



KOREA
UNIVERSITY

Integrated
Bioelectronics
Lab

2019 Microsoft Research Talk

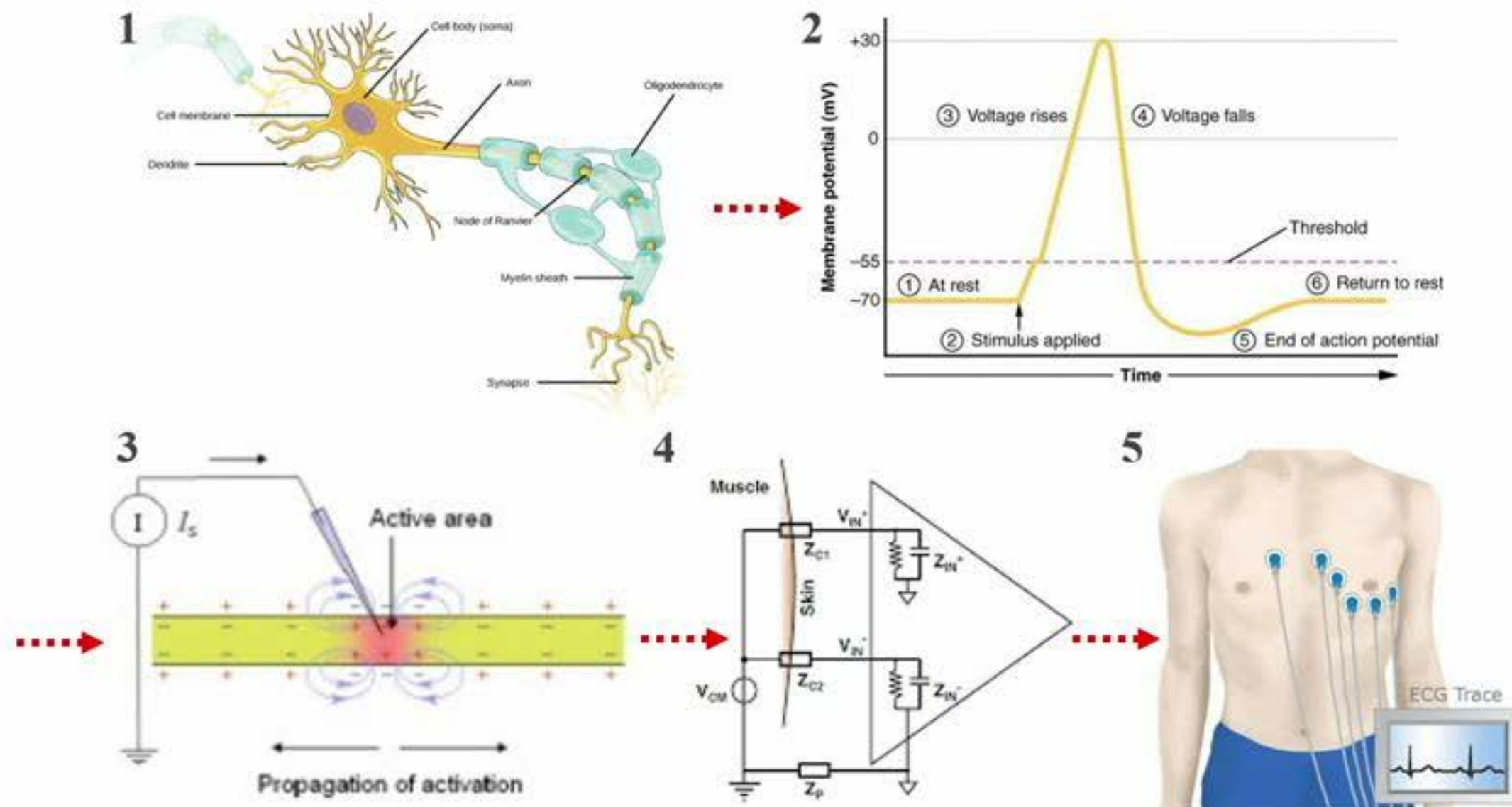
**Highly Conductive and Flexible sensor
Integrated with Personal Device for
Practical Bio-Signal Measurement and Applications**

Speaker : Joonghoon Lee

1. INTRODUCTION

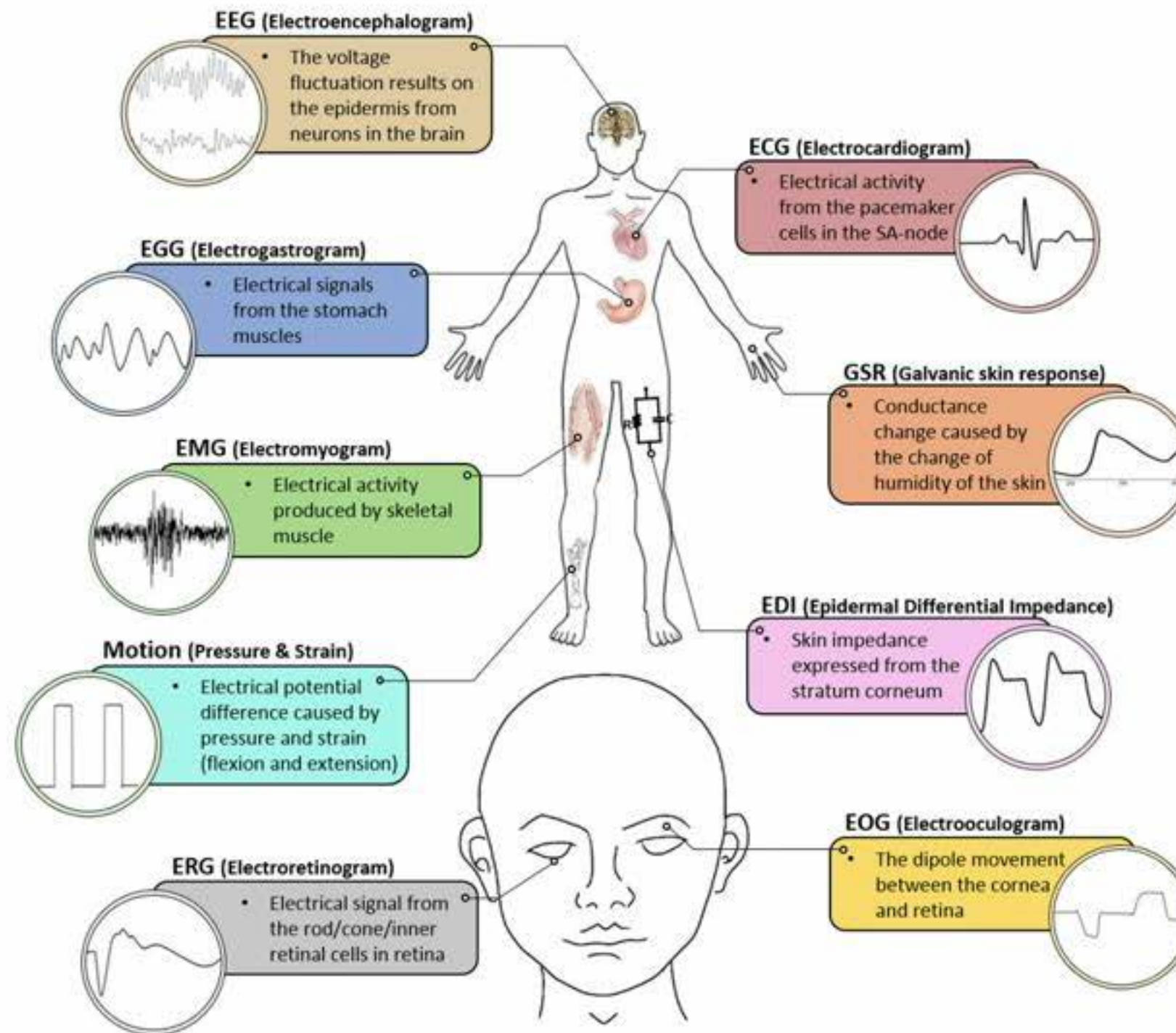
Electrophysiological Sign (Bio-signal)

The source of electrical potential on the surface of the skin is the **current generated by ions** passing through the cell membrane in neurons responsible for each function of the body



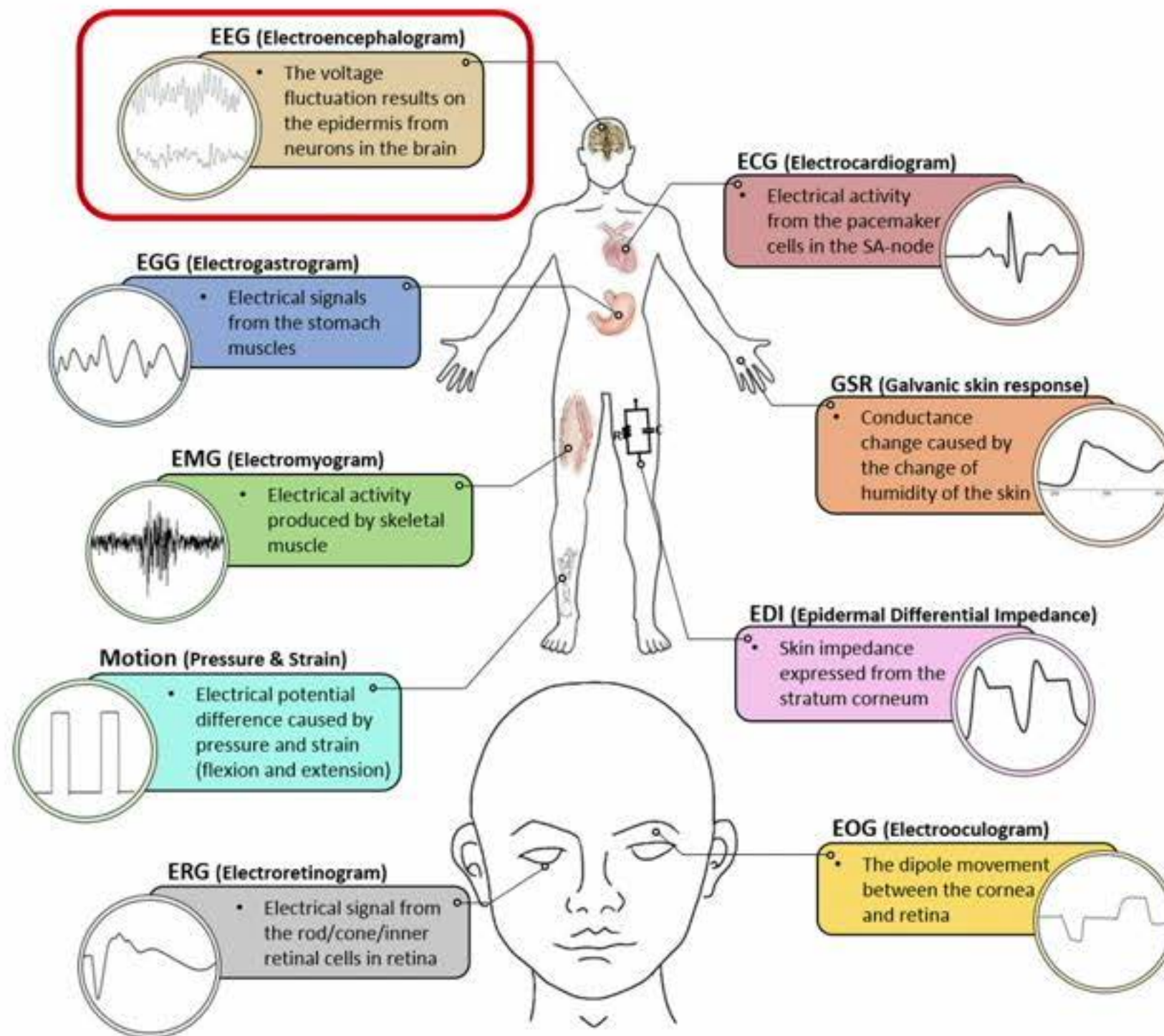
1. INTRODUCTION

Electrophysiological Sign

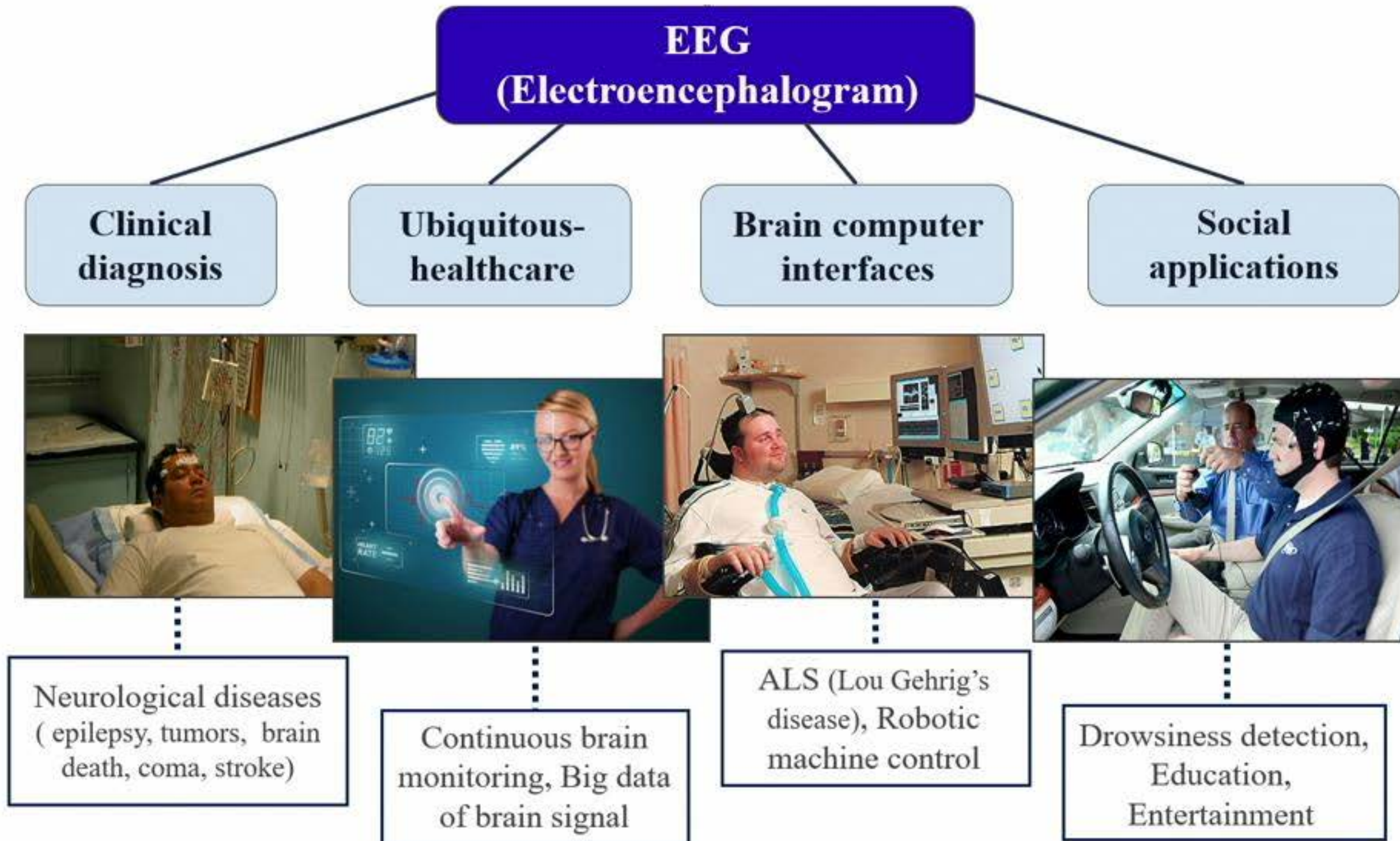


1. INTRODUCTION

Electrophysiological Sign



1. INTRODUCTION



Conventional EEG recording systems

Lots of electrodes



Limitation on mobility



Paste problem



Obtrusive wearing



Conventional EEG recording systems

Lots of electrodes

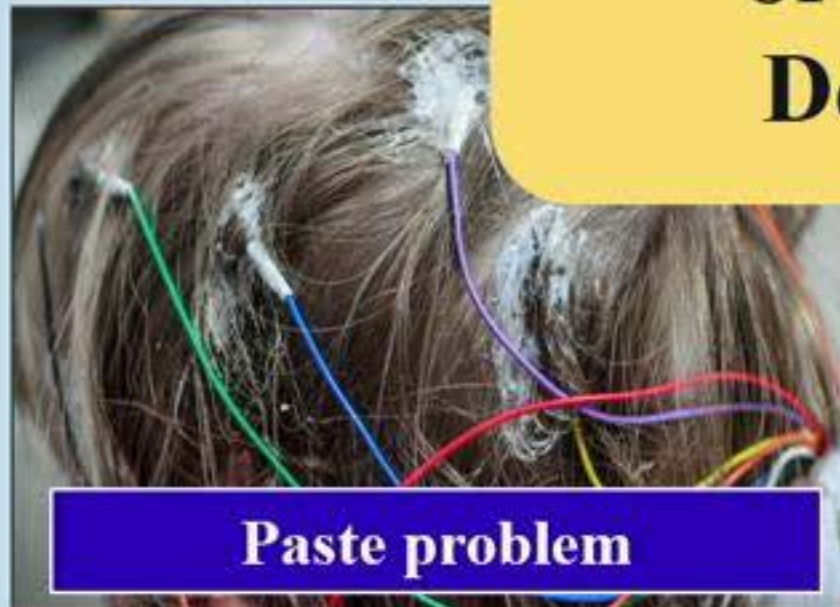


Limitation on mobility



New Paradigm
of EEG
Device

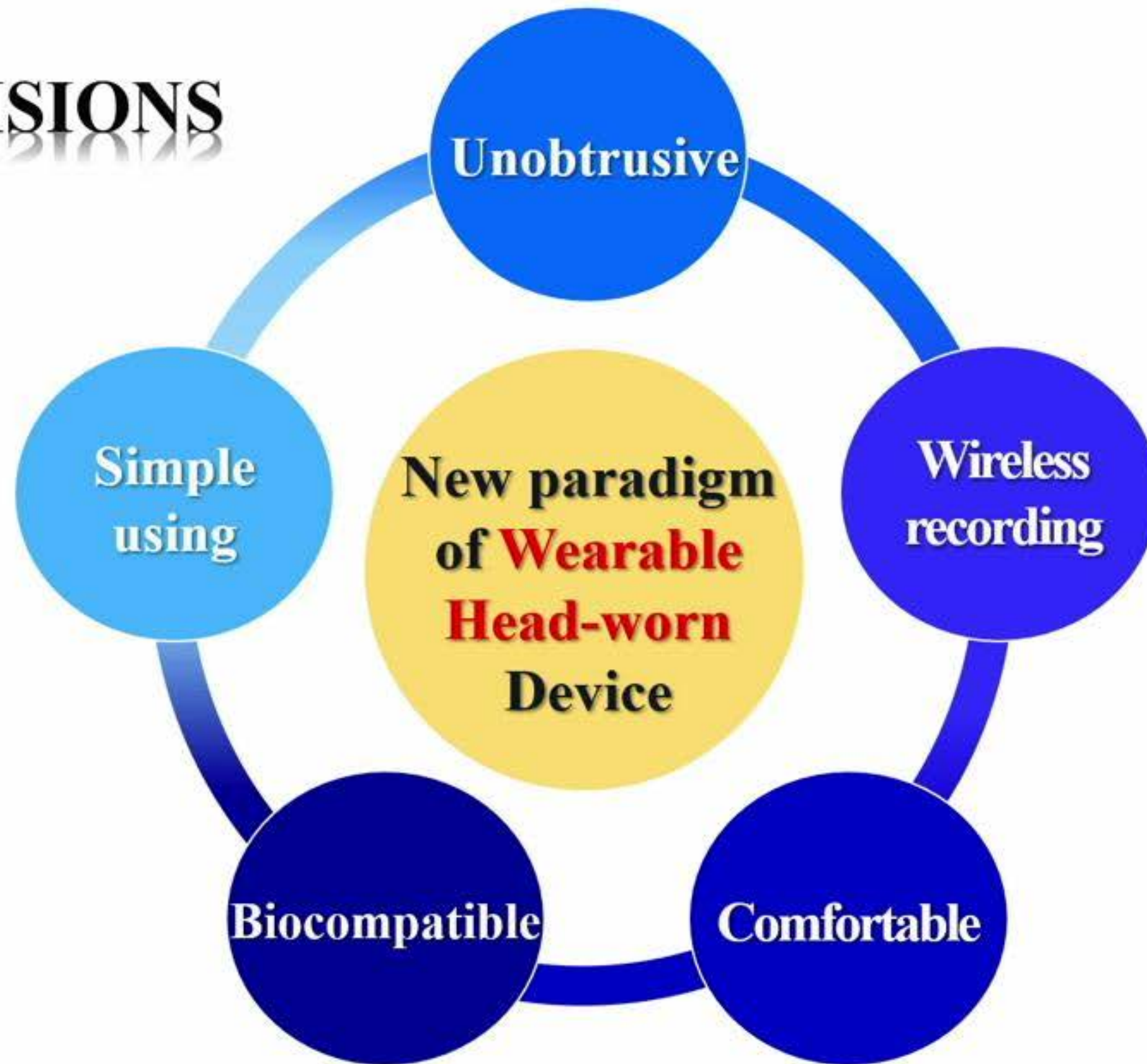
Paste problem



Obtrusive wearing



➤ 5 VISIONS



1. INTRODUCTION

Wearable Bio-signal device (Body-worn sensor)

The diagram illustrates various bio-signal sensors and their corresponding wearable devices. On the left, a human figure is shown with callouts for different sensors and their functions:

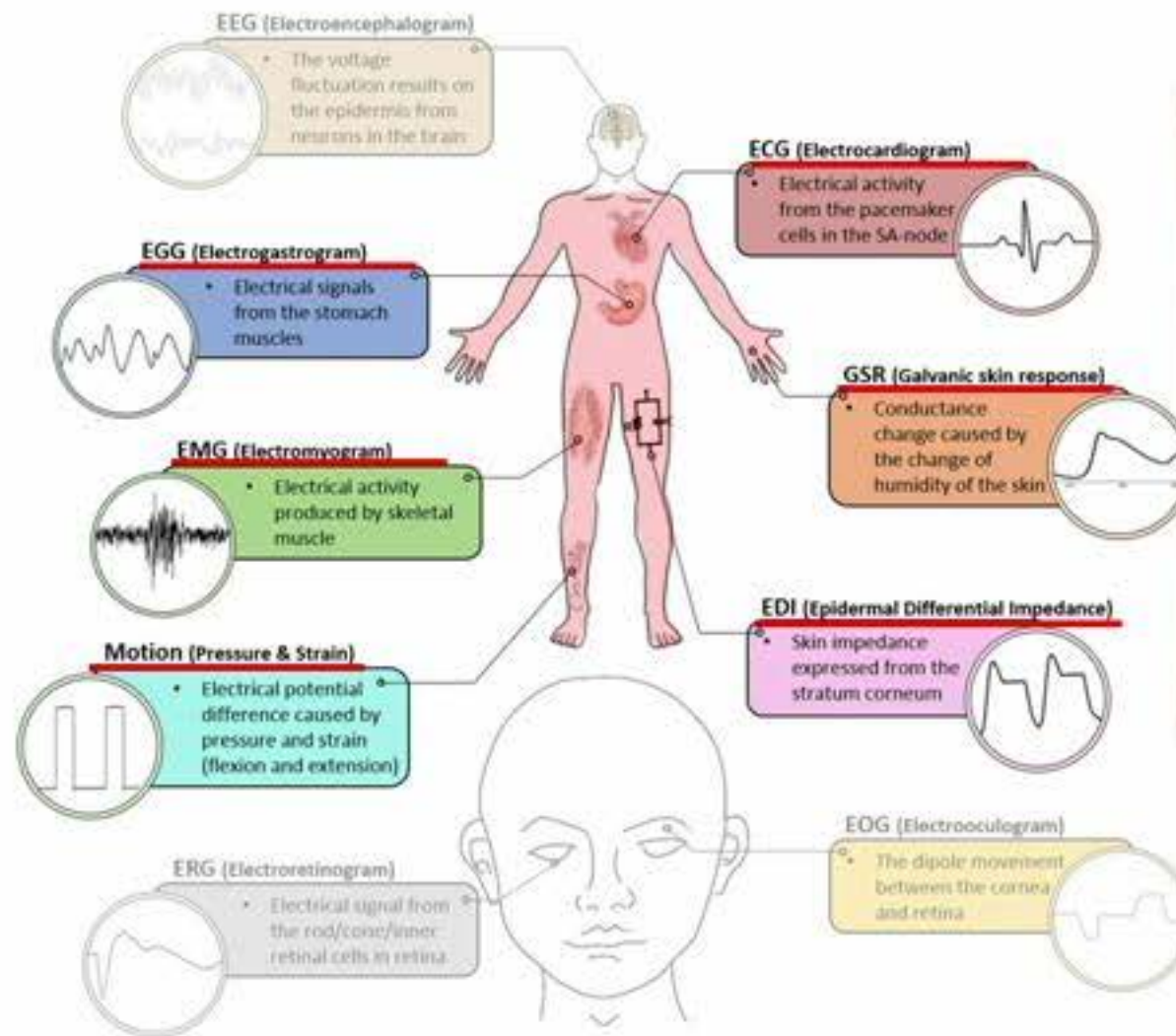
- EEG (Electroencephalogram)**: The voltage fluctuation results on the epidermis from neurons in the brain.
- ECG (Electrocardiogram)**: Electrical activity from the pacemaker cells in the SA-node.
- EGG (Electrogastrogram)**: Electrical signals from the stomach muscles.
- FMG (Electromyogram)**: Electrical activity produced by skeletal muscle.
- Motion (Pressure & Strain)**: Electrical potential difference caused by pressure and strain (flexion and extension).
- ERG (Electroretinogram)**: Electrical signal from the rod/cone/inner retinal cells in retina.
- GSR (Galvanic skin response)**: Conductance change caused by the change of humidity of the skin.
- EDI (Epidermal Differential Impedance)**: Skin impedance expressed from the stratum corneum.
- EOG (Electrooculogram)**: The dipole movement between the cornea and retina.

On the right, several wearable devices are shown:

- Mr.Wear**: A blue headband for EEG.
- V-patch**: A white chest patch for ECG.
- PIIX**: A white chest patch for ECG.
- Body-worn Wearable Devices**: A collection of various sensors, including a wrist-worn device and a chest patch.

1. INTRODUCTION

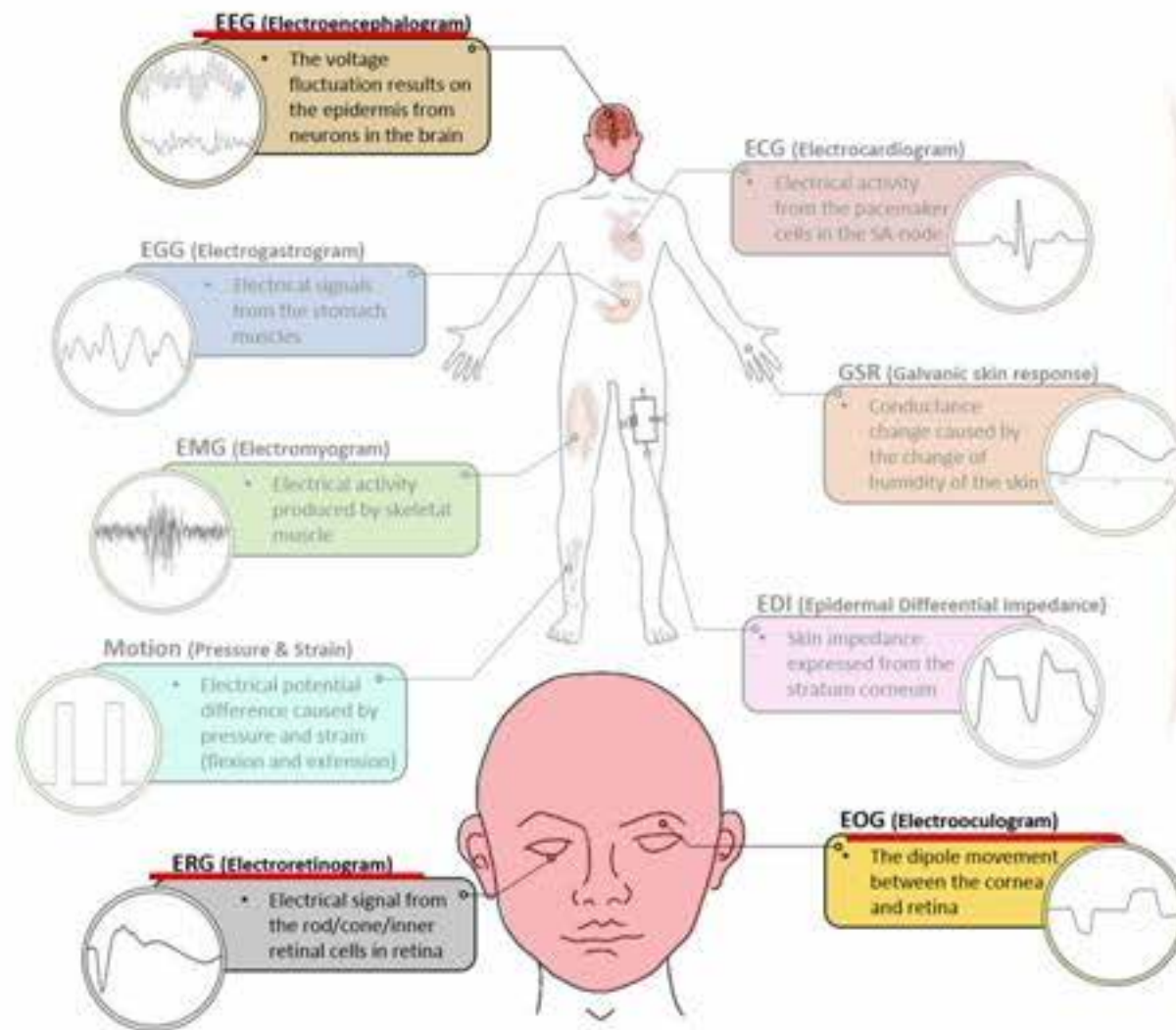
Wearable Bio-signal device (Body-worn sensor)



Body-worn Sensors are able to
hide under the clothes !

1. INTRODUCTION

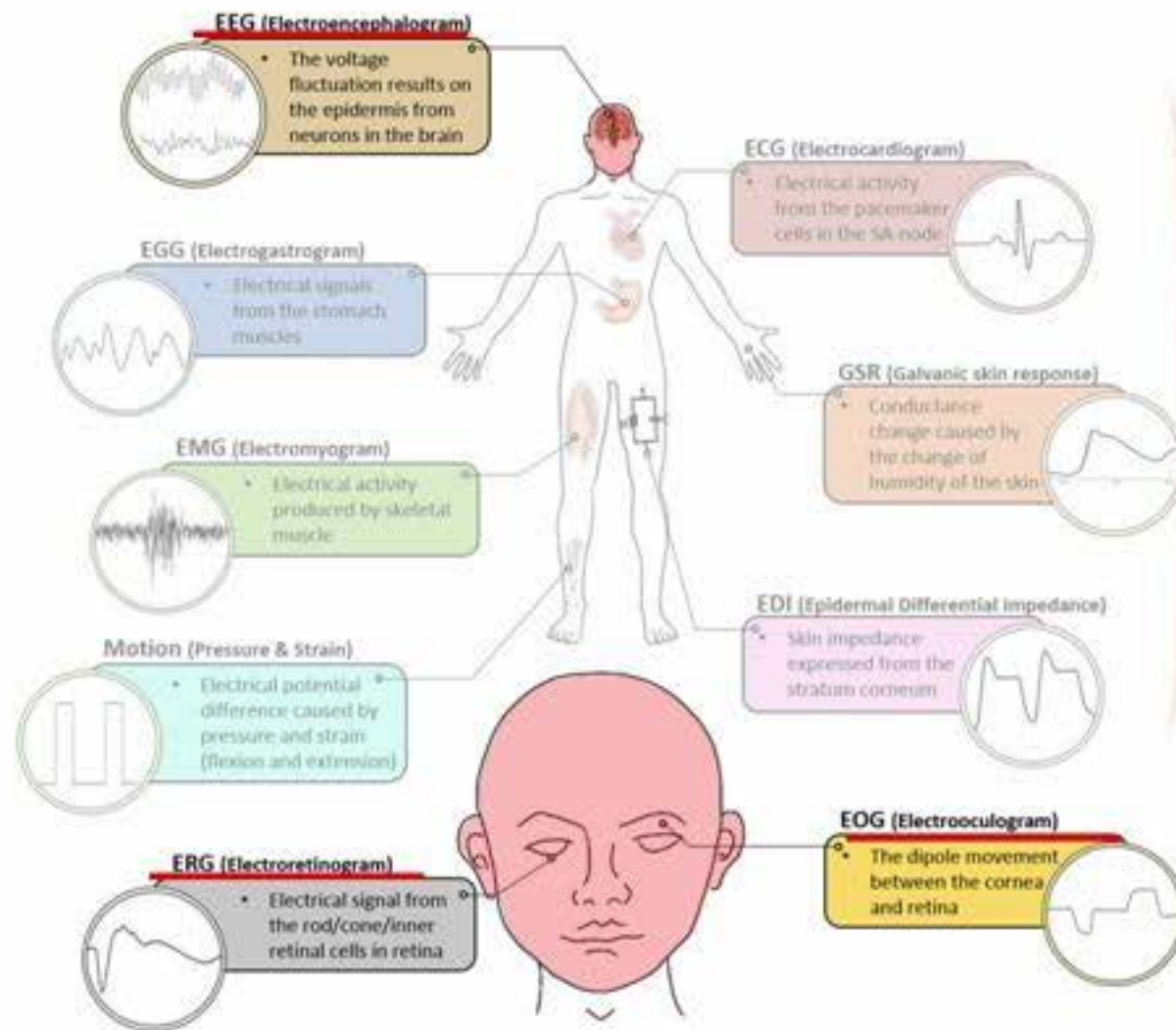
Wearable Bio-signal device (Head-worn sensor)



Head-worn Sensors are **not** able to hide under the clothes

1. INTRODUCTION

Wearable Bio-signal device (Head-worn sensor)



Head-worn Sensors are **not** able to hide under the clothes

The Form-factor of Wearable Head-worn Device is very Important!!

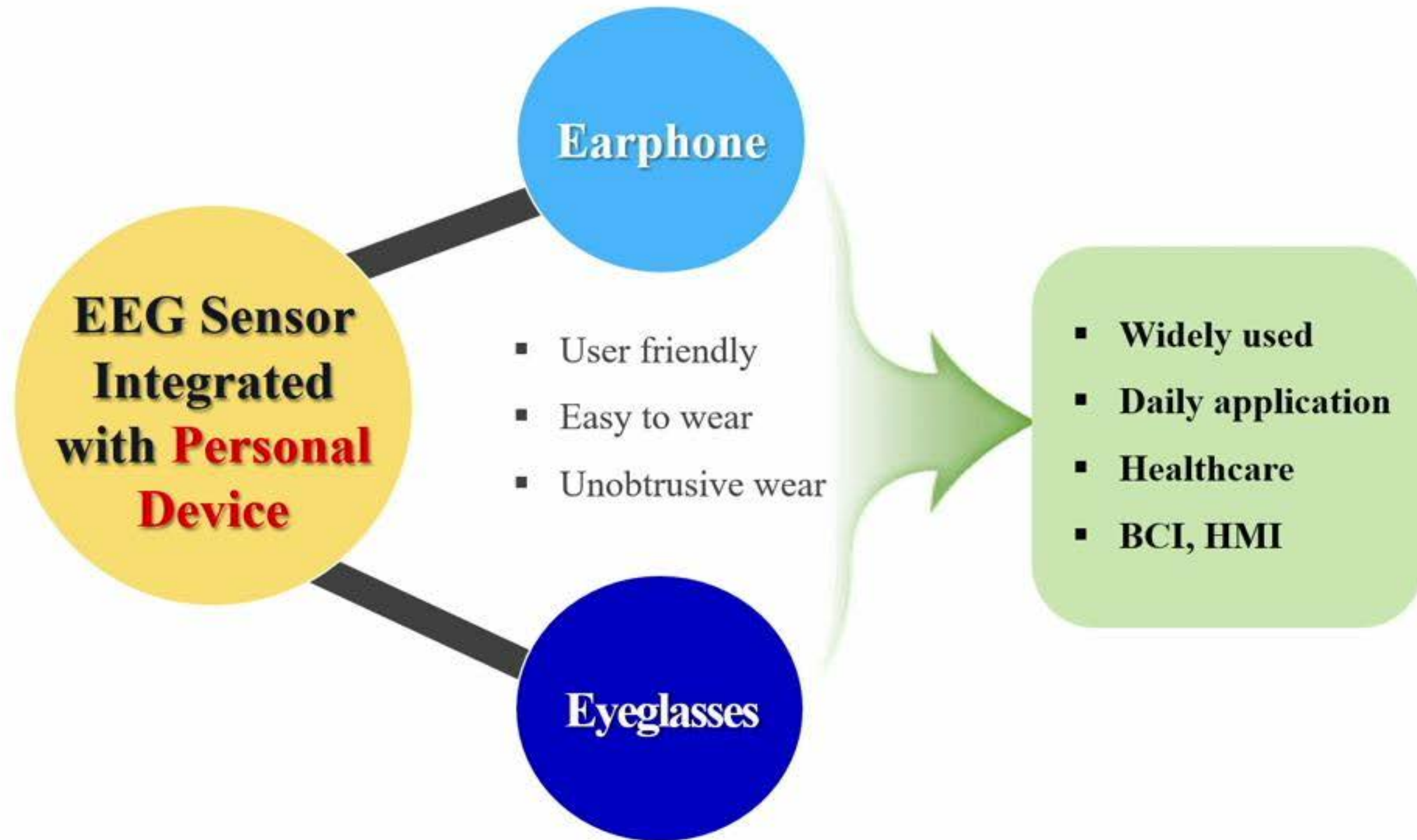
➤ **Wearable Device Concept**

**EEG Sensor
Integrated
with **Personal
Device****

➤ **Wearable Device Concept**



➤ Wearable Device Concept



1. In-ear EEG Earphone Concept

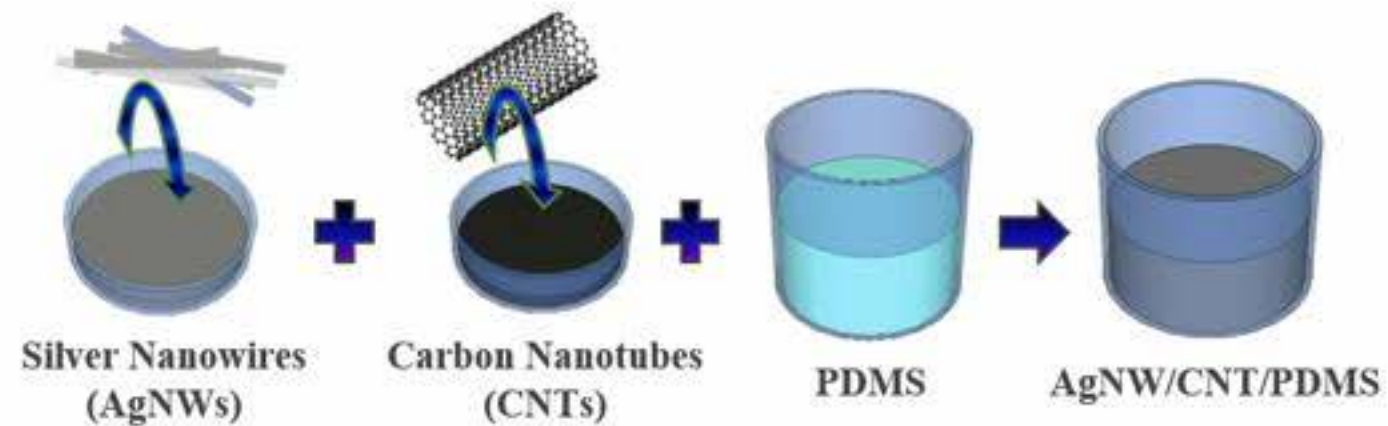


1. In-ear EEG Earphone Concept

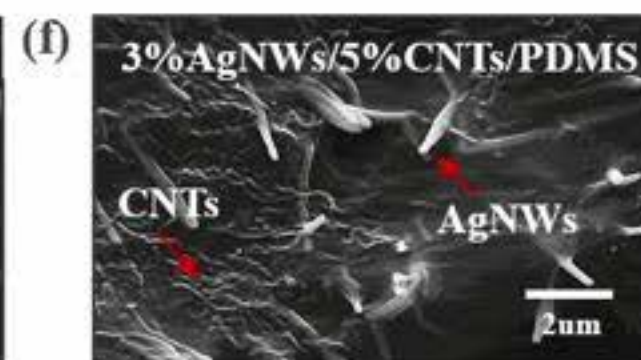
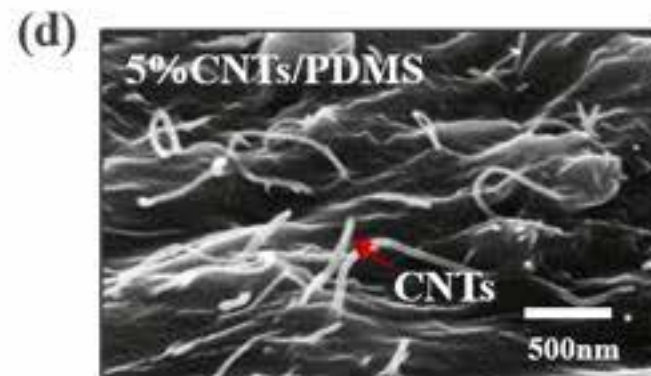
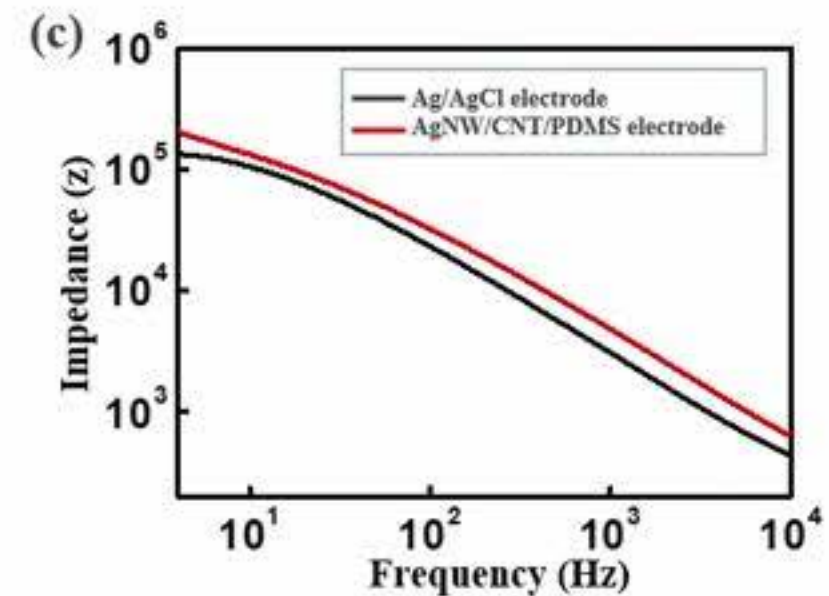
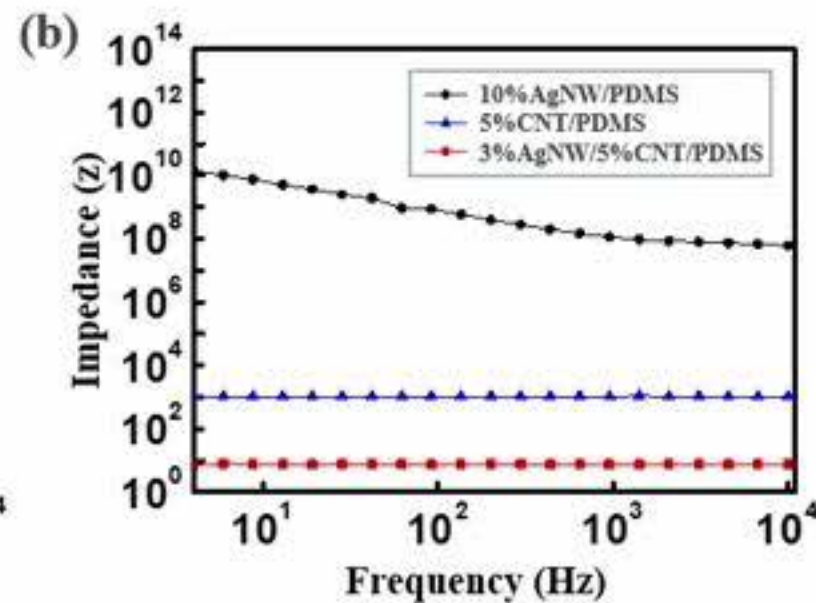
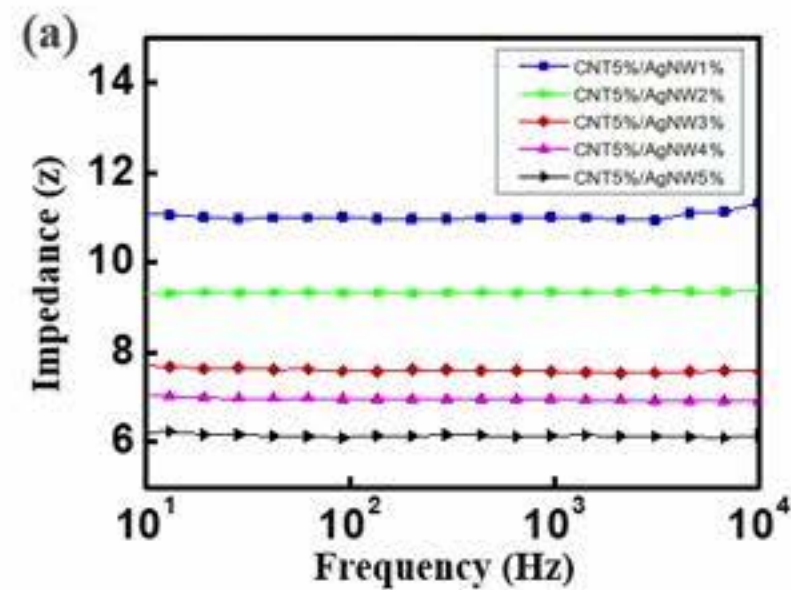


2.1 MATERIALS & METHODS

➤ AgNWs/CNTs/PDMS



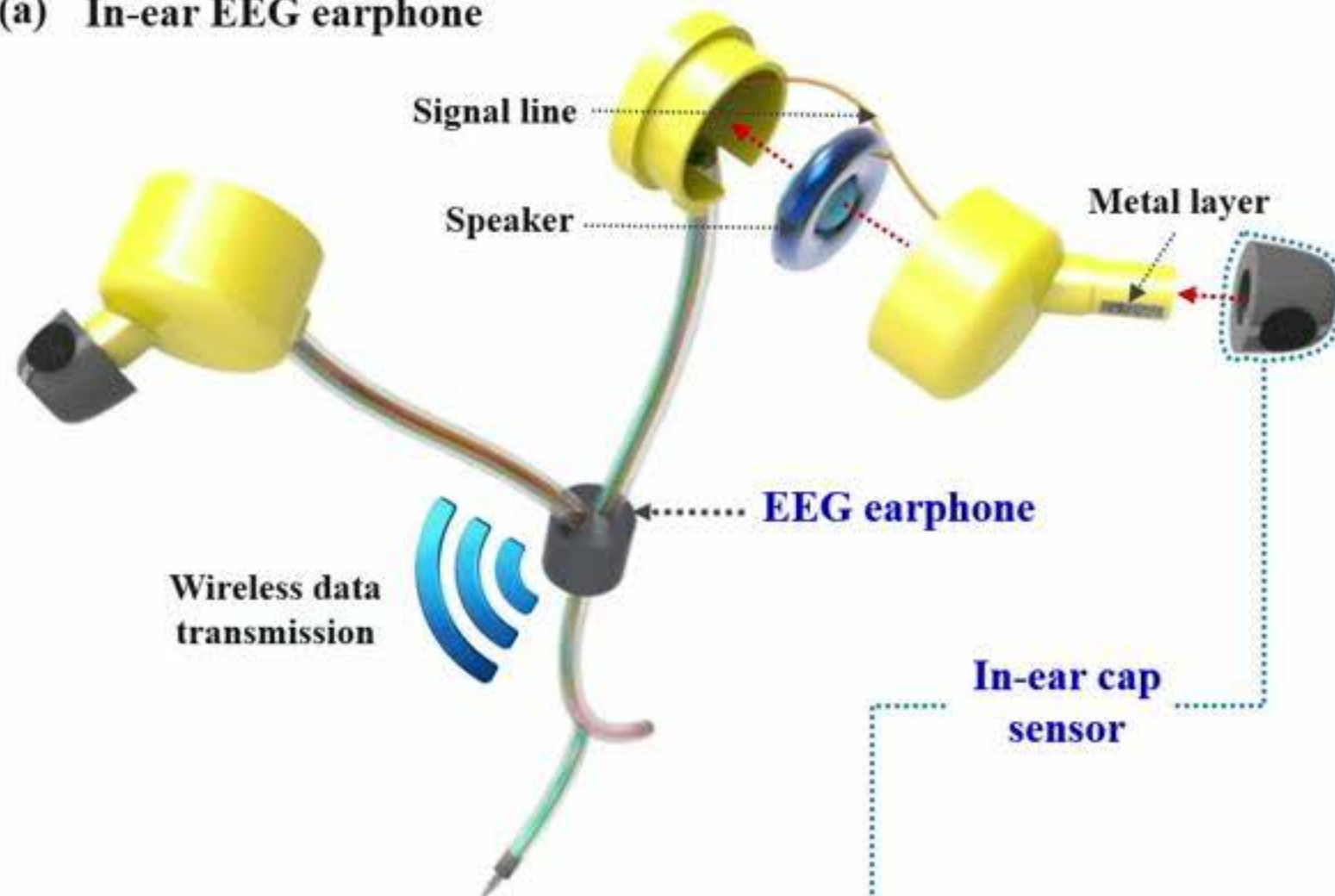
- Previous dry sensing materials = **A few Kilo Ohms**
- AgNWs/CNTs/PDMS = **A few Ohms**



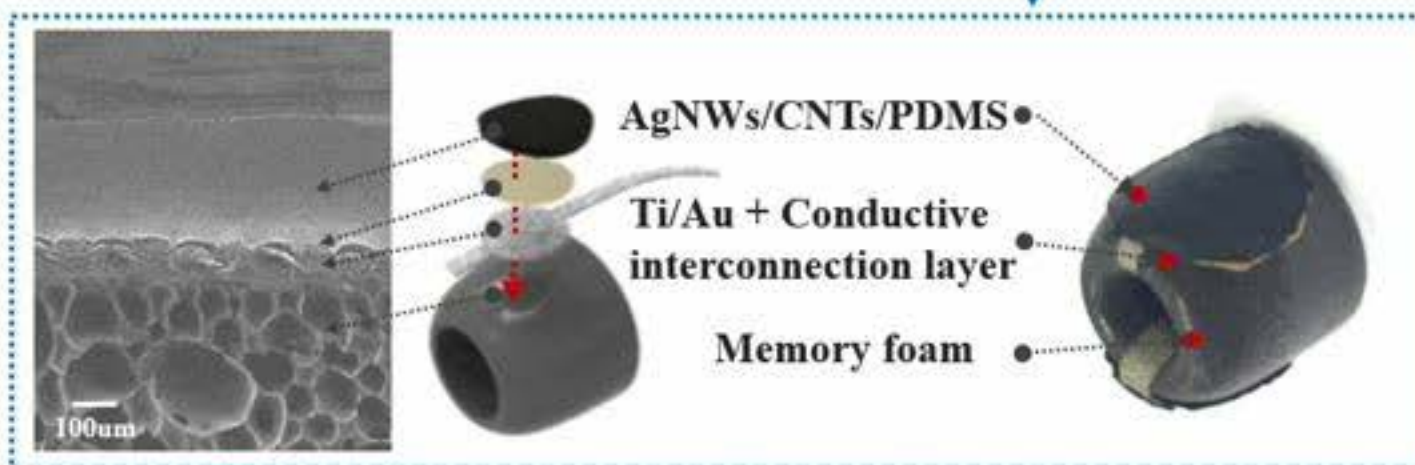
**Highly
conductive
sensing
materials!!**

➤ Component of In-ear EEG Earphone

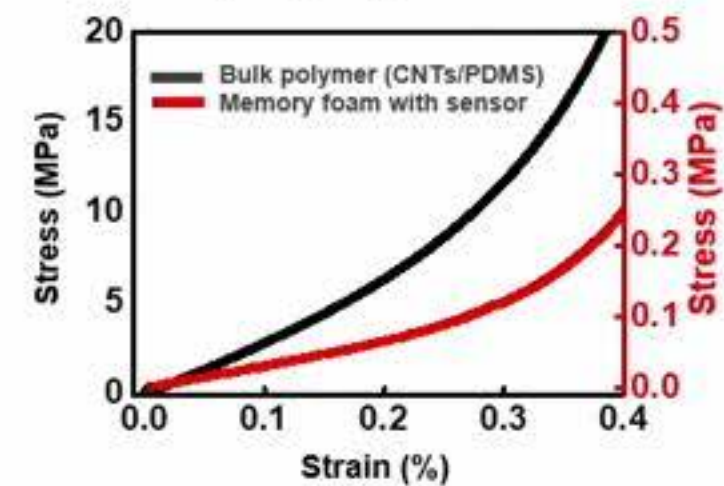
(a) In-ear EEG earphone



(b) Composition of In-ear cap sensor

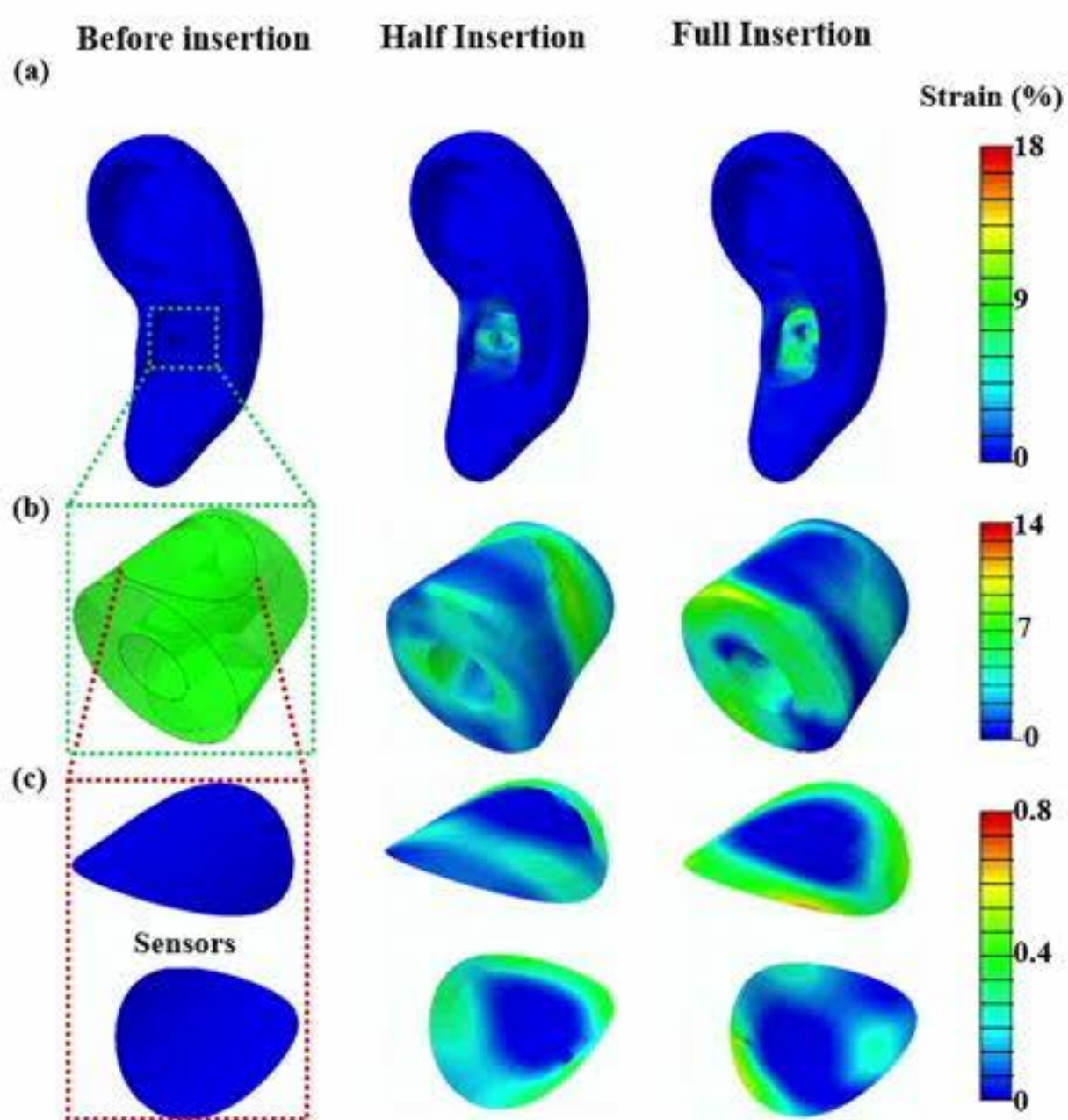


(c) Mechanical property of In-ear cap sensor

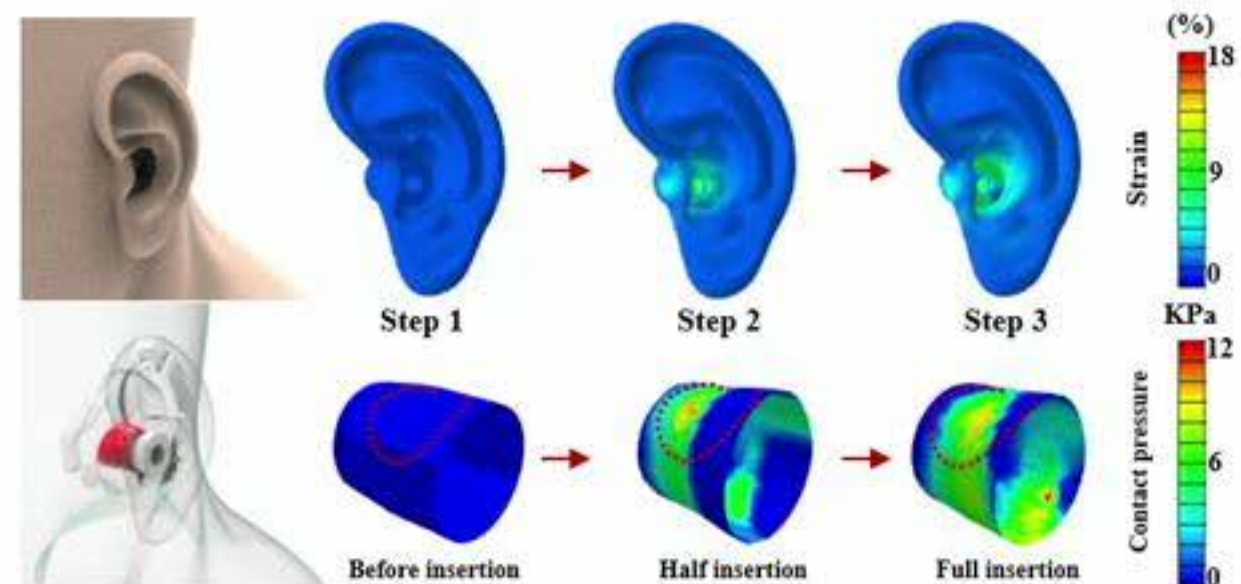


➤ Comfort study of In-ear cap sensor

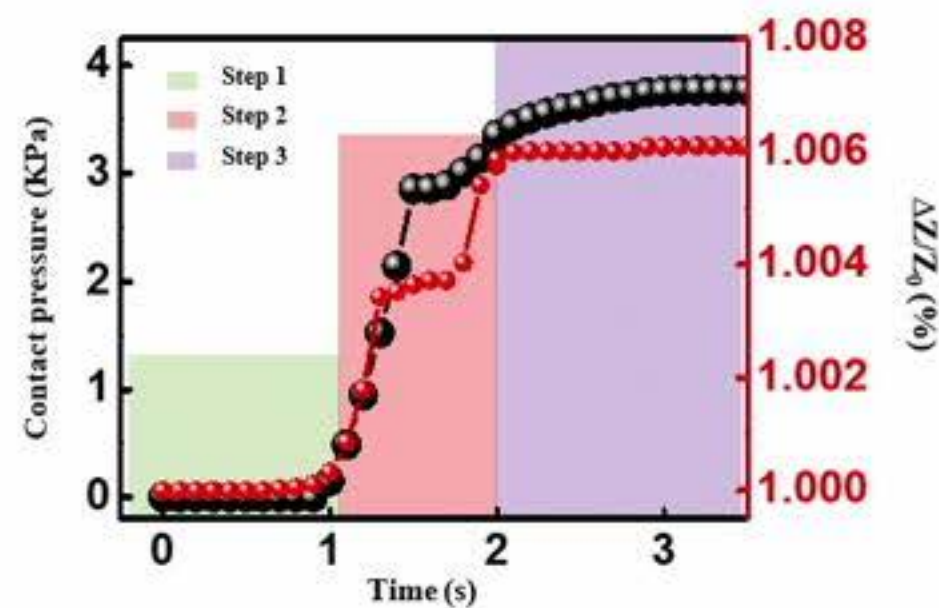
Finite element analysis (FEA) model design and simulation



FEA of the ear and sensor model

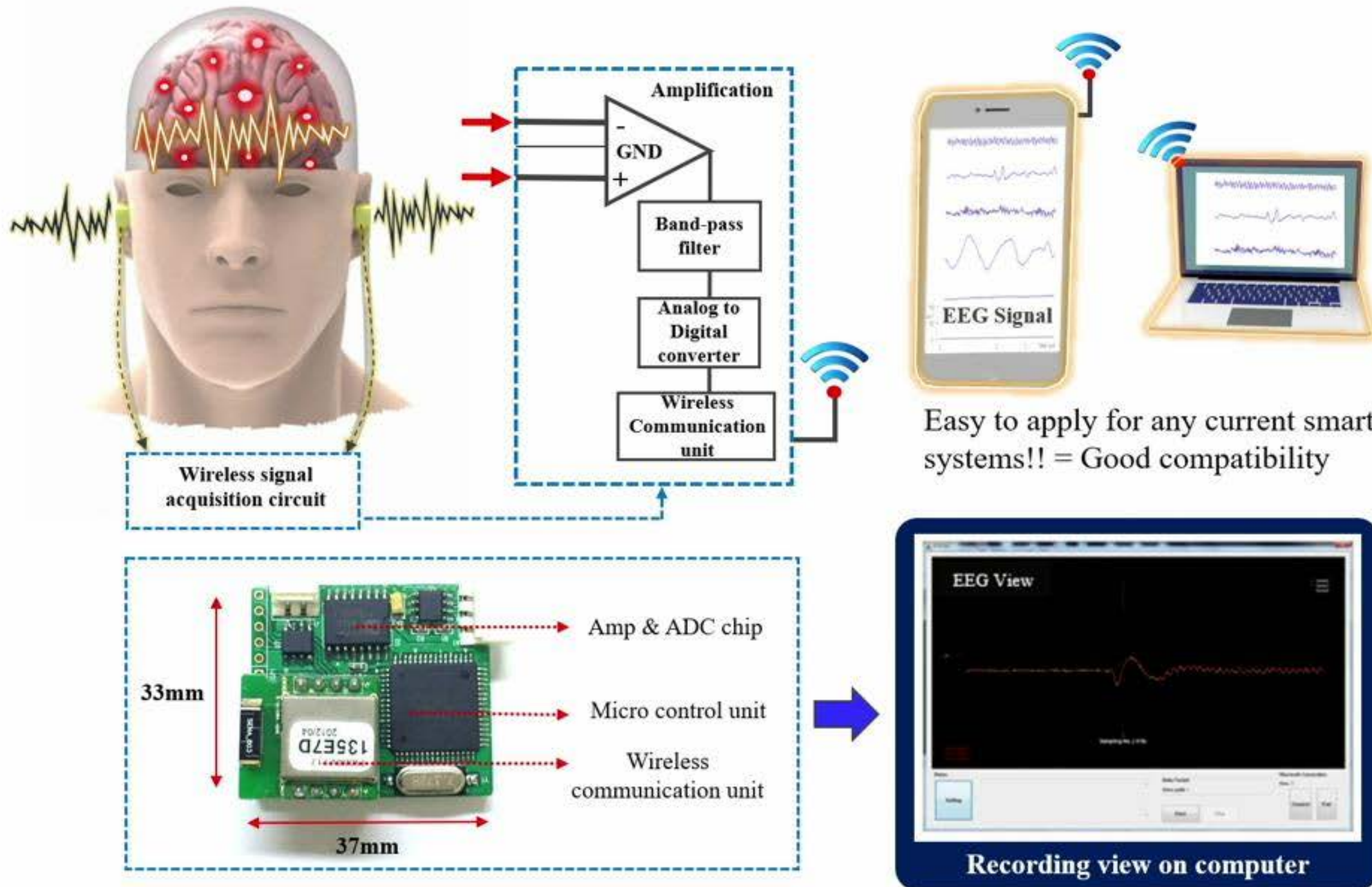


FEA for the applied pressure inside the ear



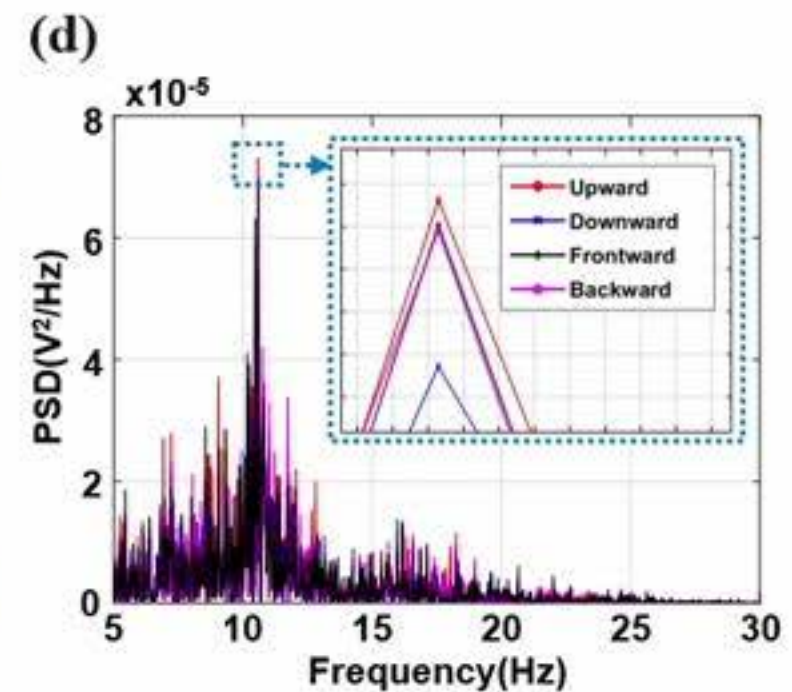
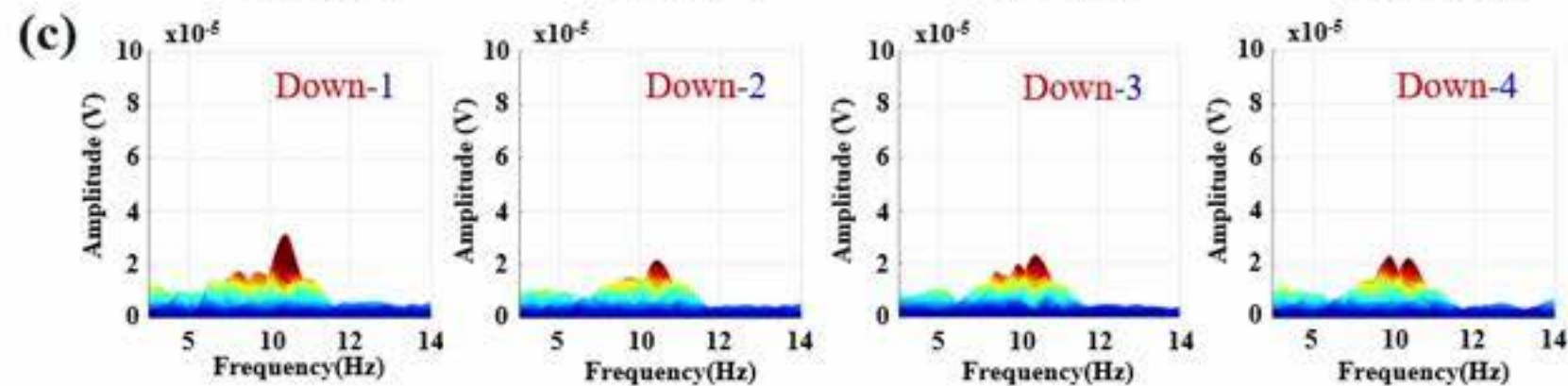
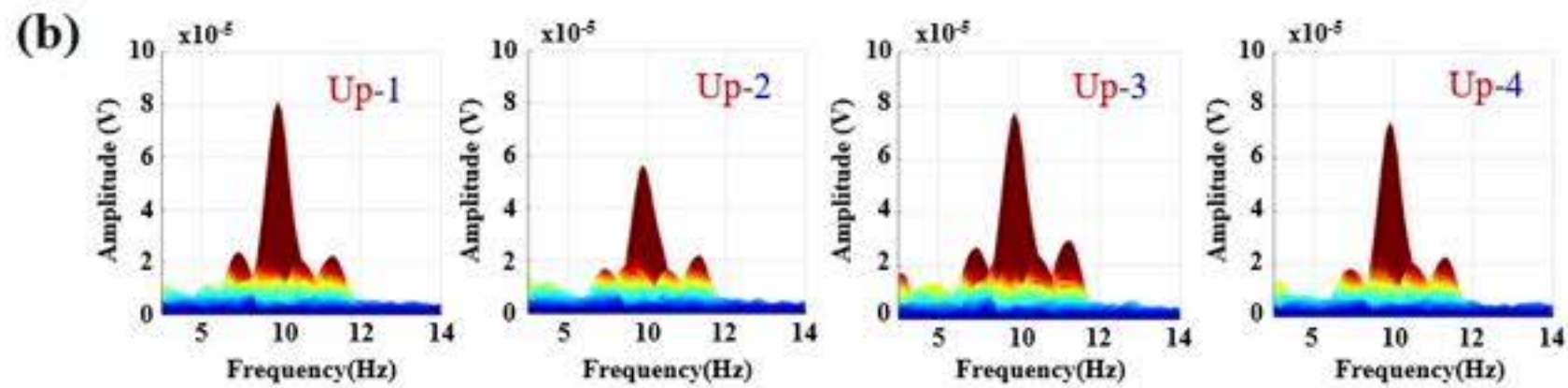
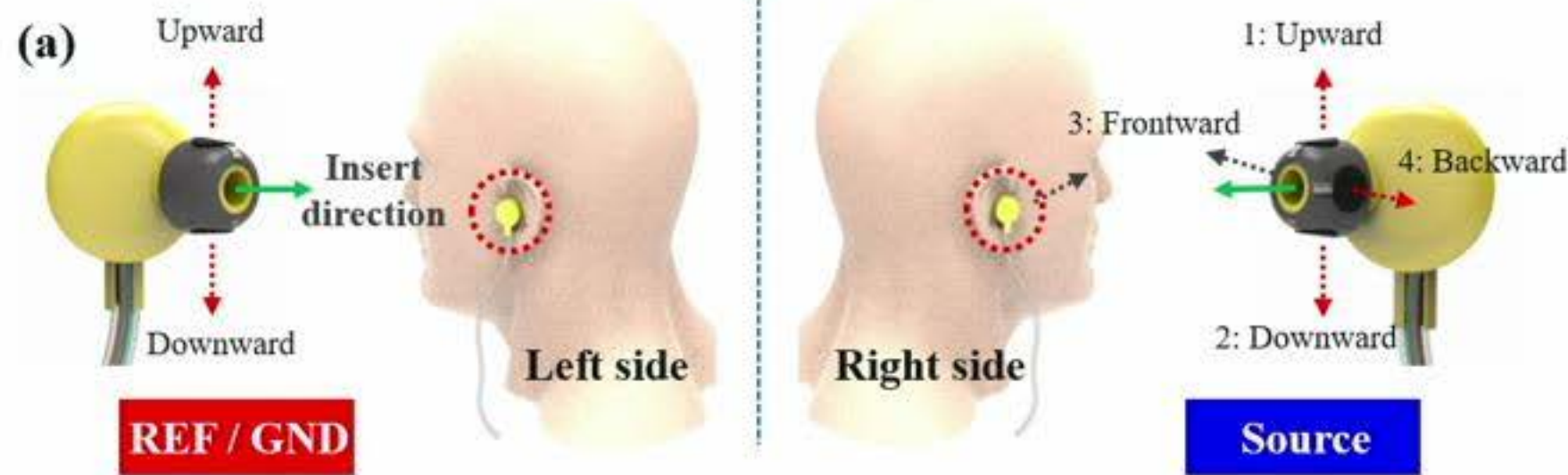
Sensor stability according to the pressure change

➤ EEG Recording systems



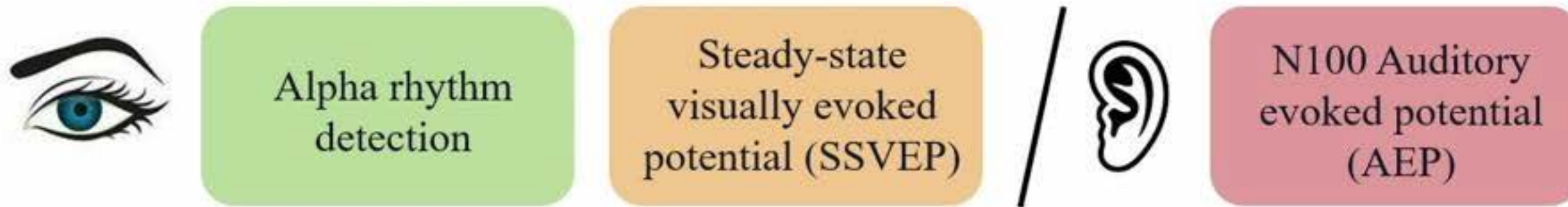
Easy to apply for any current smart systems!! = Good compatibility

➤ Sensor position optimization test

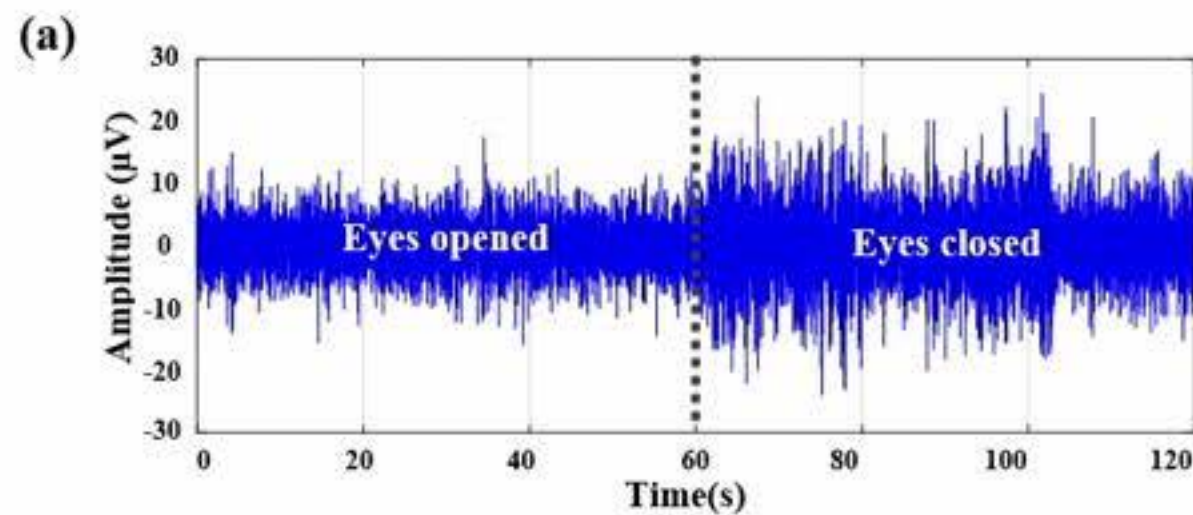


3.1 RESULTS

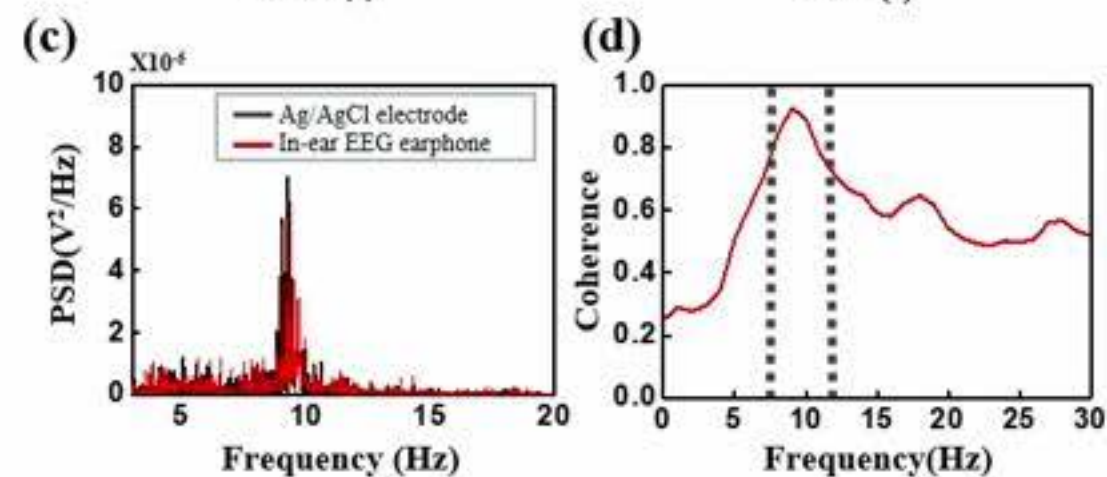
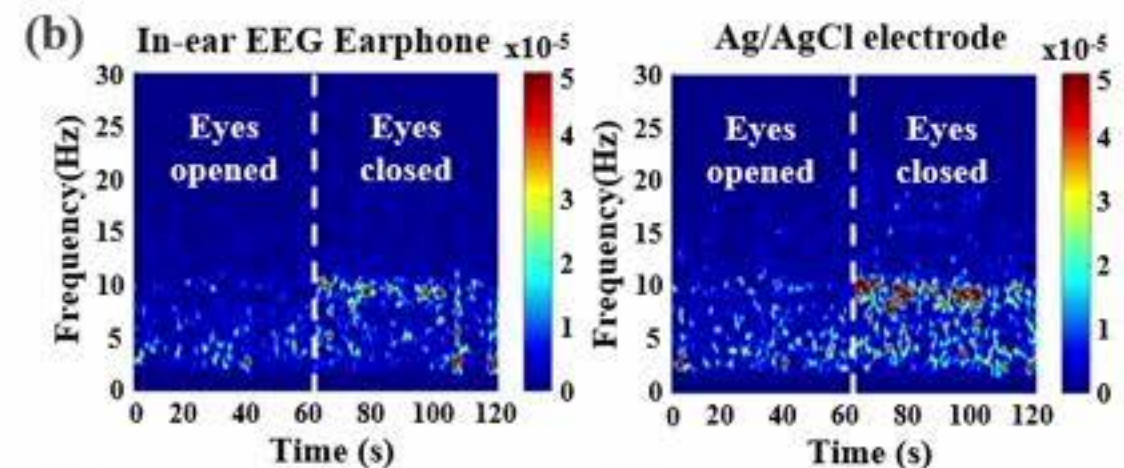
➤ Feasibility test



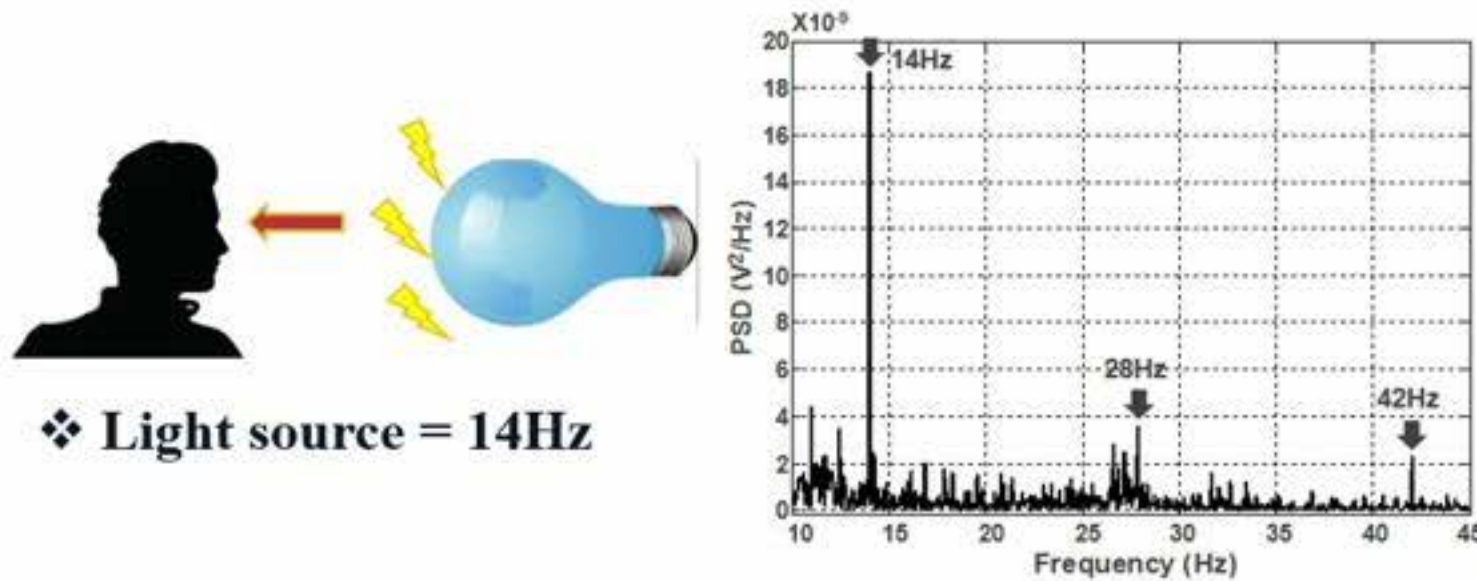
1. Alpha rhythm detection



- Alpha rhythm band = 8 ~ 14Hz
- The detection of alpha rhythms with a In-ear EEG Earphone and conventional type EEG electrodes for eyes open and closed.



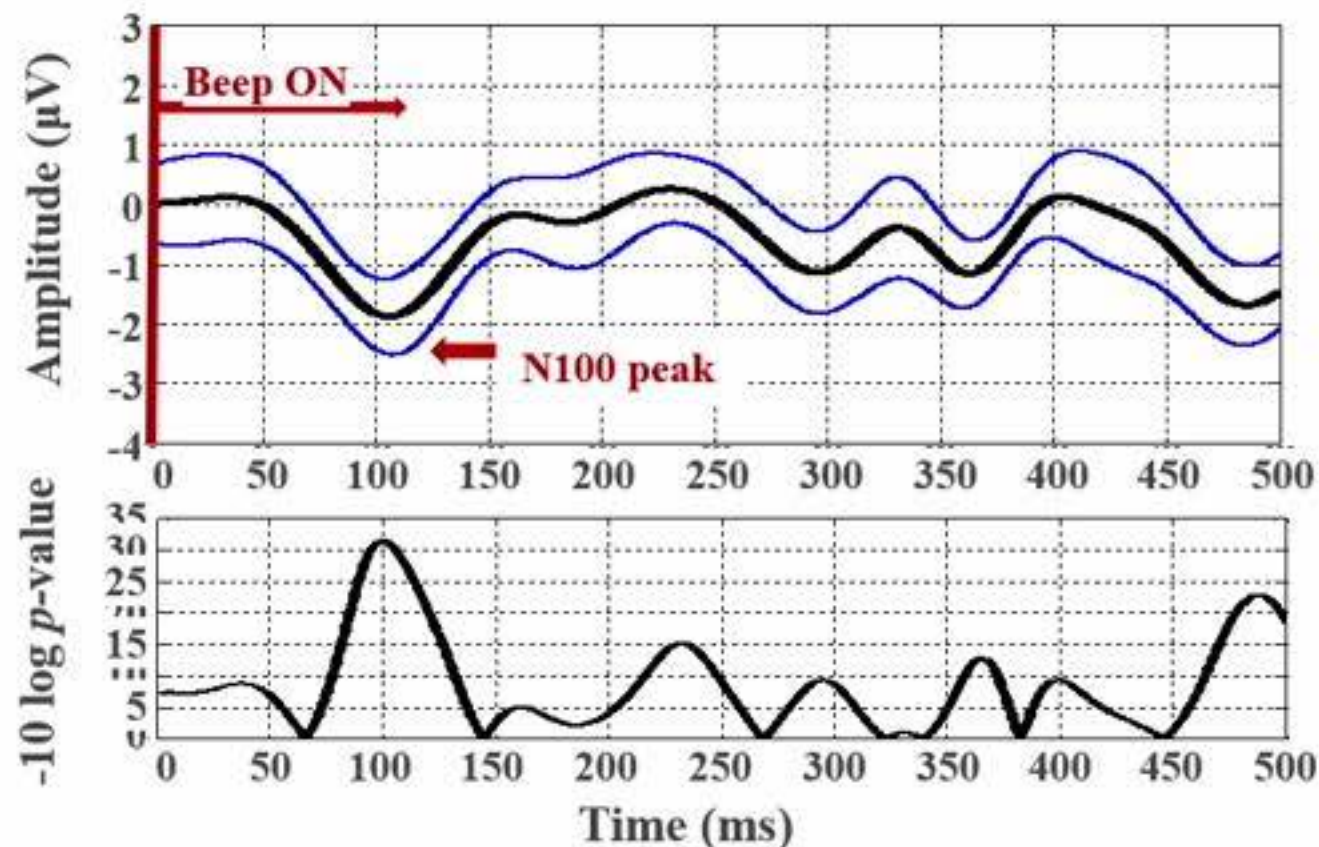
2. Steady-state visually evoked potential (SSVEP)



The power spectrum density of the EEG signal recorded by the In-ear EEG earphone on the 14 Hz SSVEP test.

In addition to the dominant 14 Hz peak, sub-harmonic peaks were also observed.

3. N100 Auditory evoked potential (AEP)

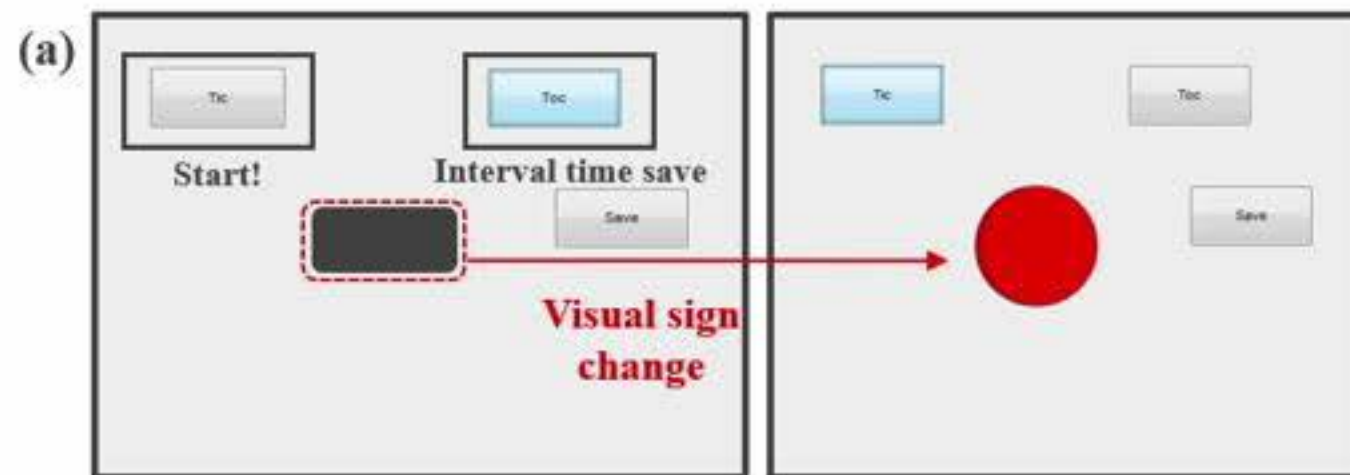


Beep sound

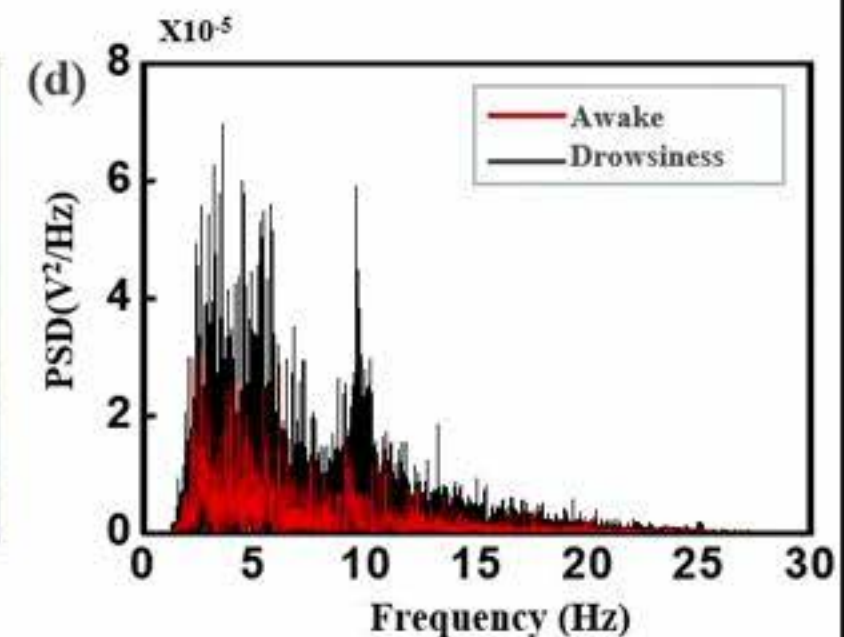
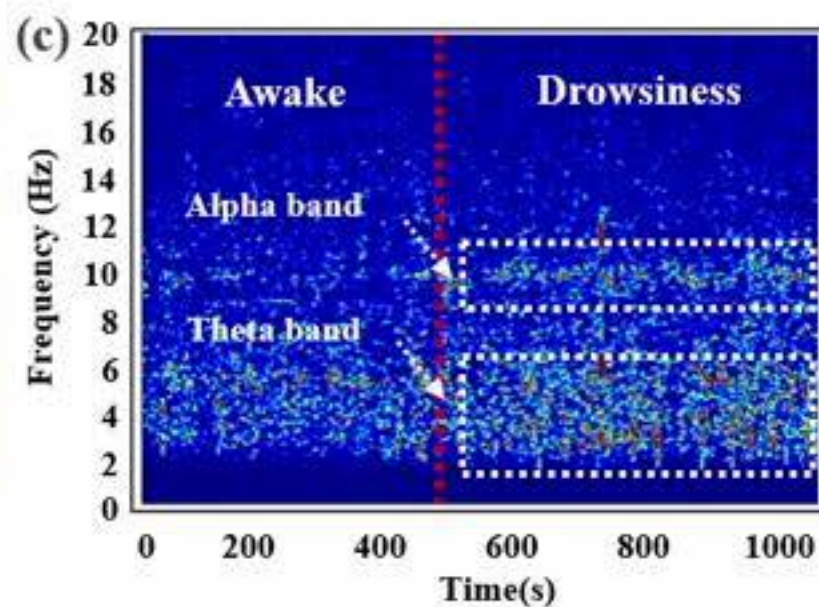
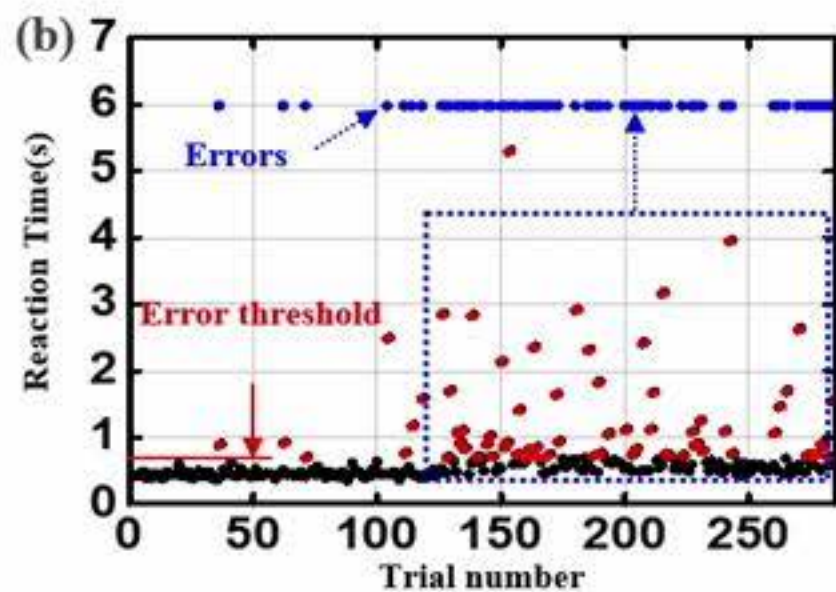
Average N100 AEP signals (black bold line) with standard deviations (blue line)

P – Value < 0.01 = Available

➤ Practical application (Drowsiness detection)



▪ Control panel images of reaction time test for drowsiness detection



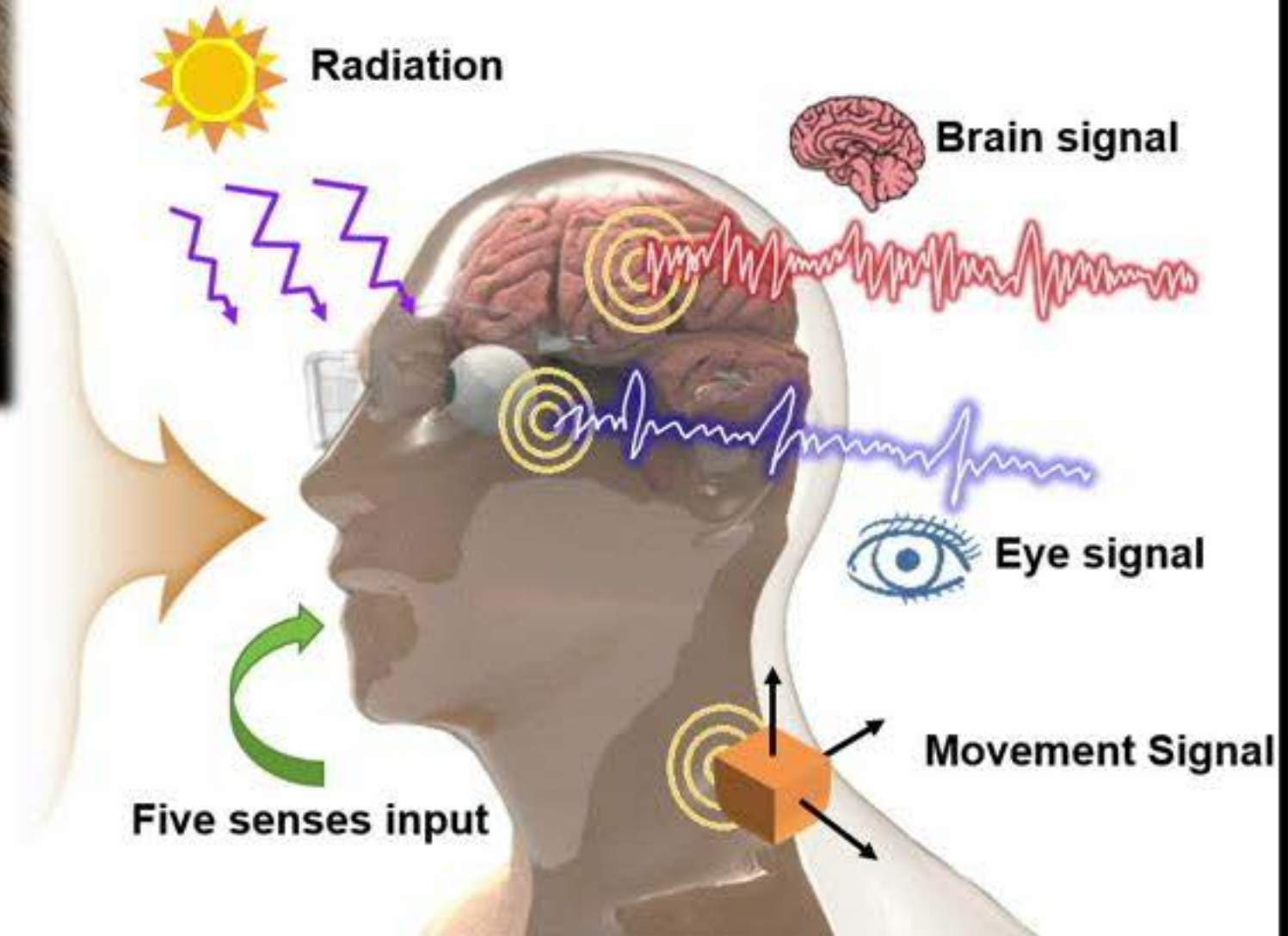
Sleep state : Theta (4-7 Hz) rhythm, Alpha (8-14 Hz) rhythm is getting strong !

Drowsiness state is completely detected by In-ear EEG earphone!

2. Smart Eye-glasses Concept

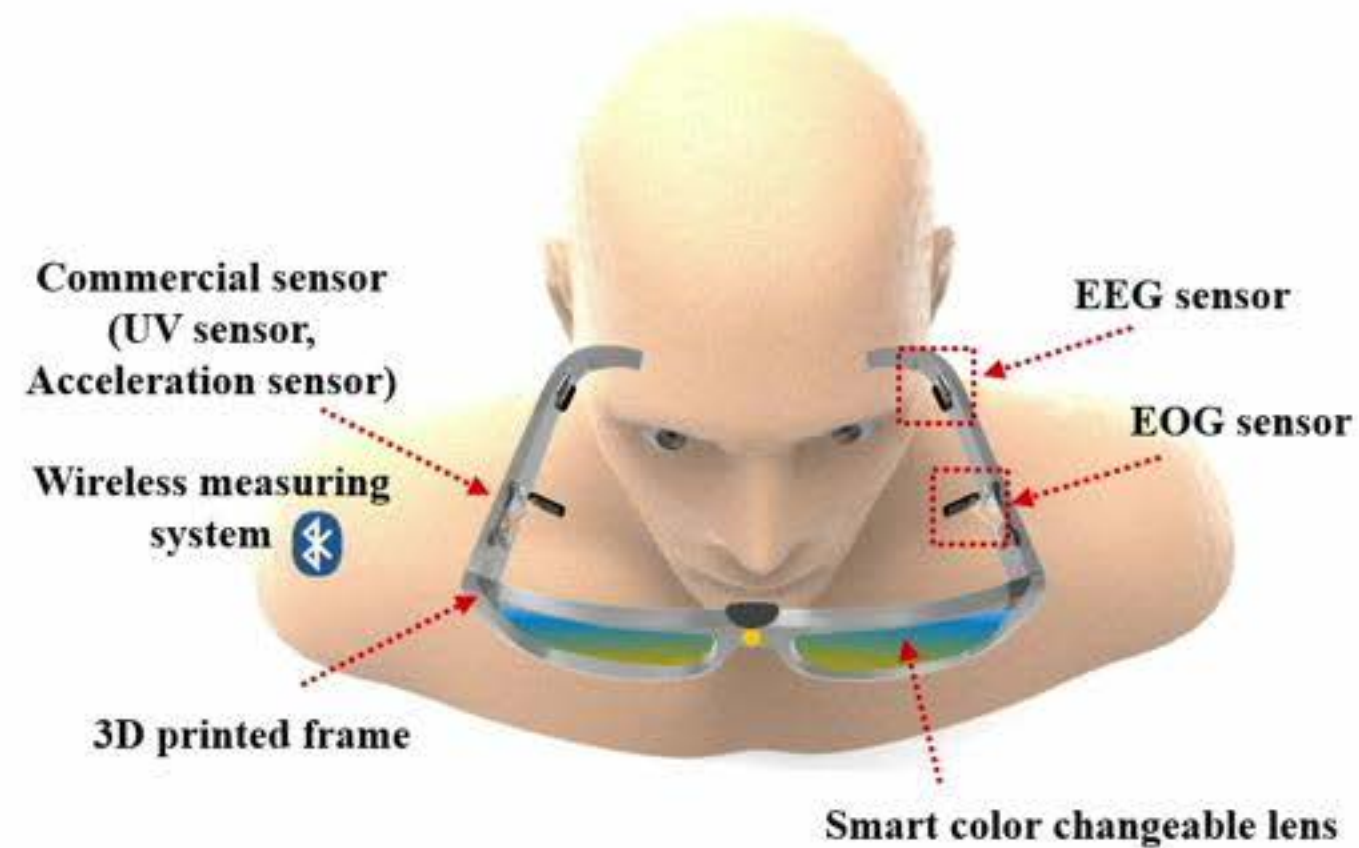


- About 87% of human sensory input is obtained by head !!
Ex) Five senses
- Brain signal measurement
- Eye signal measurement



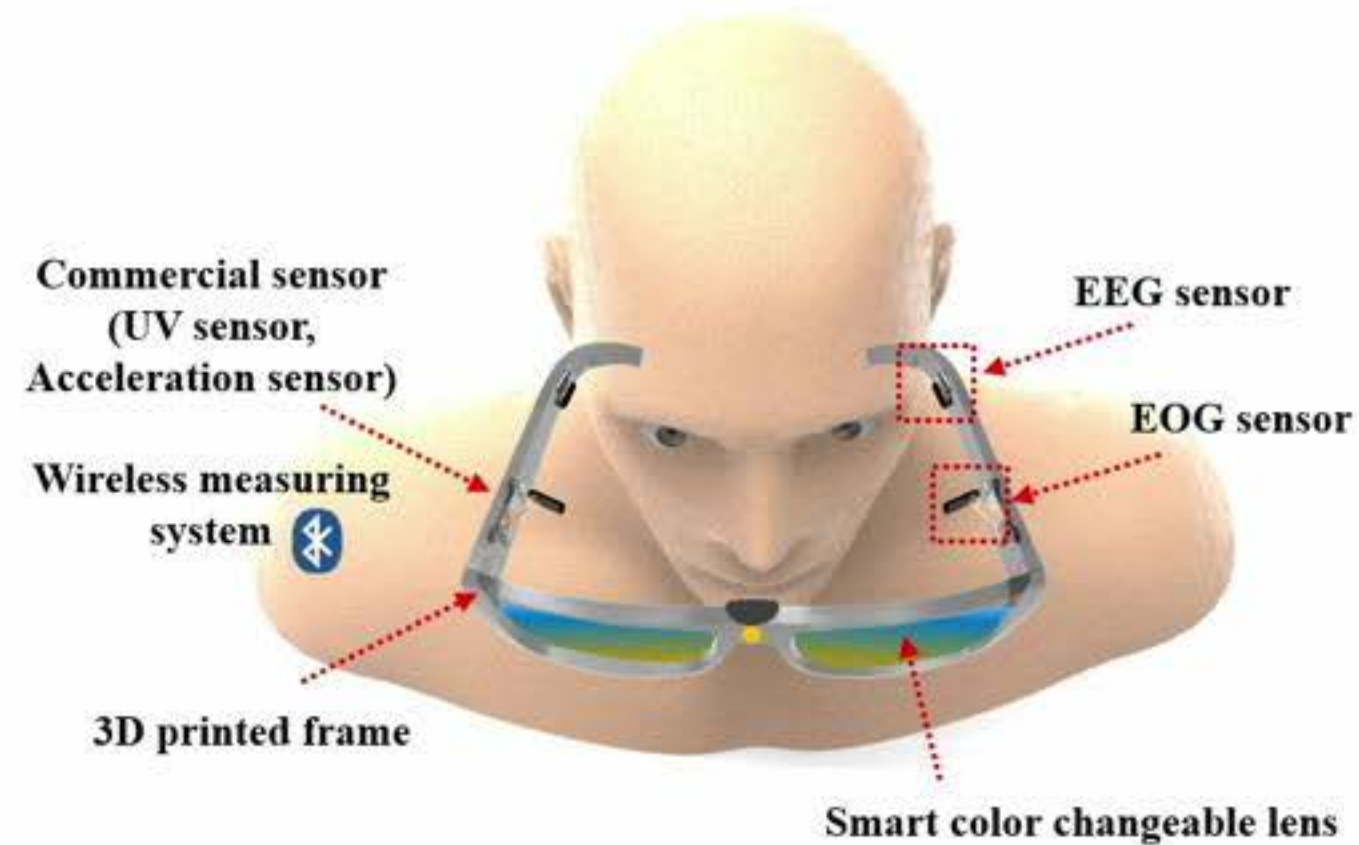
2.2 MATERIALS & METHODS

▪ Component of Multi-functional Smart Electronic Eyeglasses

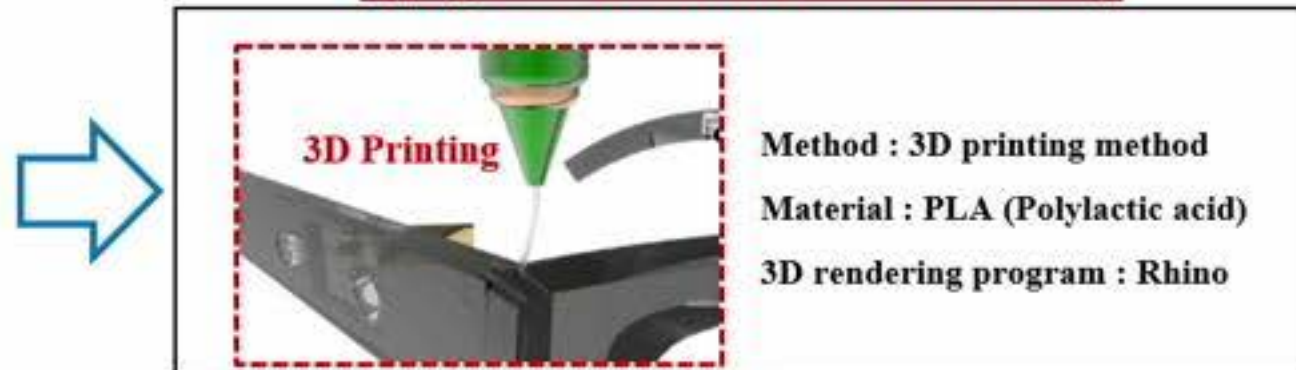


2.2 MATERIALS & METHODS

▪ Component of Multi-functional Smart Electronic Eyeglasses

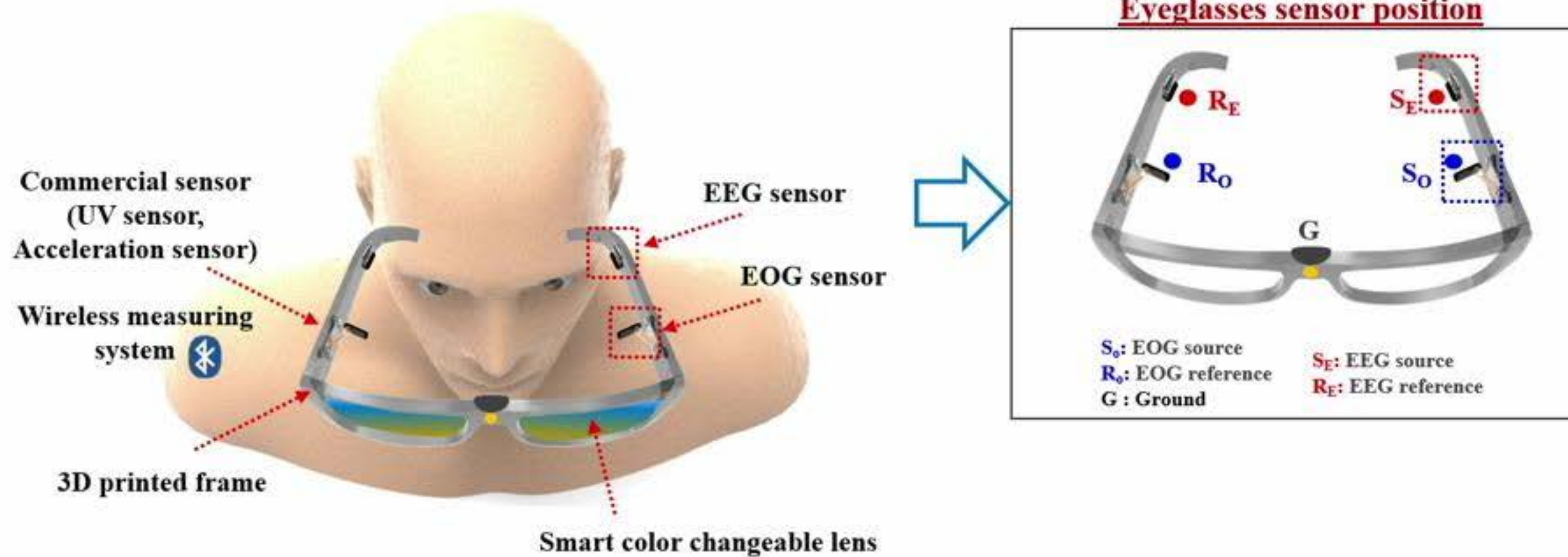


Eyeglasses structure manufacturing

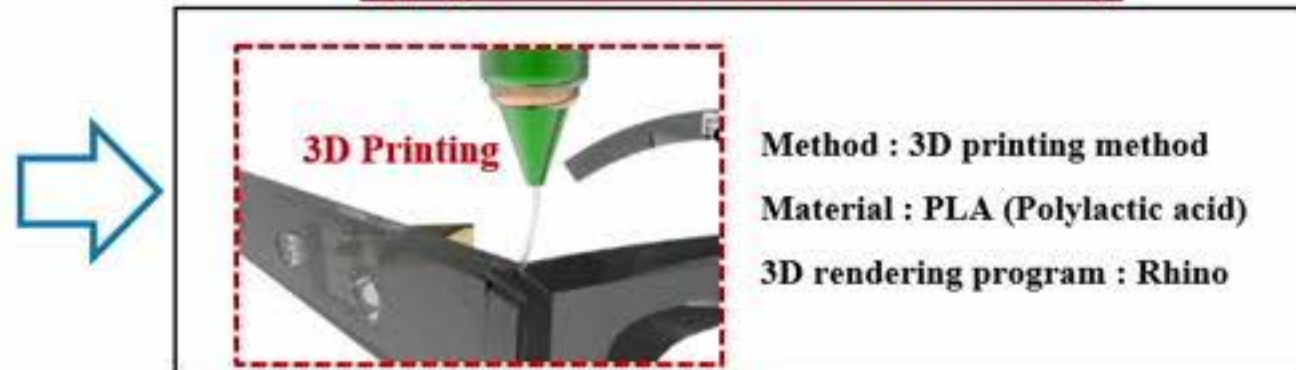


2.2 MATERIALS & METHODS

Component of Multi-functional Smart Electronic Eyeglasses

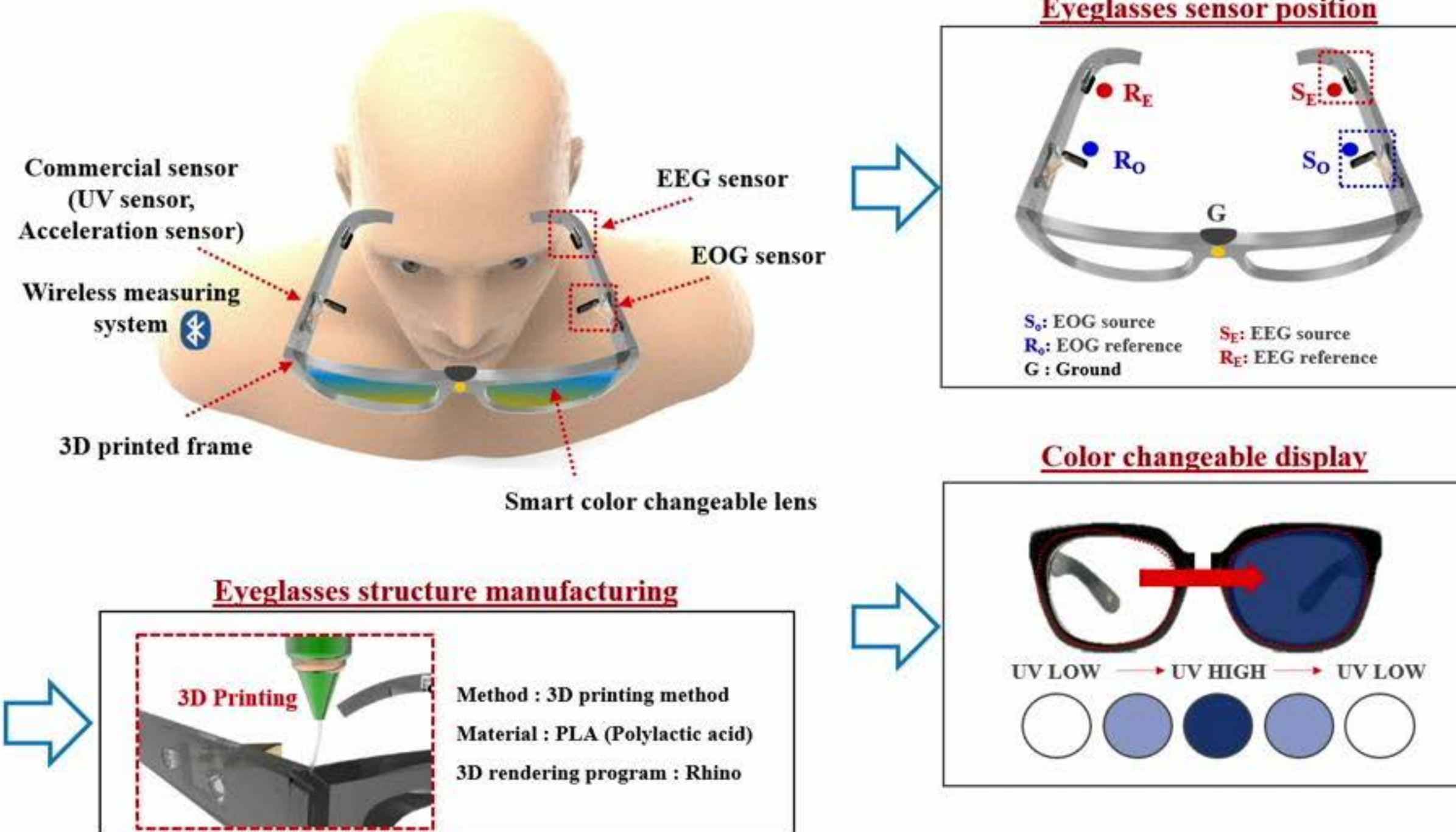


Eyeglasses structure manufacturing



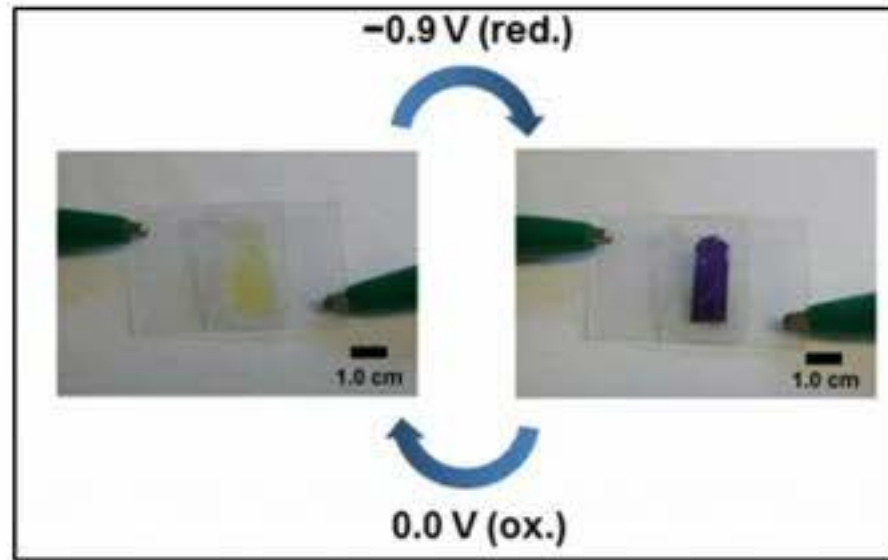
2.2 MATERIALS & METHODS

Component of Multi-functional Smart Electronic Eyeglasses

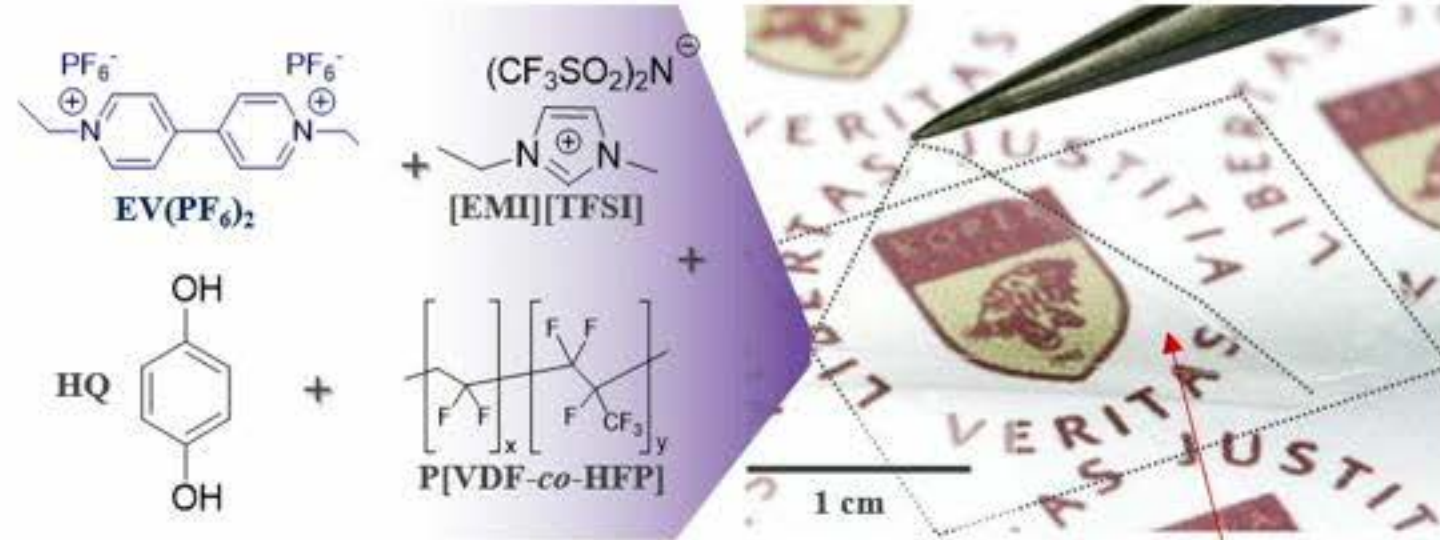


- Color changeable glass lens (Electro chromic gel)

Fabrication of electrochromic gel



*H C Moon et al. Chem. Mater. (2015)



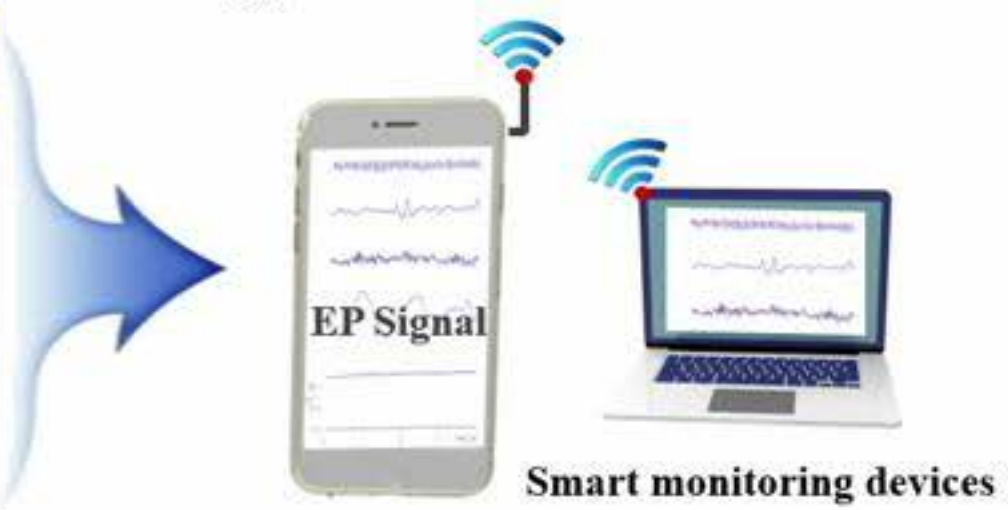
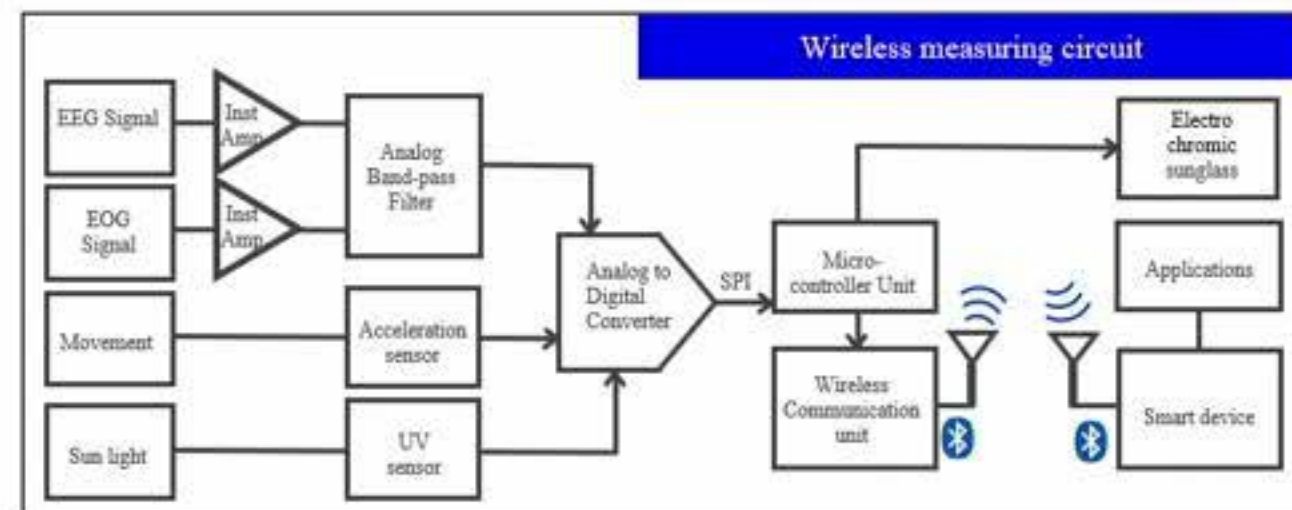
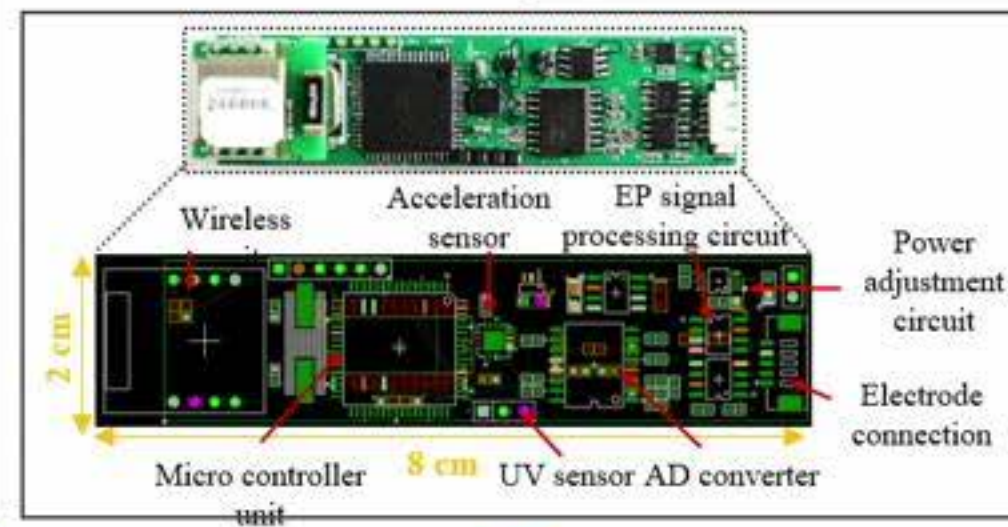
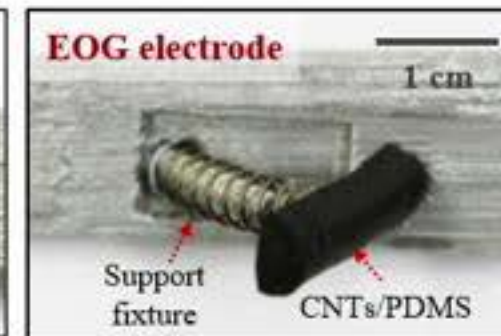
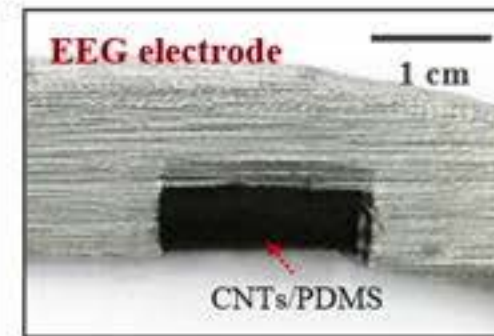
Electro chromic gel

Color changeable lens operation system



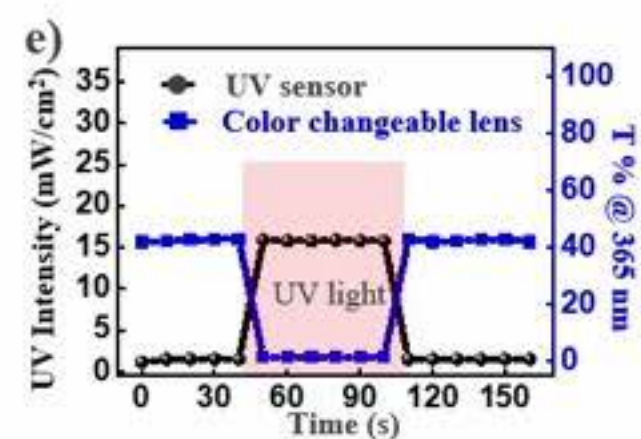
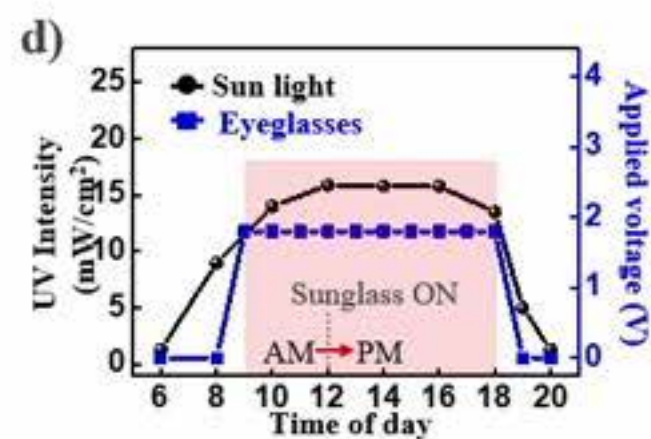
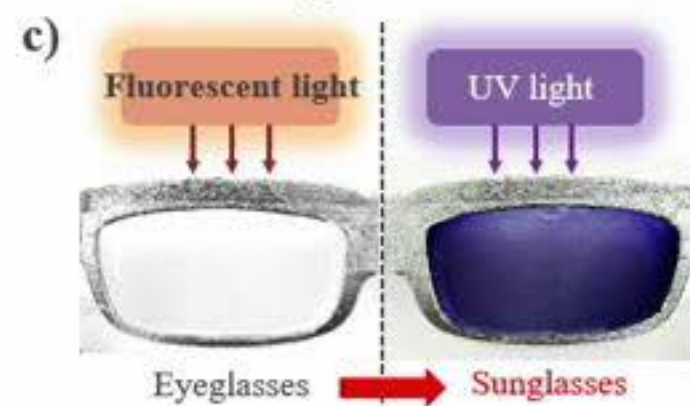
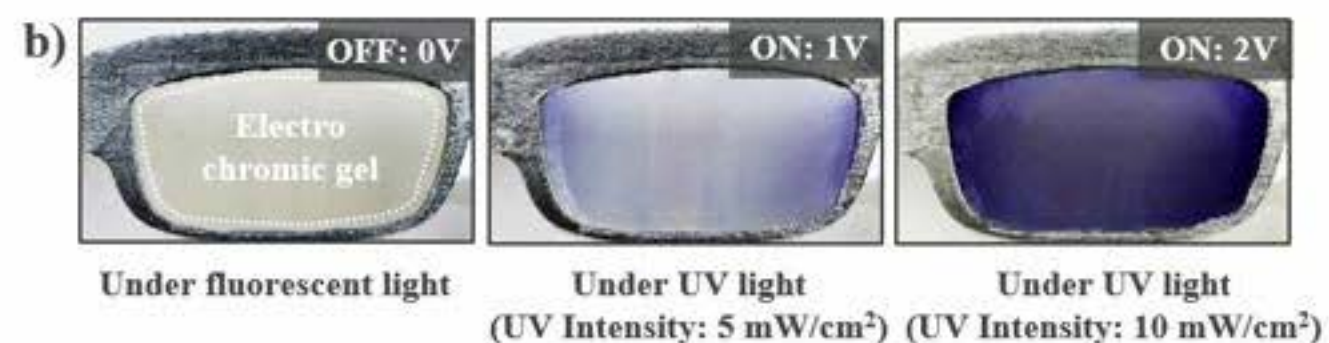
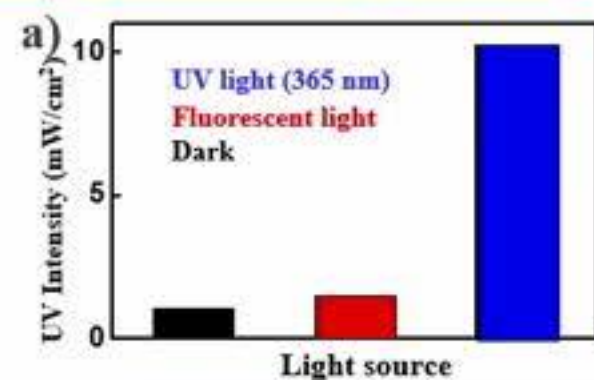
3.2 RESULTS

Smart electronic eyeglasses

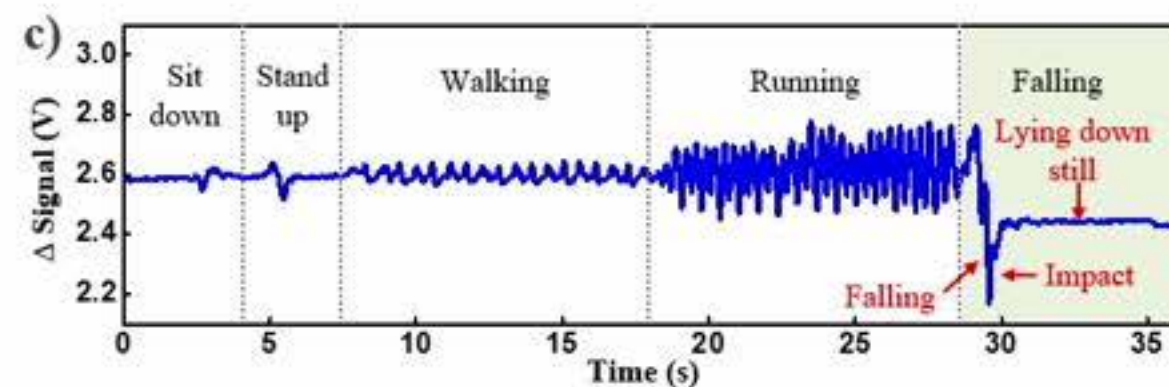
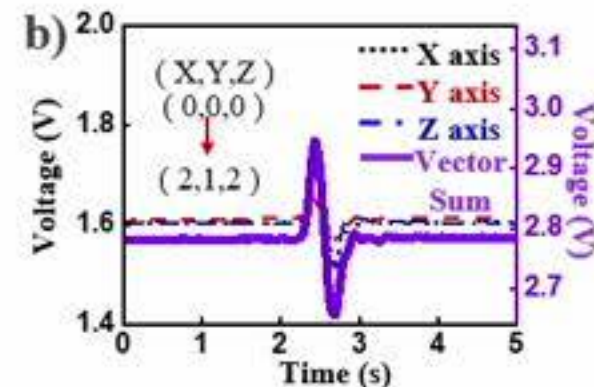
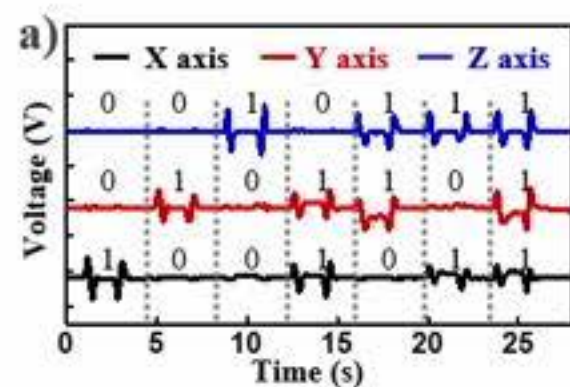


■ HMI with commercial components

Color changeable lens operation



Motion detection with acceleration sensor



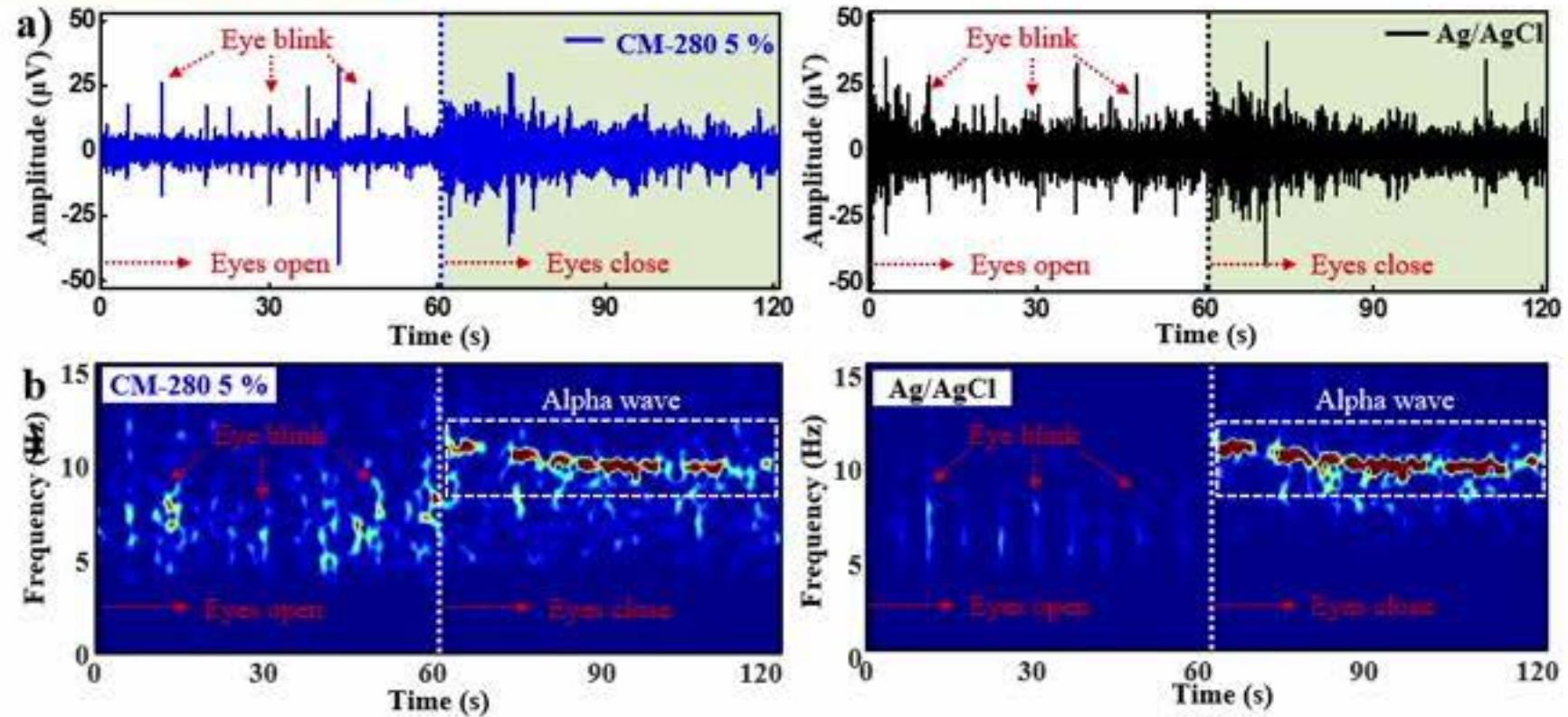
- **HMI with Brain activity (EEG signal)**

Electroencephalogram (EEG) measurement

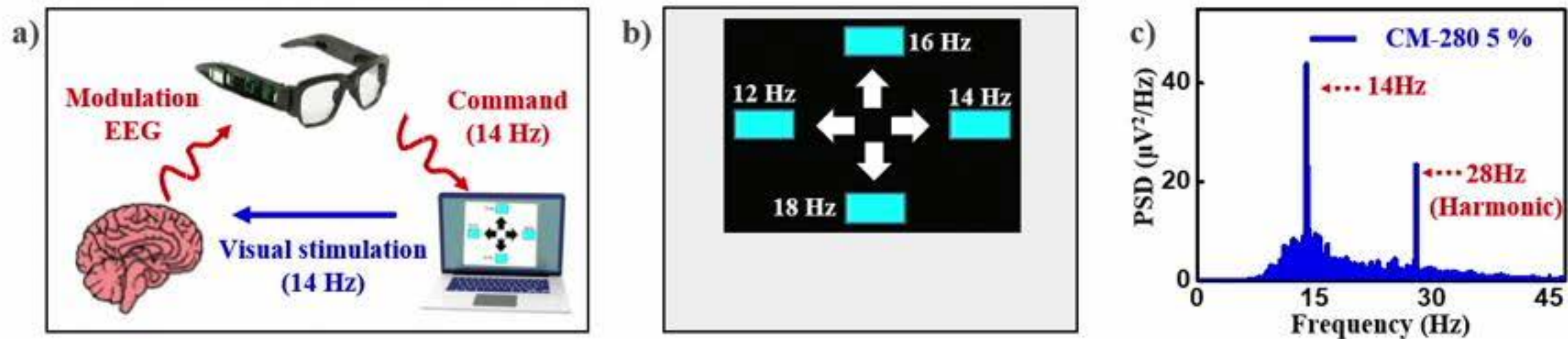


**Alpha rhythm
detection**

Alpha rhythm band =
8 ~ 14Hz



HMI application with EEG signal (Direction control)



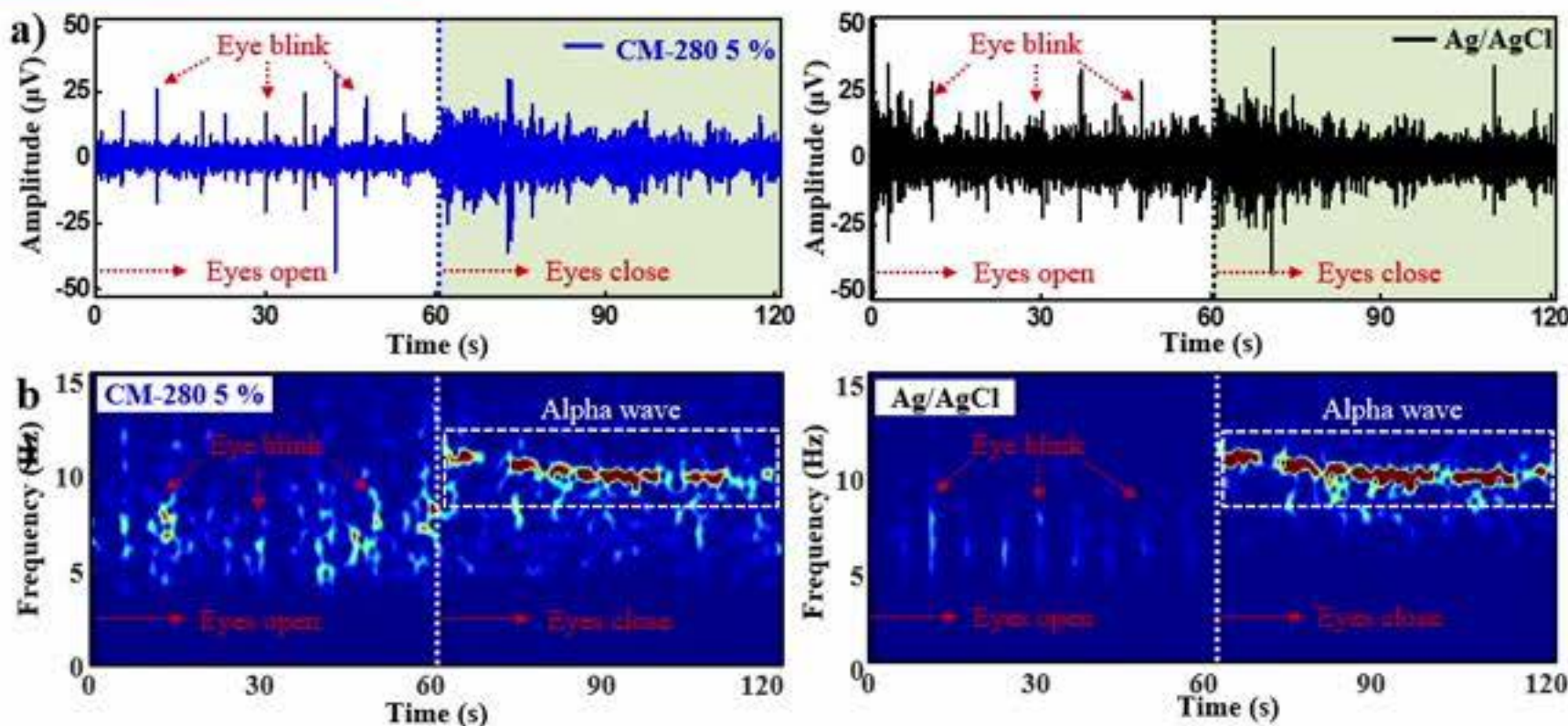
▪ HMI with Brain activity (EEG signal)

Electroencephalogram (EEG) measurement

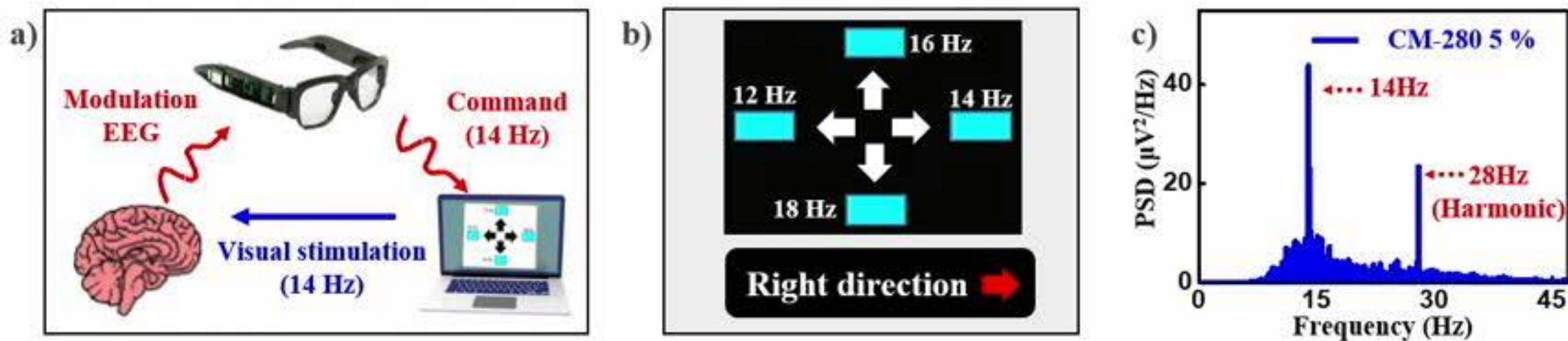


Alpha rhythm detection

Alpha rhythm band = 8 ~ 14Hz

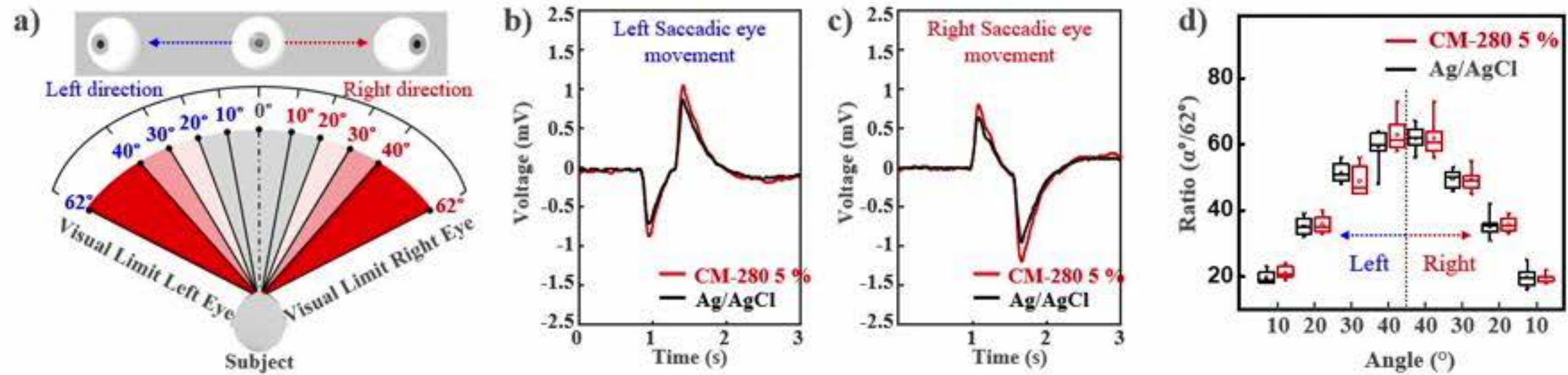


HMI application with EEG signal (Direction control)

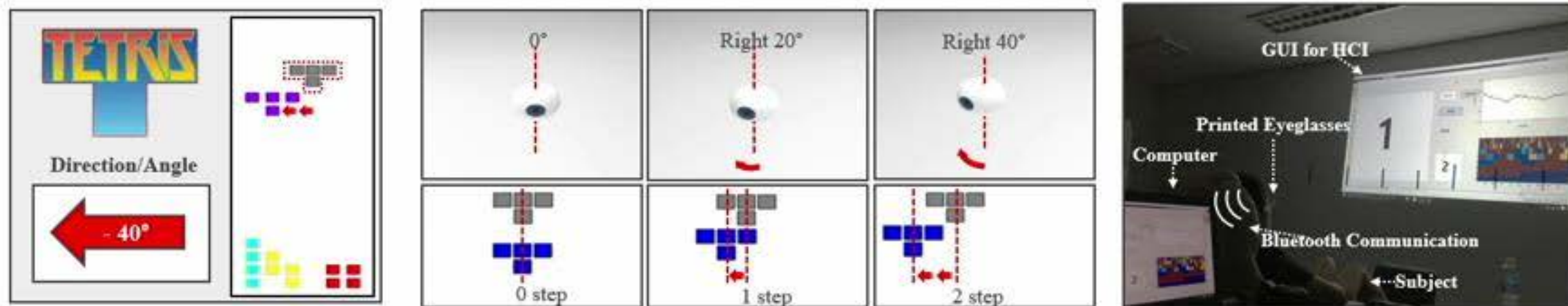


▪ HMI with Eyes activity (EOG signal)

Electrooculography (EOG) measurement

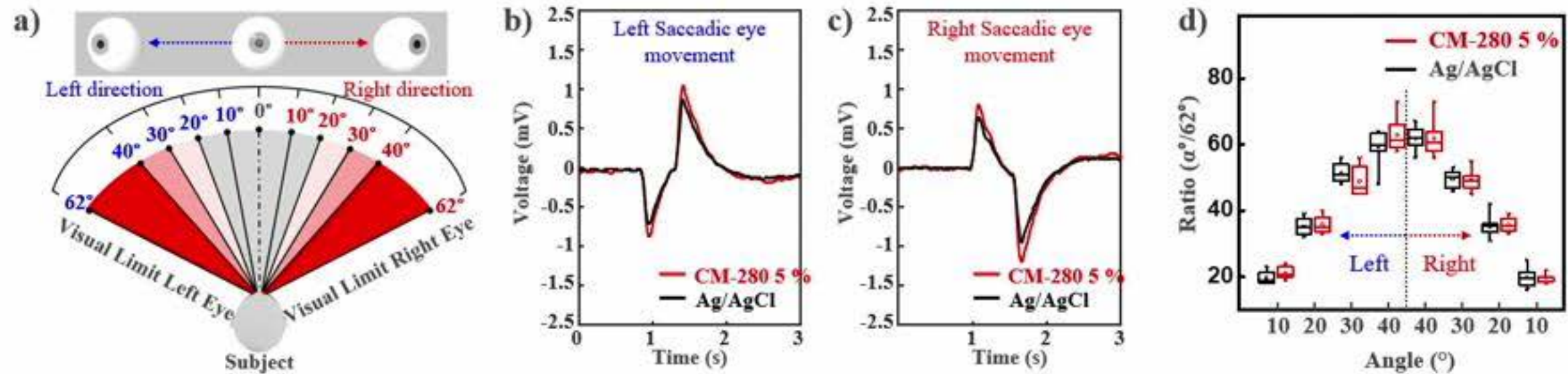


HMI application with EOG signal (Game control)

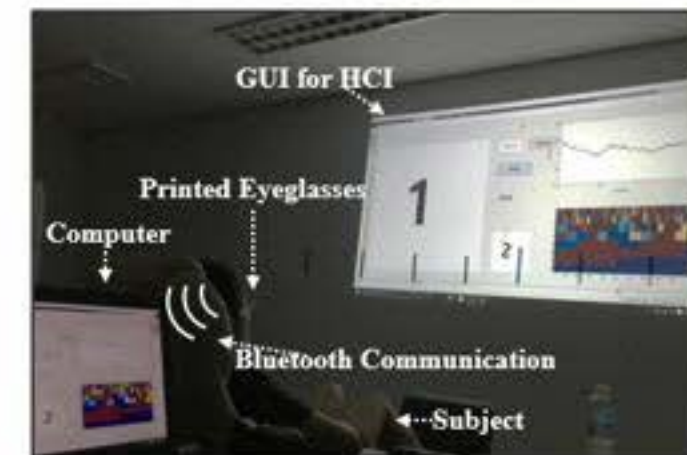
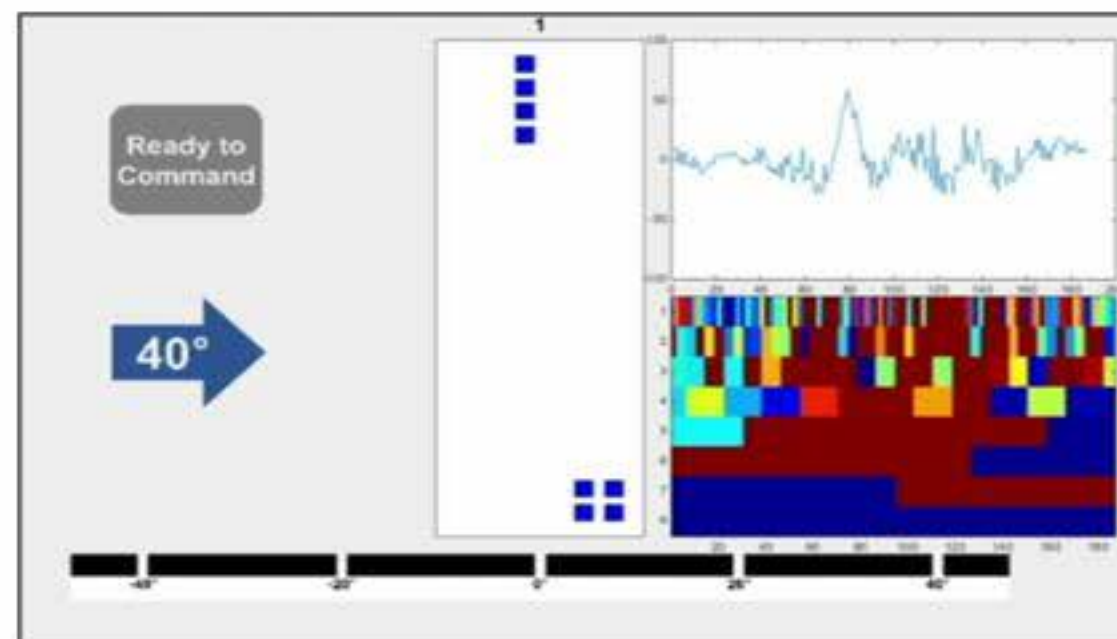


▪ HMI with Eyes activity (EOG signal)

Electrooculography (EOG) measurement

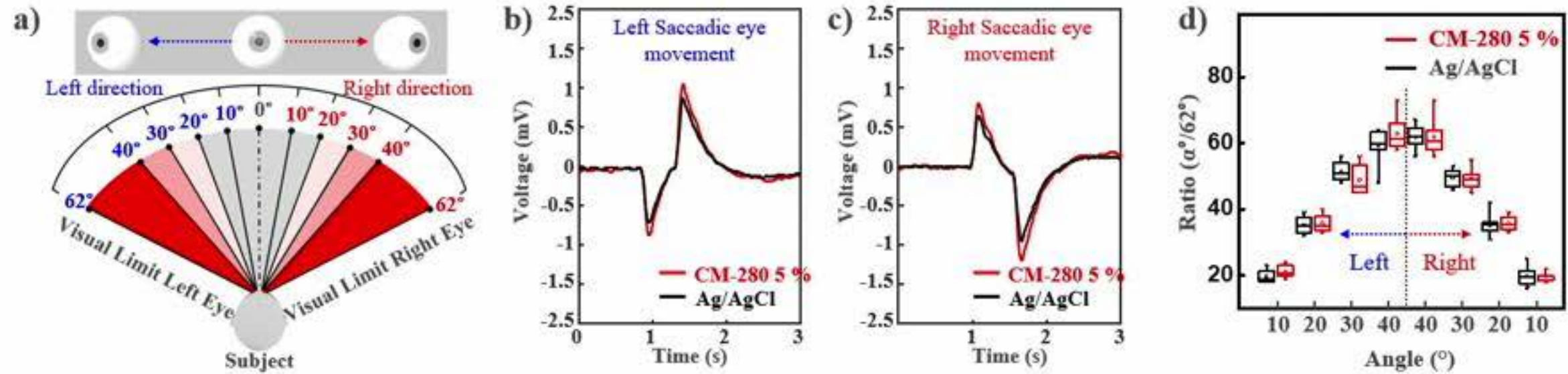


HMI application with EOG signal (Game control)

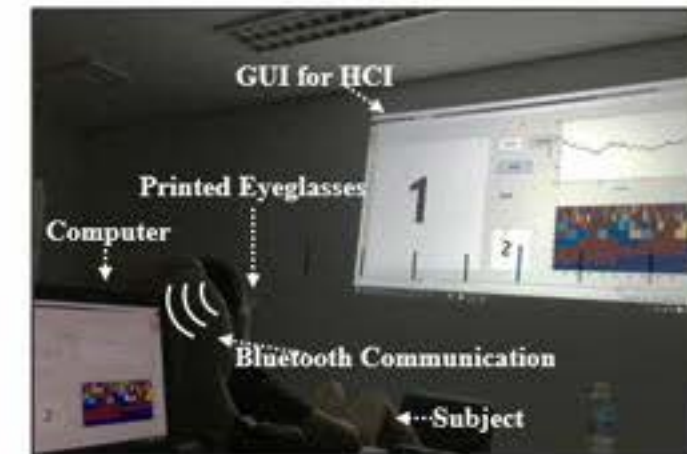
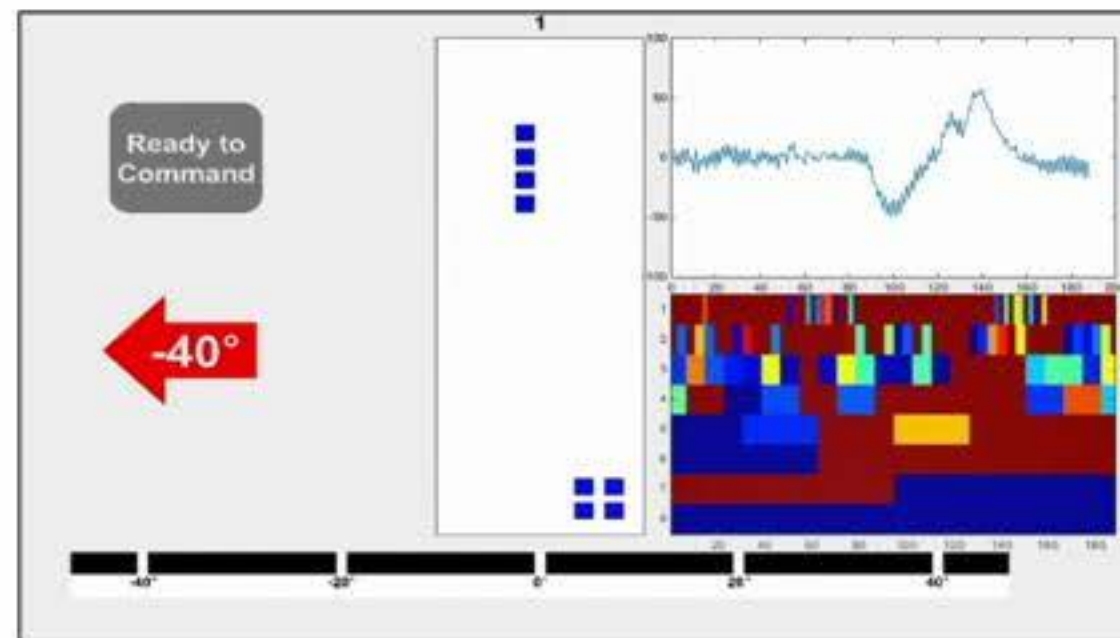


- HMI with Eyes activity (EOG signal)

Electrooculography (EOG) measurement

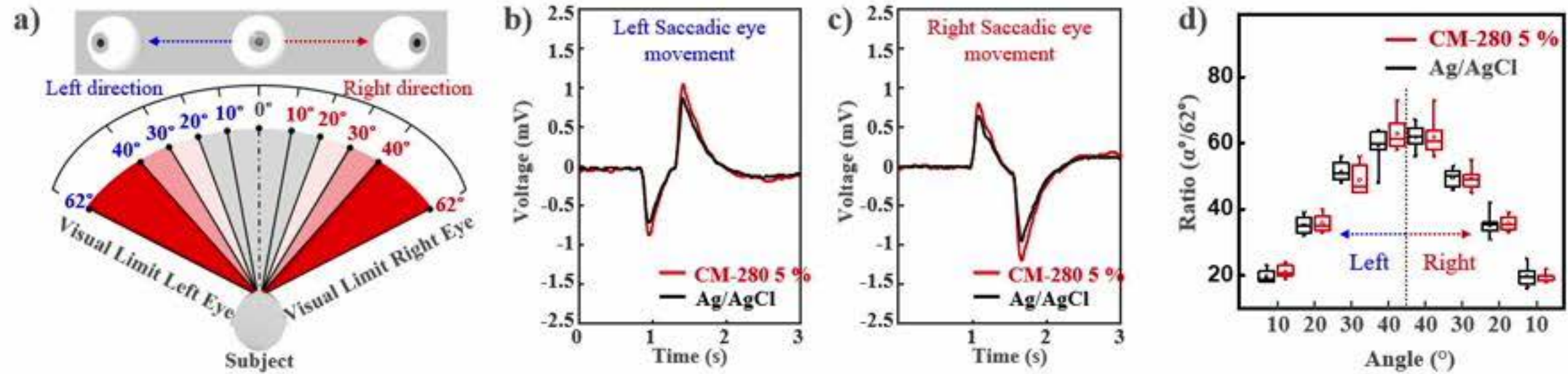


HMI application with EOG signal (Game control)

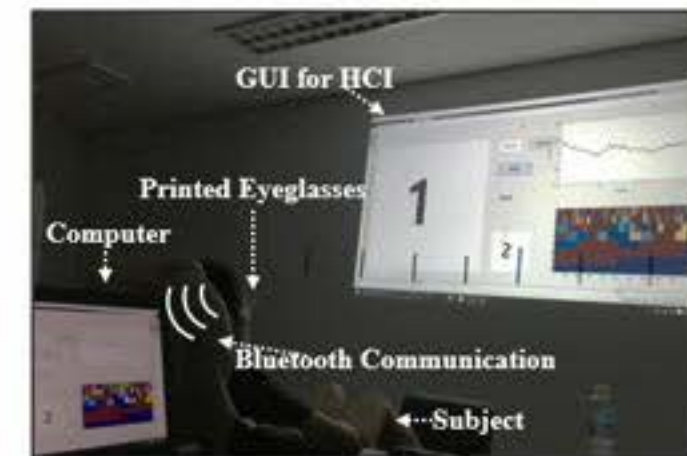
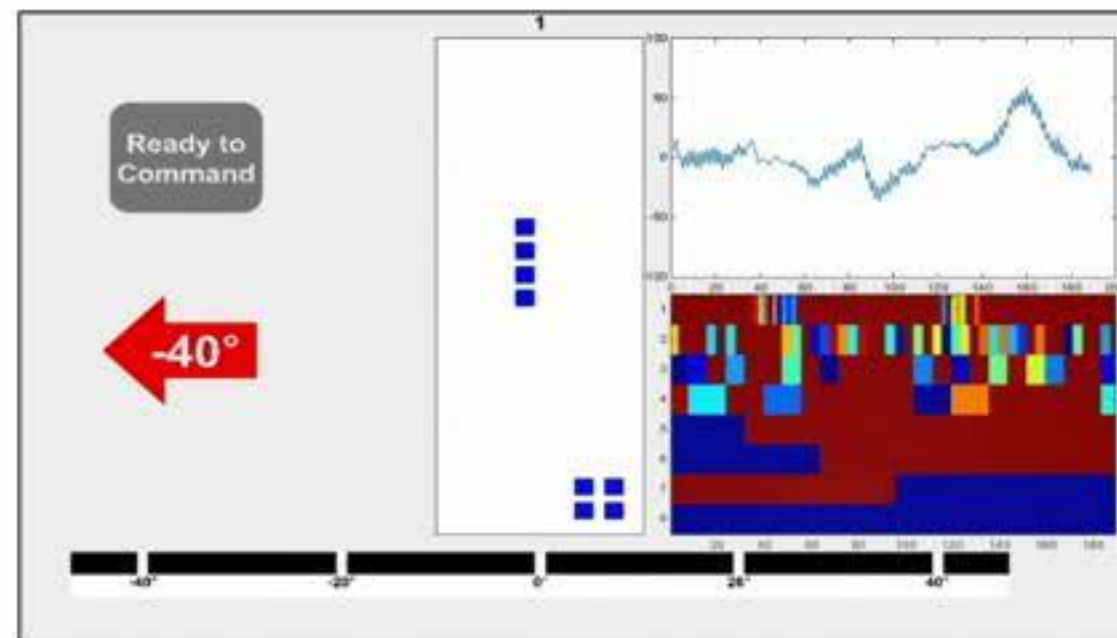


▪ HMI with Eyes activity (EOG signal)

Electrooculography (EOG) measurement

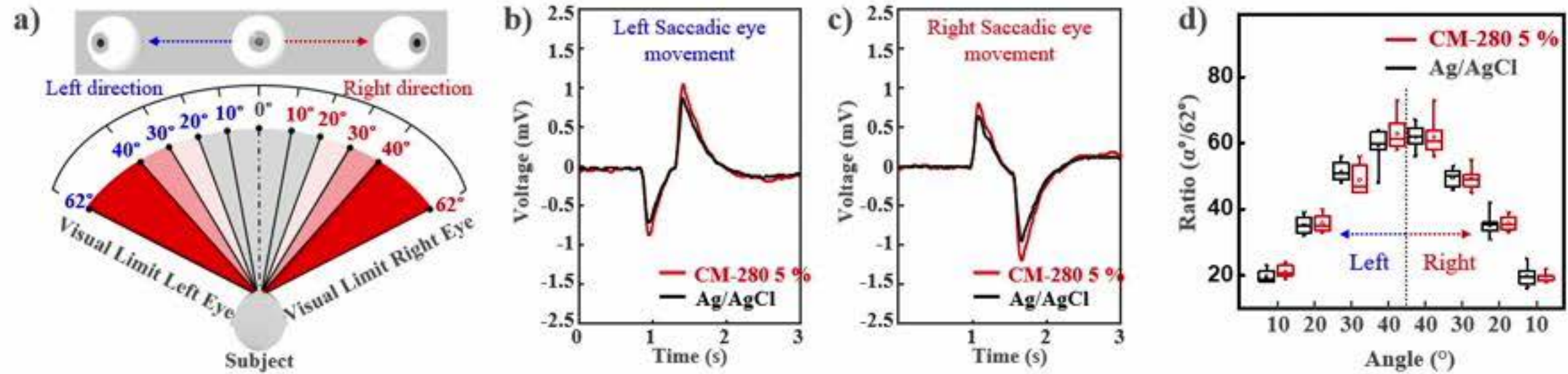


HMI application with EOG signal (Game control)

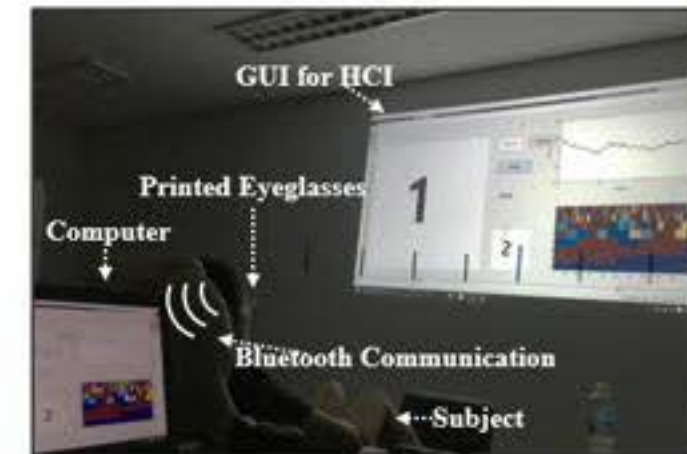
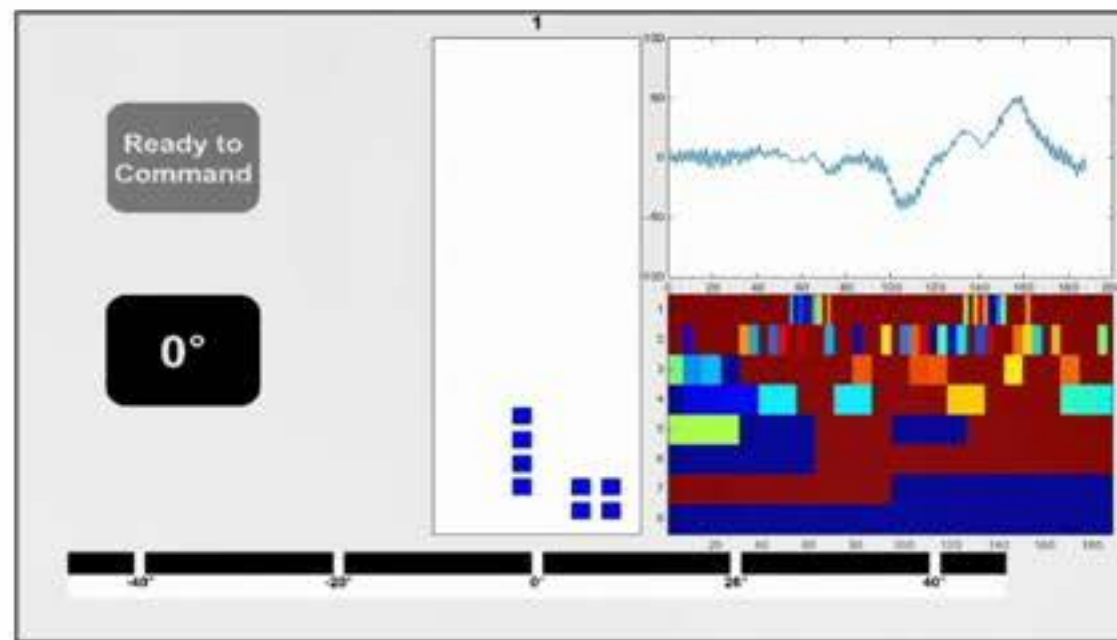


▪ HMI with Eyes activity (EOG signal)

Electrooculography (EOG) measurement

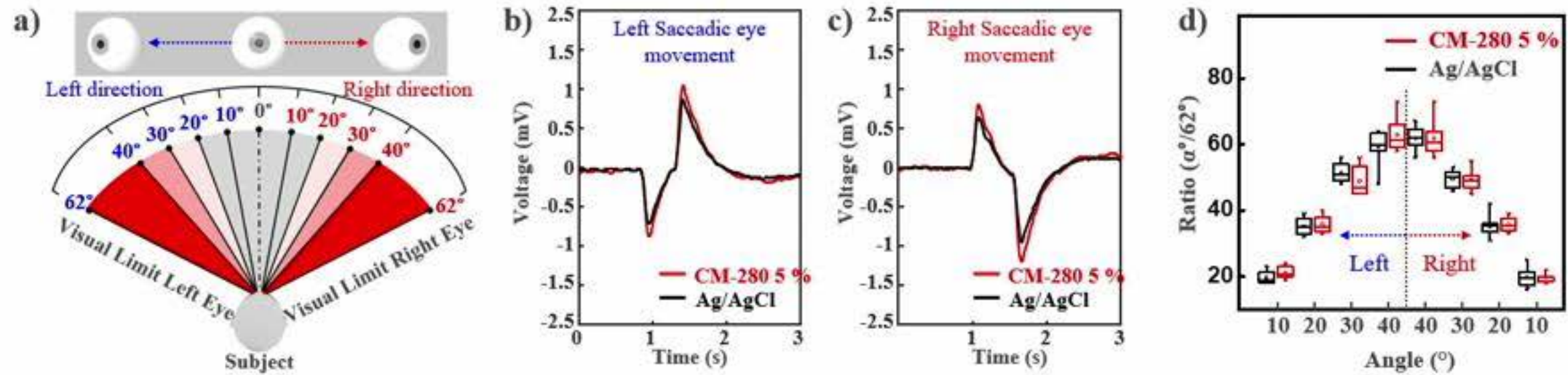


HMI application with EOG signal (Game control)

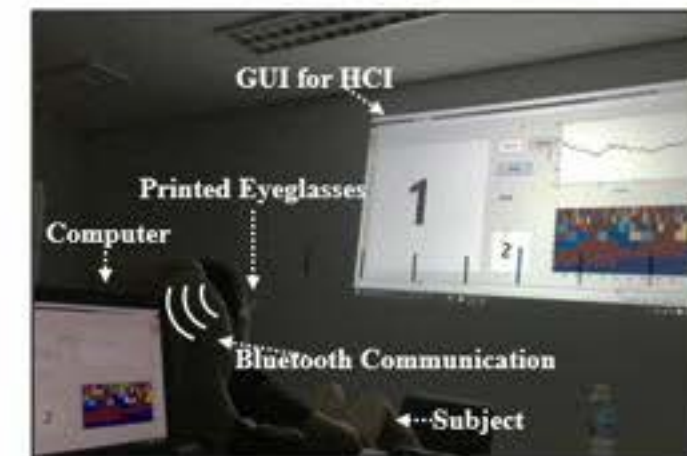
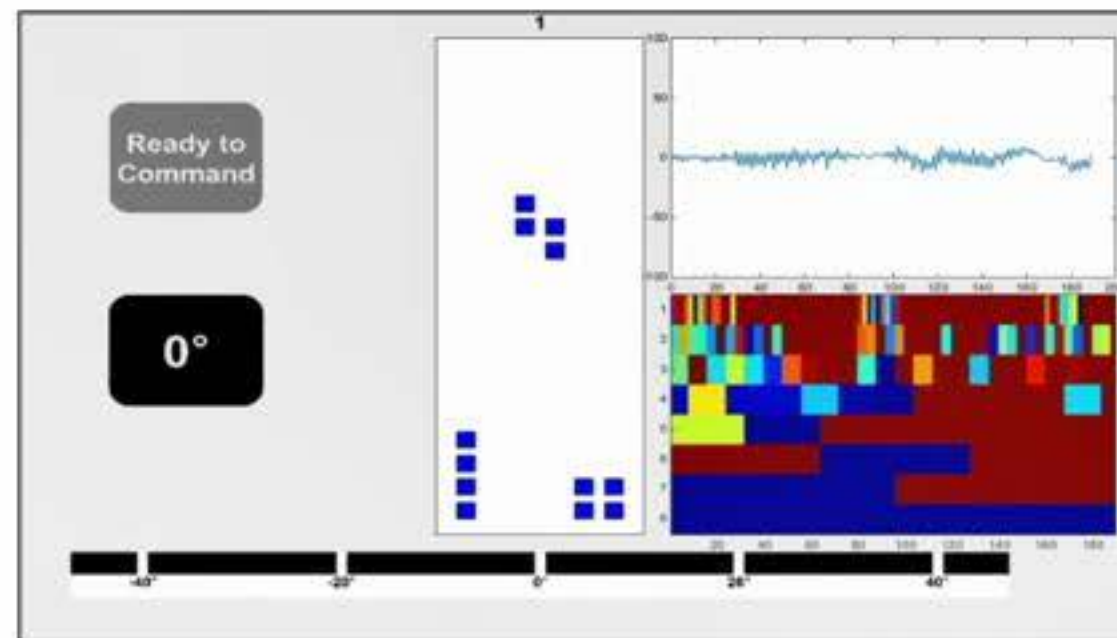


▪ HMI with Eyes activity (EOG signal)

Electrooculography (EOG) measurement



HMI application with EOG signal (Game control)



4. CONCLUSION

**Promising
Personalized head
worn devices for
practical healthcare
application**

**In-ear EEG
earphone &**

**Multi-functional
Smart Eyeglasses**

3D printed, Customizable design

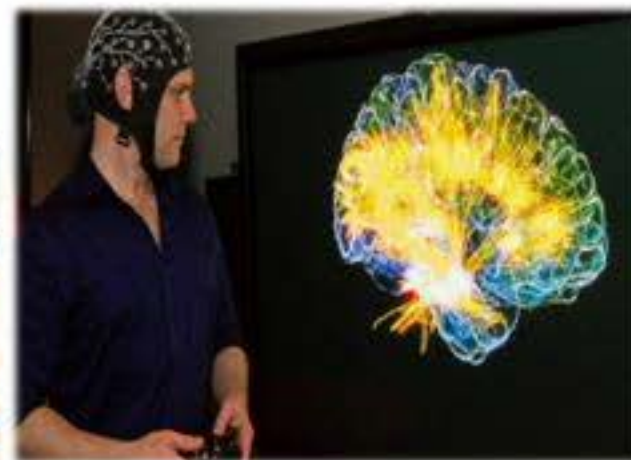
Simple, Convenience, Comfortable using

Reasonable appearance in daily life using

**Recording various health information from the head
(EEG, EOG, Movement, Radiation signal)**

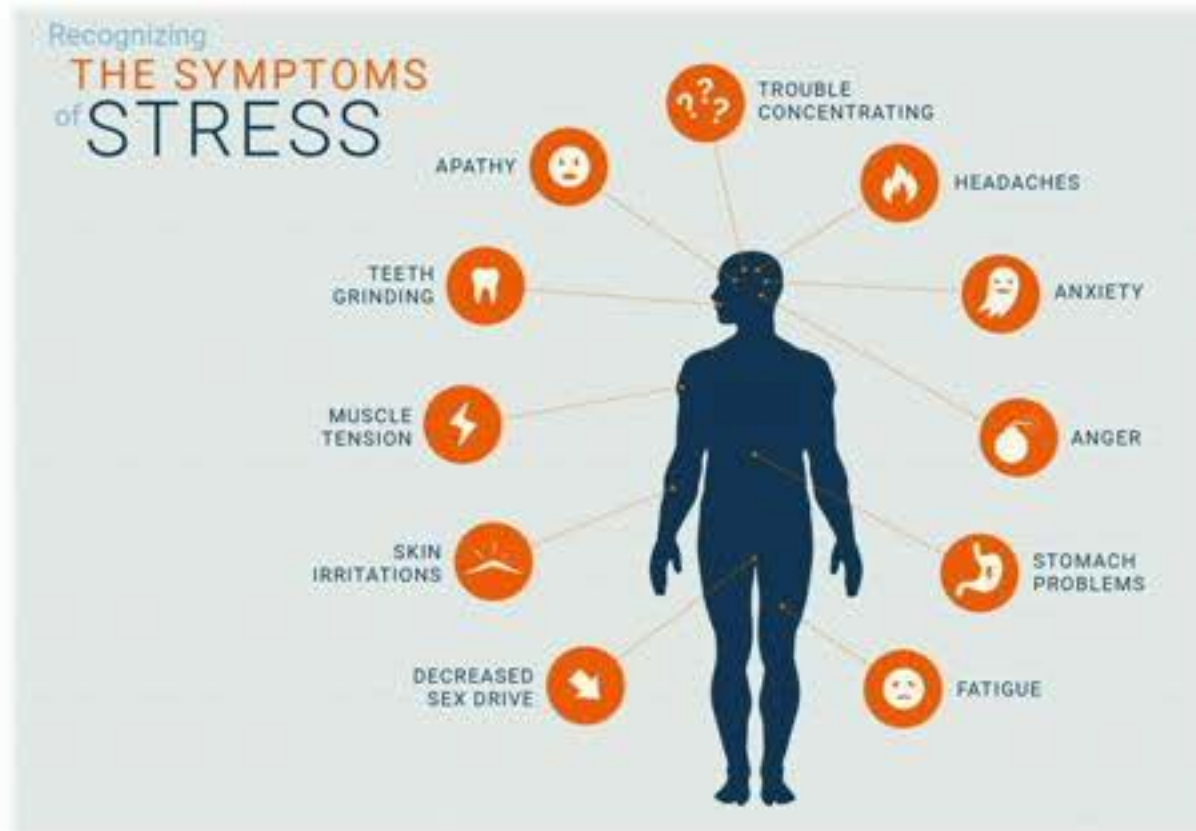
Fully wearable → Wireless measurement

Promising head-worn biosignal device for BCI & HMI applications



Intern Research Topic

■ Stress Detection with Biosignal



About **95 percent** of diseases are related to the stress.

More than **75 percent** of U.S. adults report having at least one symptom of stress.

-Survey from the American Psychological Association-



Intern Research Topic

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About **95 percent** of diseases are related to the stress.

More than **75 percent** of U.S. adults report having at least one symptom of stress.

-Survey from the American Psychological Association-



Stress level detector is highly required in our daily life!!

Intern Research Topic

COMMON FEATURES FOR PHYSIOLOGICAL STRESS DETECTION

Physiological signal	Feature	Explanation
ECG	Mean HR	Heart rate (mean)
	SDNN	Standard deviation of the R-R peaks
	RMSSD	Root mean square of the successive differences between R-R peaks
	pNN20	Percentage of successive normal sinus R-R intervals more than 20ms
	pNN50	Percentage of successive normal sinus R-R intervals more than 50ms
	HF	High frequency range of the R-R intervals (0.15 - 0.4Hz)
	LF	High frequency range of the R-R intervals (0.04 - 0.15Hz)
	LF/HF	Ratio of low versus high frequency ranges
	SD ₁	Crosswise standard deviation of the Poincaré plot
	SD ₂	Lengthwise standard deviation of the Poincaré plot
SC	SCL	Skin conductance level (mean)
	SCR duration	Skin conductance response duration
	SCR magnitude	Magnitude of the skin conductance response
	SCRR	Skin conductance response rate
	OPD	Ohmic Perturbation Duration: period during which a subject remains under stimulation effect and is measured from the start of the stimulus until the recovery initiates
EMG	RMS	Root mean square of the EMG signal
	Gaps	One or more segments (0.2-4 s) in a row with an RMS value below 5% of the RMS reference contraction
	Static load	10th percentile of rank-ordered RMS values
	Median load	50th percentile of rank-ordered RMS values
BP	Peak load	90th percentile of rank-ordered RMS values
	SBP	Systolic BP, pressure when the heart beats
Pupil	DBP	Diastolic BP, pressure between heart beats
	Pupillary dilation	Diameter of the pupil
Eye blinks	Frequency	Frequency of the eye blinks
	ST	Mean
SD		Standard deviation of the ST
Slope		Slope of the ST
Respiration	MeanRsp	Mean respiration frequency
	EB1	Spectral power density, summing the energy in band 0-0.1Hz
	EB2	Spectral power density, summing the energy in band 0.1-0.2Hz
	EB3	Spectral power density, summing the energy in band 0.2-0.3Hz
	EB4	Spectral power density, summing the energy in band 0.3-0.4Hz
EEG	Delta	0.5-3.5 Hz frequency range of the EEG signal
	Theta	4-7.5 Hz frequency range of the EEG signal
	Alpha	8-13 Hz frequency range of the EEG signal
	Beta	14-32 Hz frequency range of the EEG signal
	SEn	Sample entropy

Intern Research Topic

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Alpha		8-13 Hz frequency range of the EEG signal	
Beta		14-32 Hz frequency range of the EEG signal	
SEn		Sample entropy	

Intern Research Topic

■ Fully Wearable In-Ear Biometric Stress Detector



Commercial sports earphone



Earphone foam-factor wearable stress detector



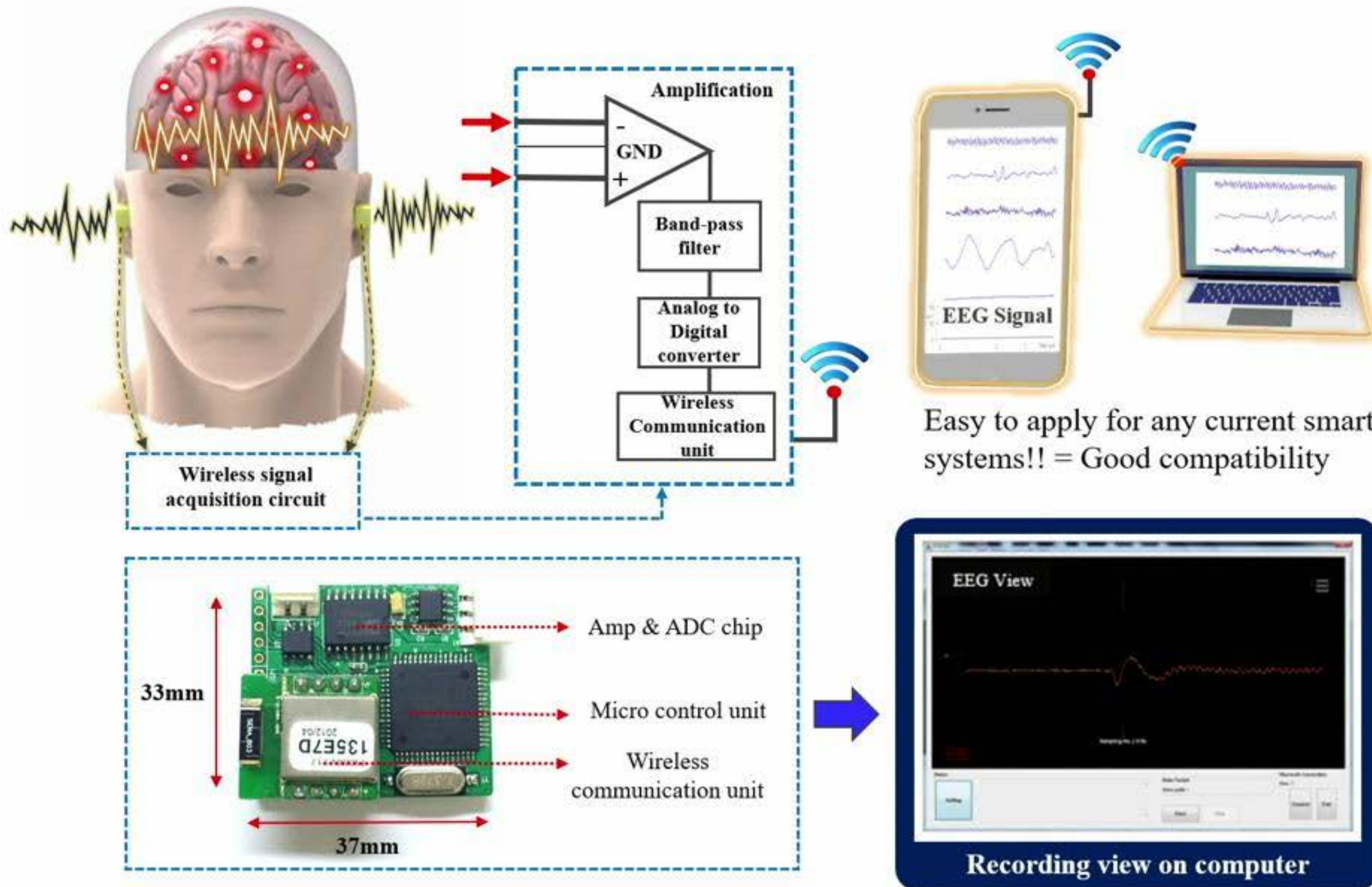
Stress level is **high** → "You need to rest" or Alarm with **LED** or **beep!!**

Joonghoon Lee (t-joolee@Microsoft.com)

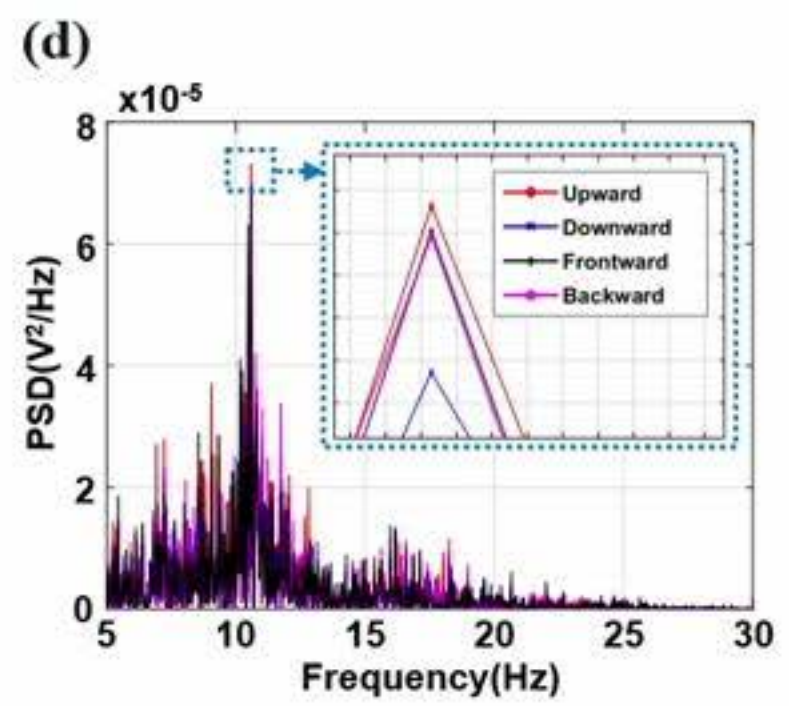
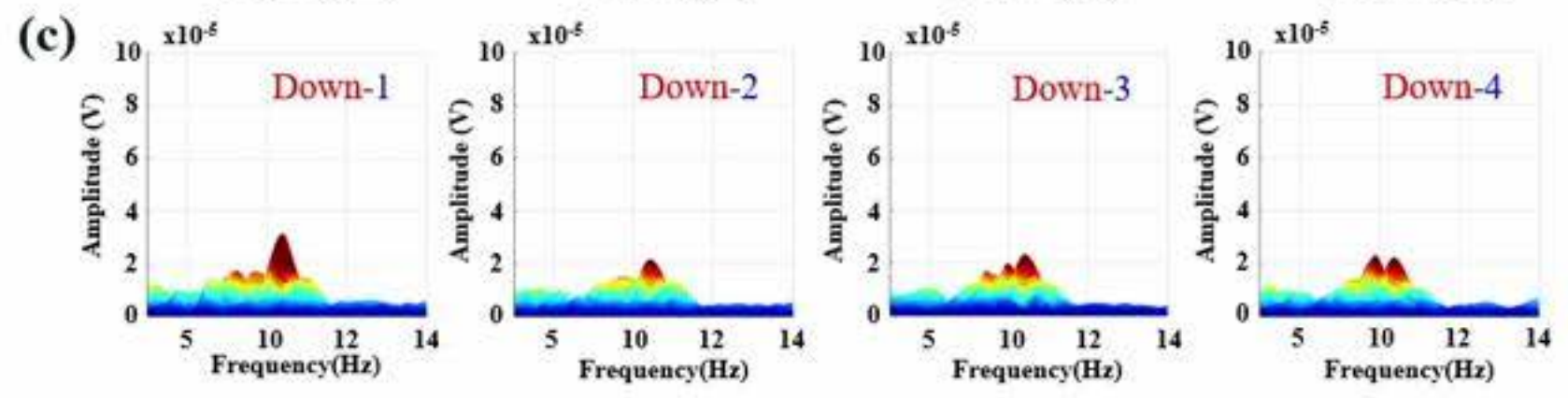
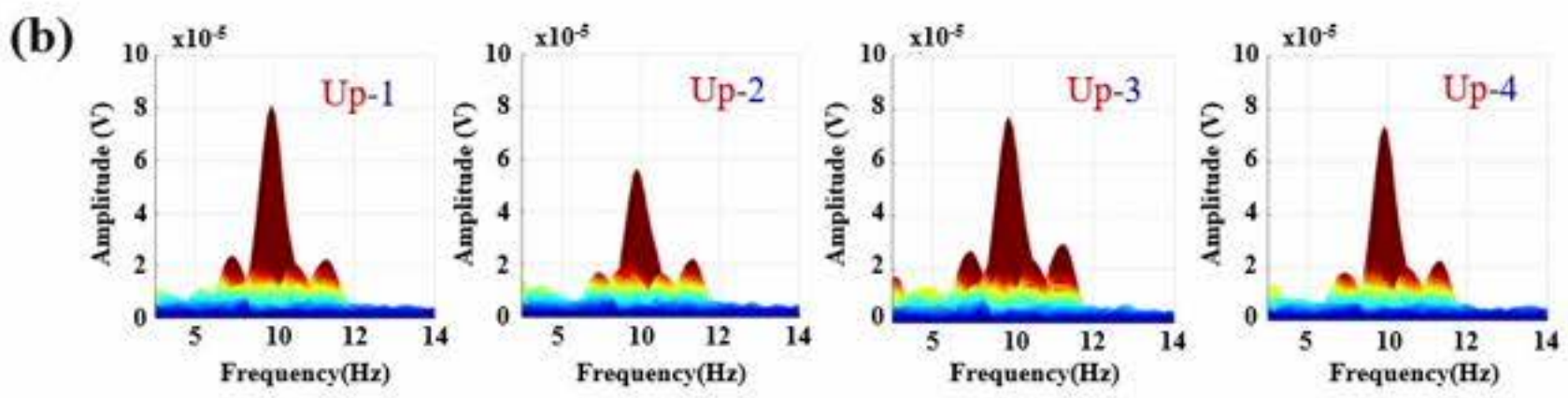
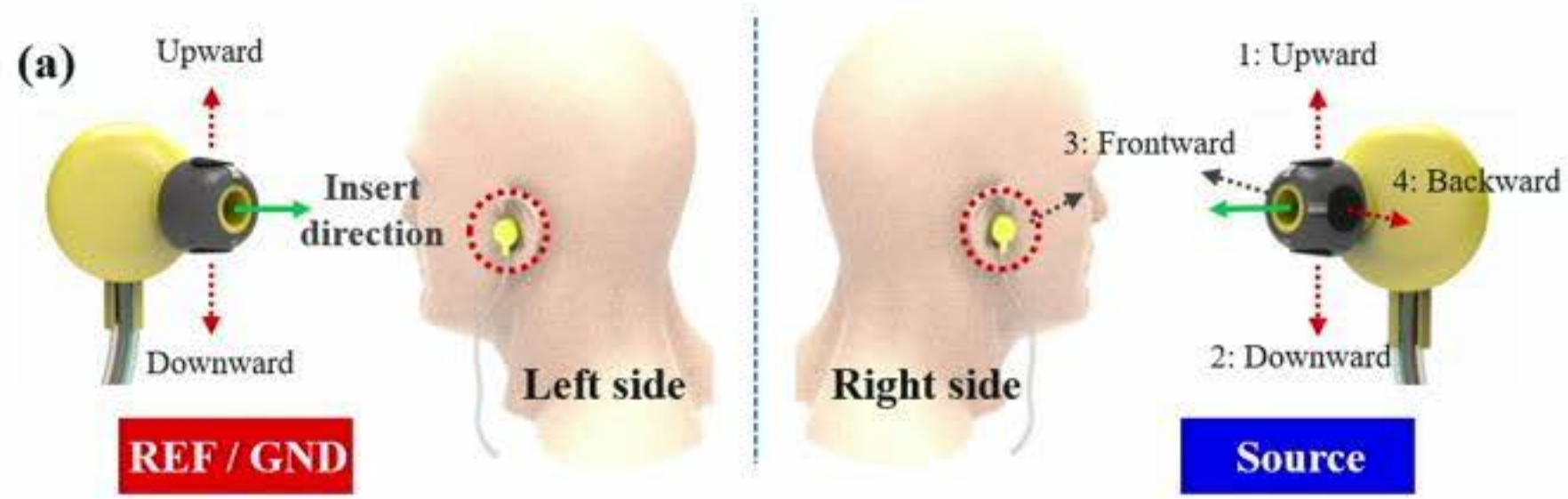
Thank you for listening

Joonghoon Lee (t-joolee@Microsoft.com)

➤ EEG Recording systems

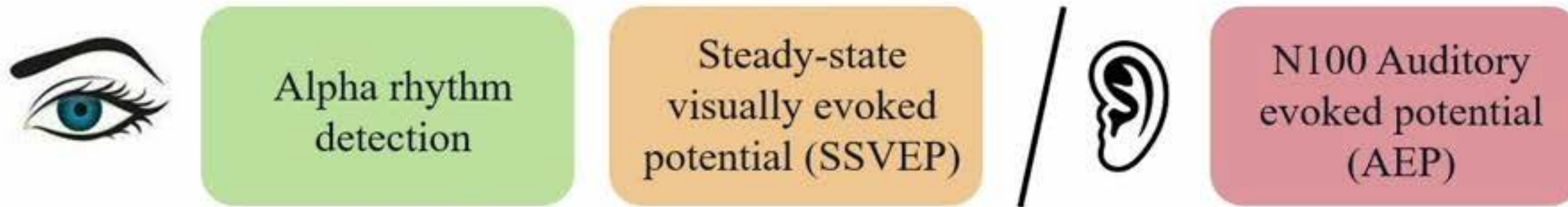


➤ Sensor position optimization test

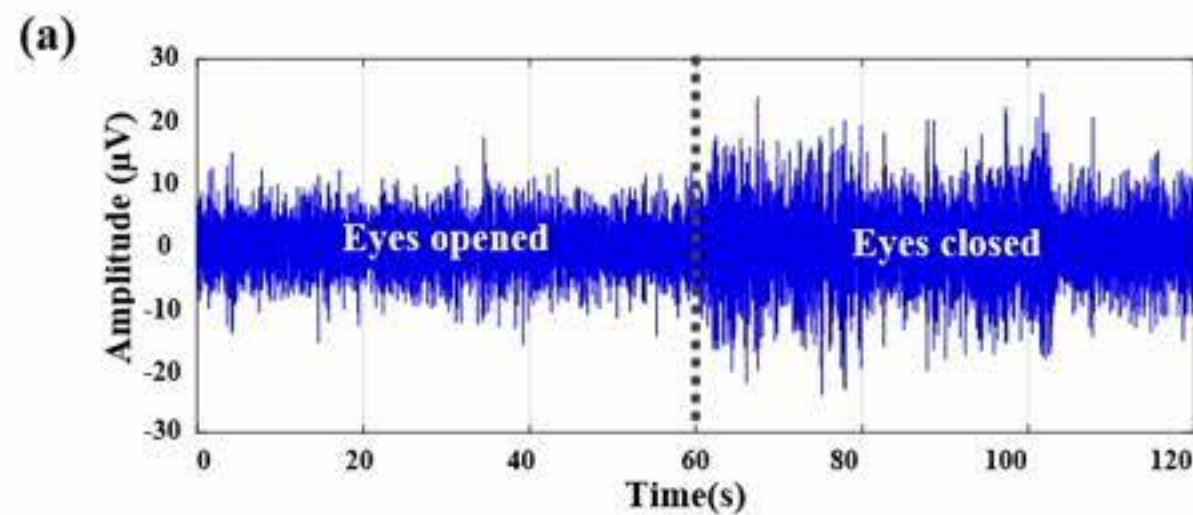


3.1 RESULTS

➤ Feasibility test



1. Alpha rhythm detection



- Alpha rhythm band = 8 ~ 14Hz
- The detection of alpha rhythms with a In-ear EEG Earphone and conventional type EEG electrodes for eyes open and closed.

