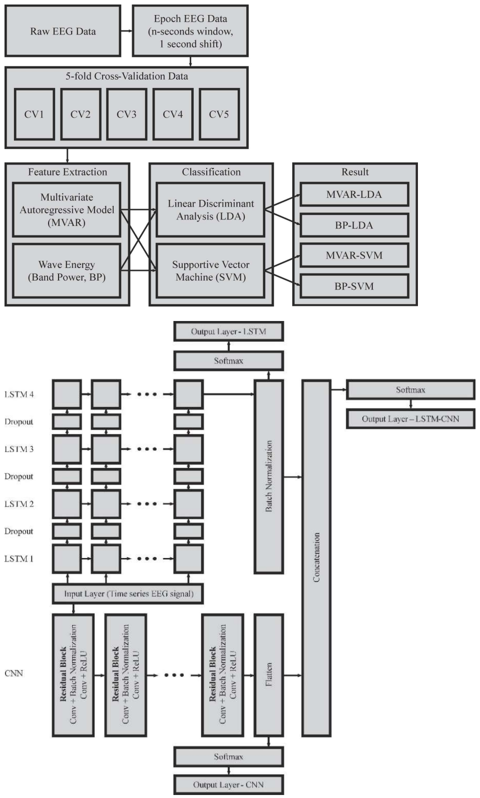
- EEG-based
- Awake, Drowsy, Sleep
- Awake-to-Drowsy Early Detection

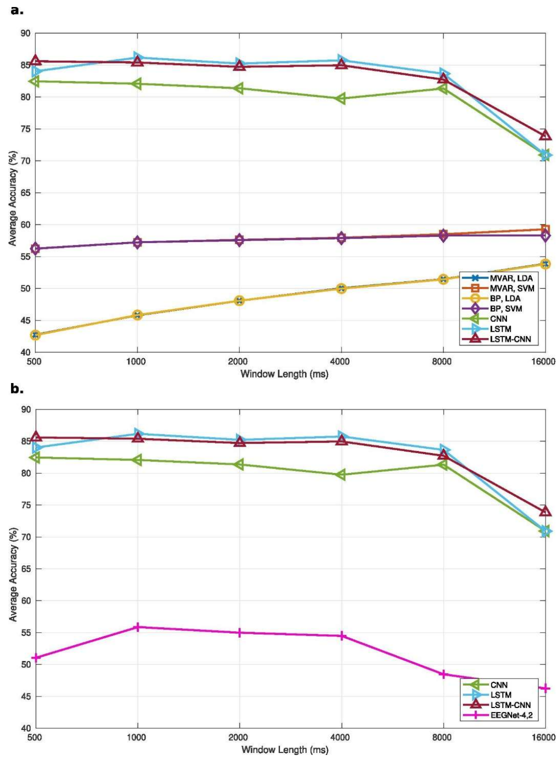


C. Lee, J. An, LSTM-CNN model of drowsiness detection from multiple consciousness states acquired by EEG, (2023) ESWA

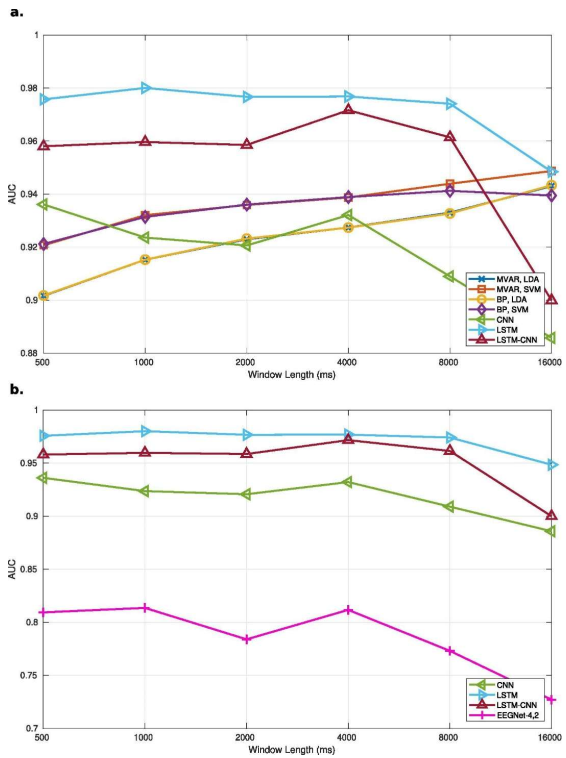
Consciousness States Decoding

- Feature-based ML vs. Data-driven DL



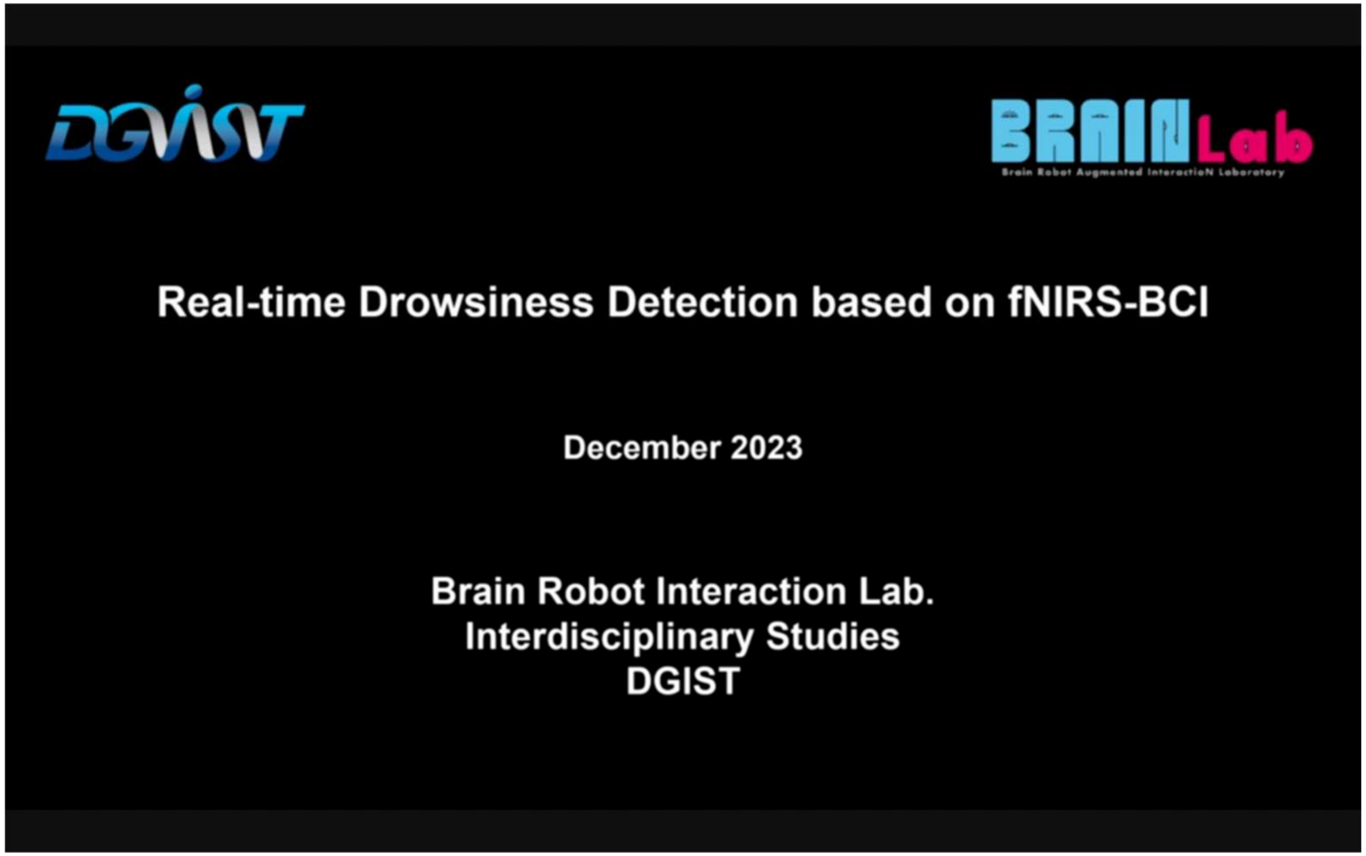


3 Classes Classification



Awake-to-Drowsy Detection

Real-time Drowsiness Detection



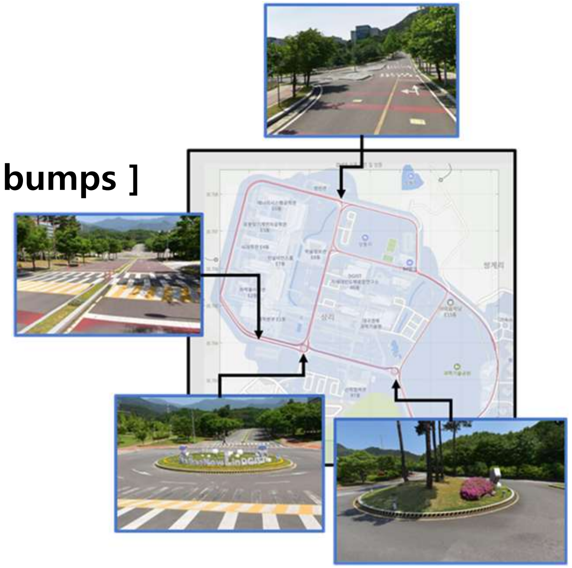
Motion Sickness Level Classification

Sensory conflict theory [1]

Acceleration (Vestibular system)

[Up-down Hill]

[Speed bumps]

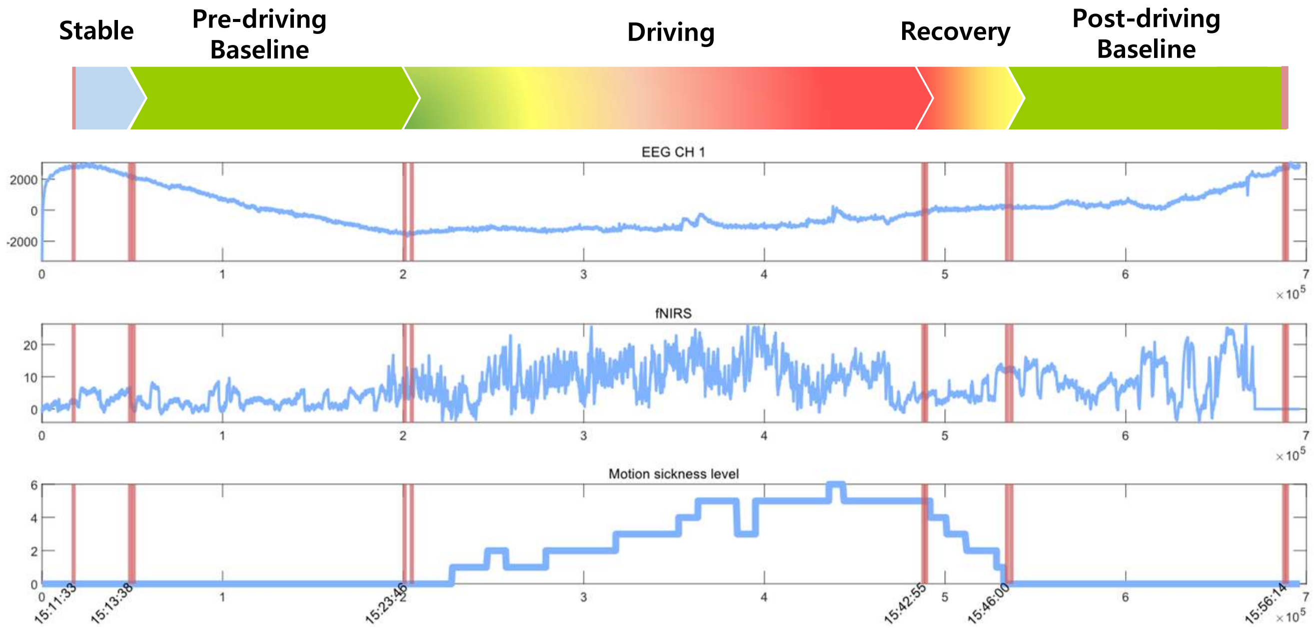


[Centrifugal roundabout]

Non-driving Activity (Optical system)

[1] Oman, C, M. (1990) Motion sickness: a synthesis and evaluation of the sensory conflict theory. Canadian journal of physiology and pharmacology 68.2: 294-303.

Motion Sickness Level Classification



Measurements consists of five sections:

- Stable : Section for stabilizing the measurement data
- Baseline : EEG measured in the resting state before (pre-driving baseline) and after driving (post-driving baseline)
- Driving : Recording motion sickness levels while performing non-driving activities (e.g., smartphone use)
- Recovery : Recording motion sickness levels until returning to a normal state

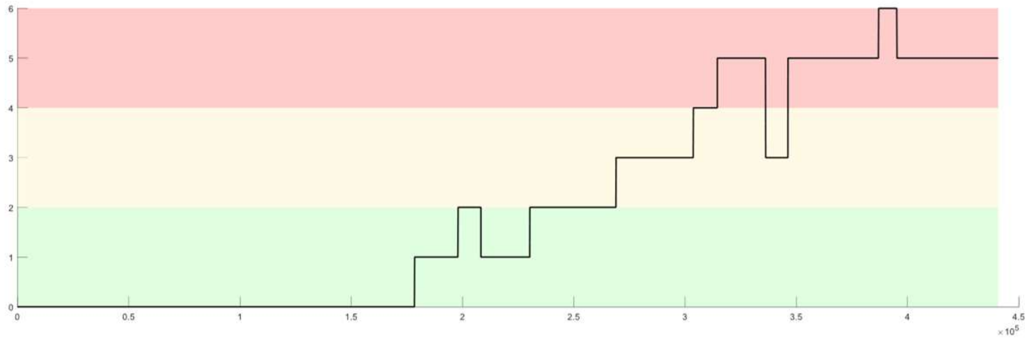
Motion Sickness Level Classification

◆ Motion sickness severity scale, MSSS [4]

Level	0	1	2	3	4	5	6
Symptoms	No symptoms	Stomach awareness or Discomfort	Mild nausea	Moderate nausea	Severe nausea	Retching	Vomiting

[Self-reporting]

Motion sickness level



According to MSSS,

For binary classification, class combination is "Low sickness(Level 1234) vs High sickness(Level 56)"

For ternary classification, class combination is "Low sickness(Level 12)vs Mild sickness(Level 34) vs Severe sickness(Level 56)"

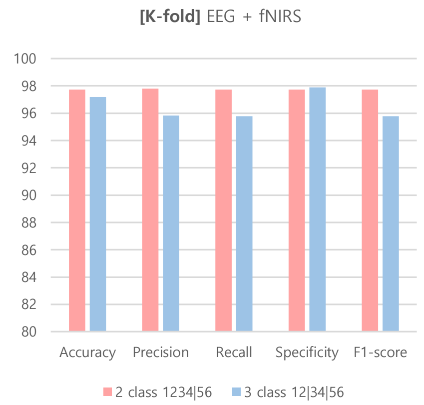
→ These combination reflects the difference in terms of symptoms[5].

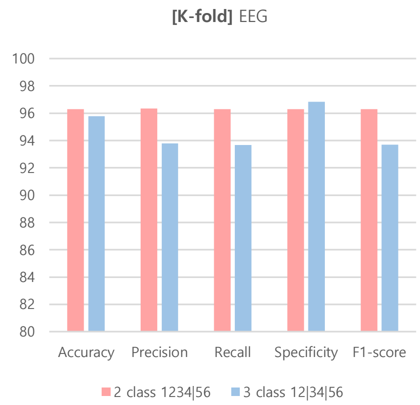
[4] Cha, Y.-H., et al. (2021). Motion sickness diagnostic criteria: Consensus Document of the Classification Committee of the Bárány Society. Journal of Vestibular Research 31.5: 327-344.
[5] Czeisler, Mark É., et al. "Validation of the motion sickness severity scale: Secondary analysis of a randomized, double-blind, placebo-controlled study of a treatment for motion sickness." *Plos one* 18.1 (2023): e0280058.

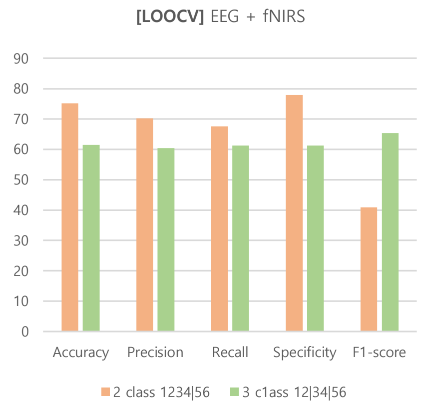
Motion Sickness Level Classification

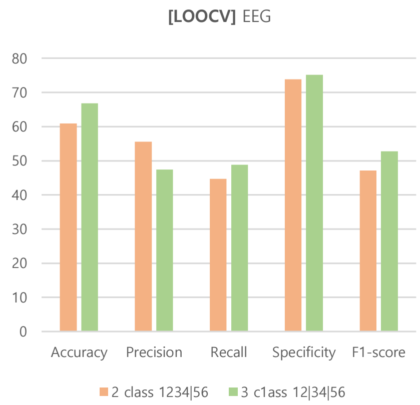
◆ Classification performance

Training Method	Input	N-Class	Accuracy	Precision	Recall	Specificity	F1-score
K-fold	EEG + fNIRS	2 class 1234|56	97.74	97.79	97.74	97.74	97.74
		3 class 12|34|56	97.19	95.82	95.79	97.90	95.79
	EEG	2 class 1234|56	96.29	96.35	96.29	96.29	96.291
		3 class 12|34|56	95.79	93.78	93.68	96.84	93.70
LOOCV	EEG + fNIRS	2 class 1234|56	75.22	70.20	67.59	78.00	40.95
		3 c1ass 12|34|56	61.50	60.42	61.31	61.31	65.36
	EEG	2 class 1234|56	60.90	55.64	44.69	73.88	47.20
		3 c1ass 12|34|56	66.83	47.42	48.80	75.24	52.75







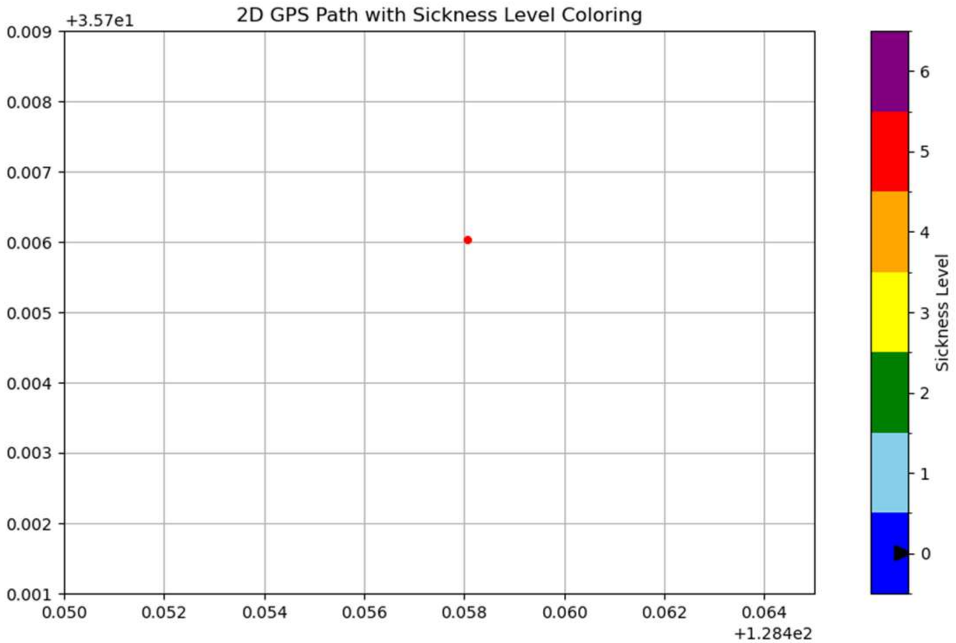


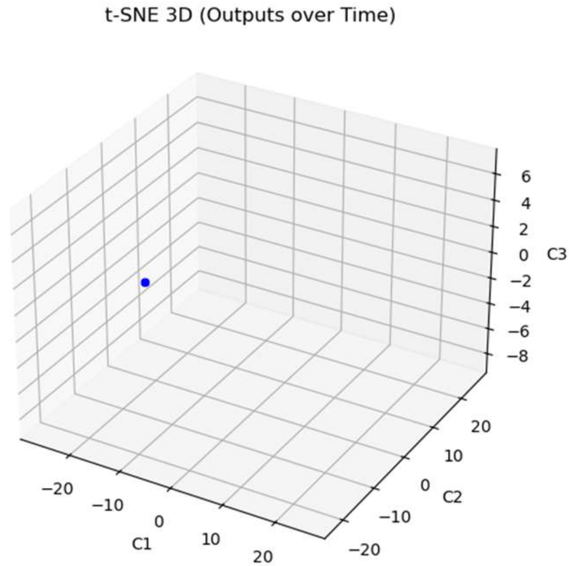
- High performance in both binary and ternary classification under K-fold and LOOCV for the proposed combinations
- Combining EEG with fNIRS yielded better performance than using EEG alone, which can be attributed to the effects of neurovascular coupling[6].

[6] Ren, B., et al. (2024). A Brain Network Analysis Model for Motion Sickness in Electric Vehicles Based on EEG and fNIRS Signal Fusion. Sensors, 24(20), 6613.

Motion Sickness Level Classification

◆ t-SNE (t-distributed Stochastic Neighbor Embedding)

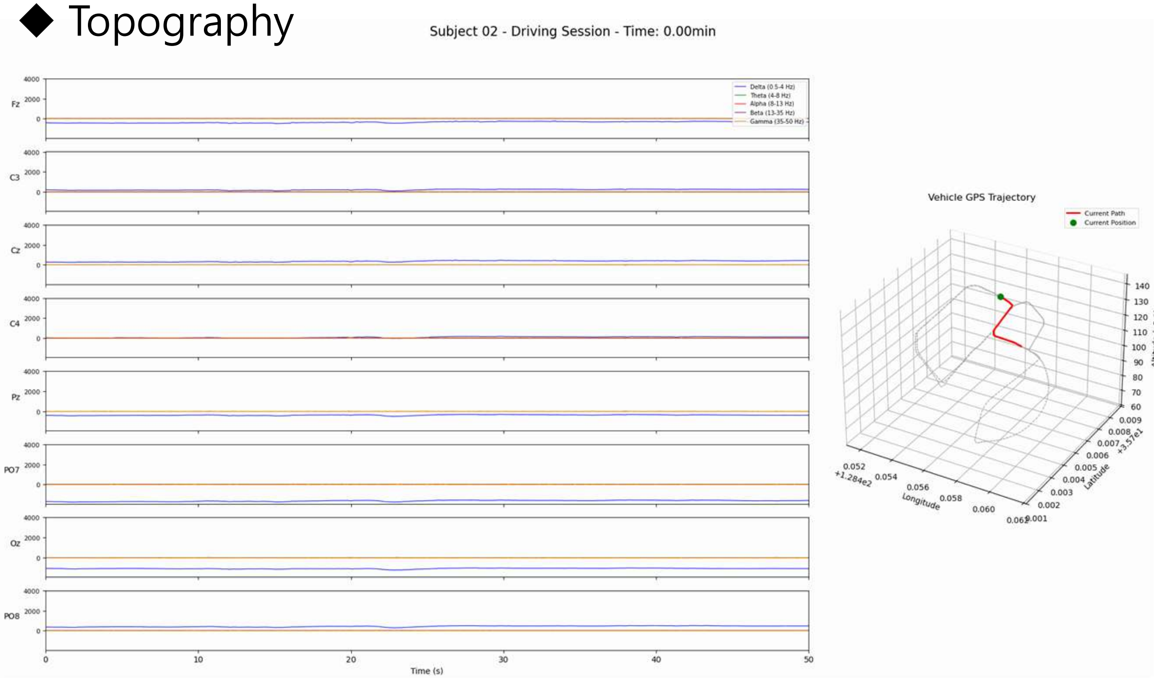


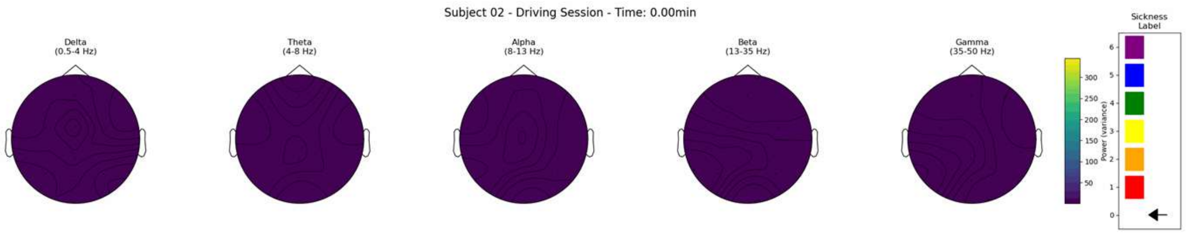


- When applying t-SNE to the three-class classification in the k-fold visualized together with GPS data, the clusters were clearly separated according to the motion sickness level along with vehicle position.
- It was confirmed that the three features for ternary classification were well separated in the feature space.
- These findings indicate that motion sickness can be effectively distinguished using brain signals.

Motion Sickness Level Classification

◆ Topography





- When examining the real-time power across each frequency band, prominent changes were observed in the theta, alpha, and beta bands within the occipital region (PO7, Oz, PO8) and the temporal region (C3, C4).

- These findings can be interpreted as EEG changes associated with motion sickness, resulting from the sensory conflict between visual changes in the occipital region during non-driving activities (ex. using smartphone) in the occipital cortex and vestibular acceleration-related changes in the temporal cortex.