Improvement of SSVEP Detection Accuracy via Additive Averaging of Binaural Peripheral Electrodes

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Presenter's Information

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Details

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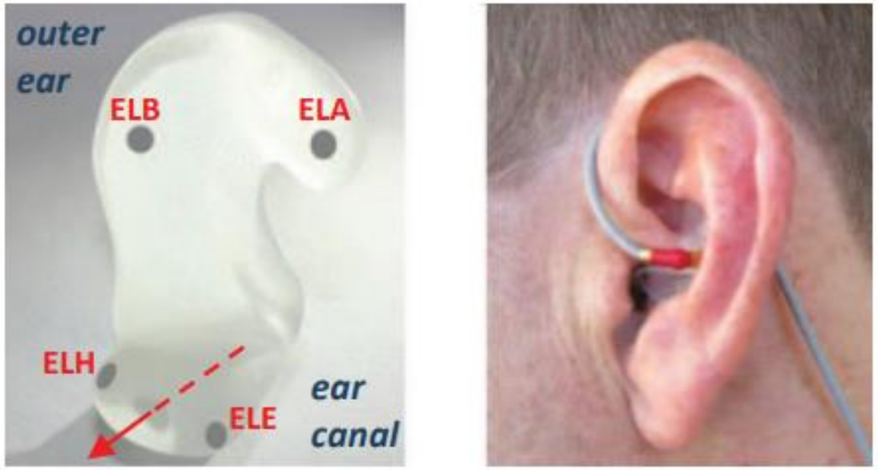
Keywords in my research

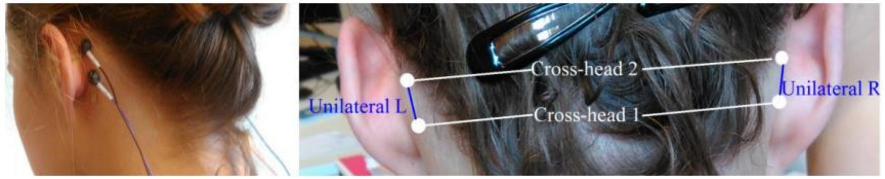
Electroencephalogram, Brain-Computer Interface, SSVEP, Ear-EEG, Neurofeedback, Deep Learning, P300

Ear-EEG

Recently, research on EEG measurement methods from sources other than the head, mainly from around and in ear, has been attracting attention.



Earpiece-type EEG device[1]



Behind-the-ear affixable device[2]

Accuracy of discriminating sleep state using EEG with head and in ear measurements [%][3]

Sleep state (896 *epochs*)		head	in ear
Wake		6.9	7.2
Rem Sleep		21.2	21.5
Non Rem Sleep	N1	1.5	1.3
	N2	40.0	45.3
	N3	30.5	24.7
Discriminant agreement rate between head and in ear		90.9 (769/846 *epoch*)	

[1] P. Kidmose et al., “Ear-EEG from generic earpieces: A feasibility study,” *35th AIC of the IEEE EMBS*, pp.543-546(2013)
[2] Y. Gu et al., “Comparison between Scalp EEG and Behind-the-Ear EEG for Development of a Wearable Seizure Detection System for Patients with Focal pilepsy”, *sensors*, vol.18(1), 29 (2017)
[3] I. Zibrandtsen et al., “Case comparison of sleep features from ear-EEG and scalp-EEG”, *Sleep Science*, vol.9(2), pp.69-72 (2016)

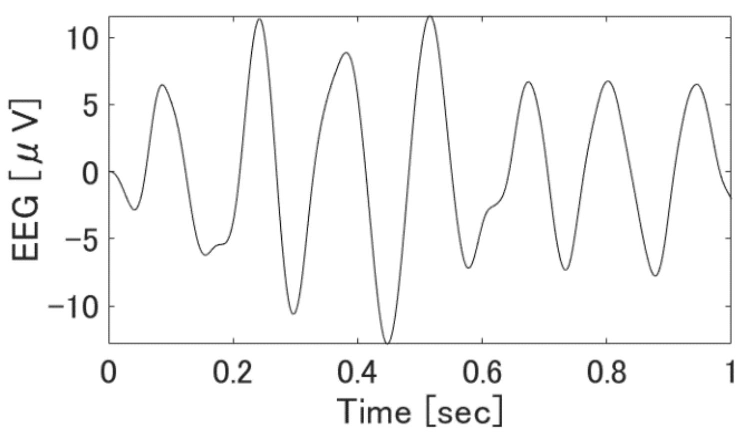
Steady-State Visual Evoked Potential (SSVEP)

Potential fluctuations evoked by visual flashing stimuli.

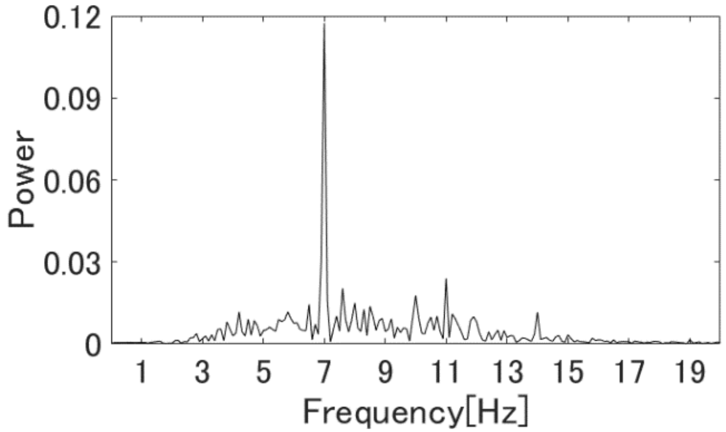
Evoked by repetitive stimulation above a certain stimulus frequency

Advantages of SSVEP

- High signal-to-noise ratio allows for quick detection
- Unlike other BCI systems, no training is required



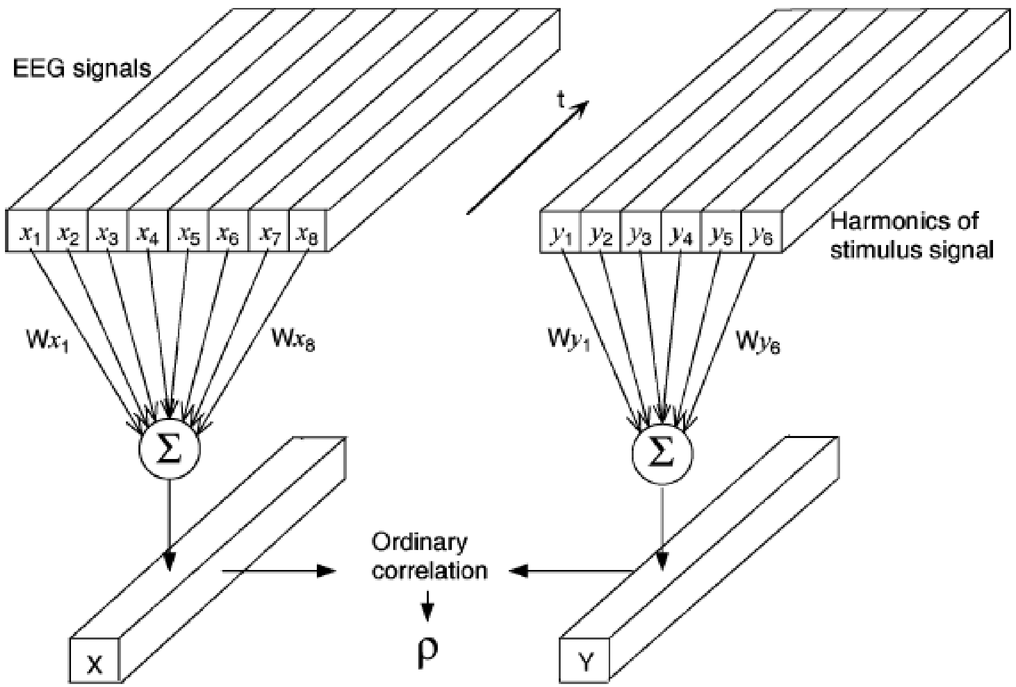
Example of time-series waveform of head during presentation of flashing stimulus (7 Hz)



Power spectrum of head during presentation of flashing stimulus (7 Hz)

Canonical Correlation Analysis (CCA)

A type of multivariate analysis to clarify the relationship between two variables by correlation coefficients.



Example of CCA[5]

$$y(t) = \left(\begin{array}{c} \sin(2\pi N_1 f t) \\ \cos(2\pi N_1 f t) \\ \sin(2\pi N_2 f t) \\ \cos(2\pi N_2 f t) \\ \sin(2\pi N_3 f t) \\ \cos(2\pi N_3 f t) \end{array} \right.$$

*: N1 is the same frequency as the visual flashing stimulus, and N2 and N3 are harmonics

Example of reference signal*[4]

[4] Z. Lin et al., “Frequency recognition based on canonical correlation analysis for SSVEP-based BCIs,” *IEEE TBE.*, vol.53(12), pp.2610-2614 (2006)

Purpose of this study

Problem

The amplitude values of measurements inside and around the ears are lower than those of head measurements, and it is considered difficult to improve accuracy significantly[5]

Purpose

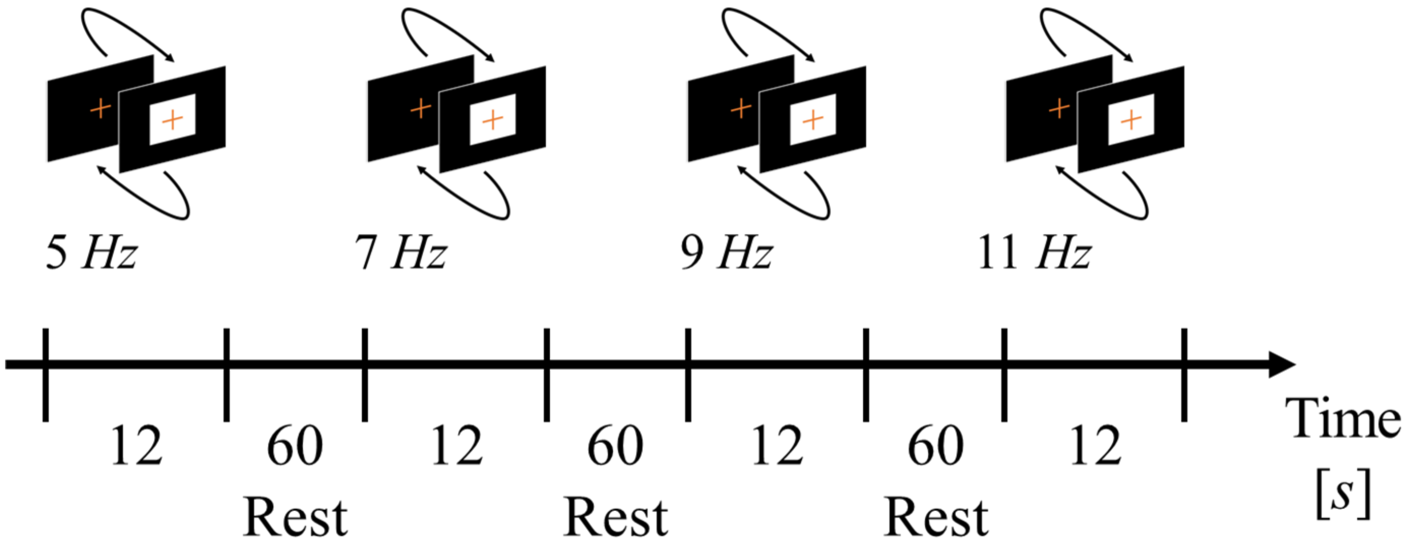
We attempted to create a new signal by applying electrodes to both ears and performing additive averaging of the EEG between the two ears. In addition, we will investigate the optimal location for detecting SSVEP from electrodes affixed around the ears when visual flashing stimuli are given. The performance of BCI is examined by comparing the unipolar induction EEG attached around the ears with the EEG obtained by the additive averaging method of binaural peripheral electrodes.

[5] C. Athavipach et al., "A Wearable In-Ear EEG Device for Emotion Monitoring," *Sensors*, vol.19(18), 4014(2019)

Methods

- Subject : 14 subjects (10 men and 4 women) were healthy (Mean ± SD : 21.87 ± 0.83 years)

Experimental protocol



The above protocol was used as one set, and two sets were performed.

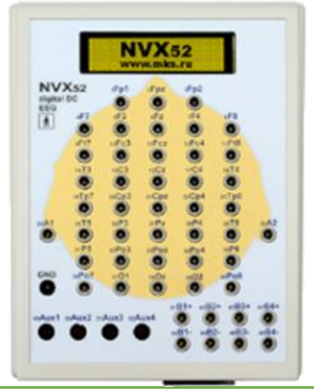
Measure

Measurement Item

Device : BIO-NVX 52 (East Medic, Japan)

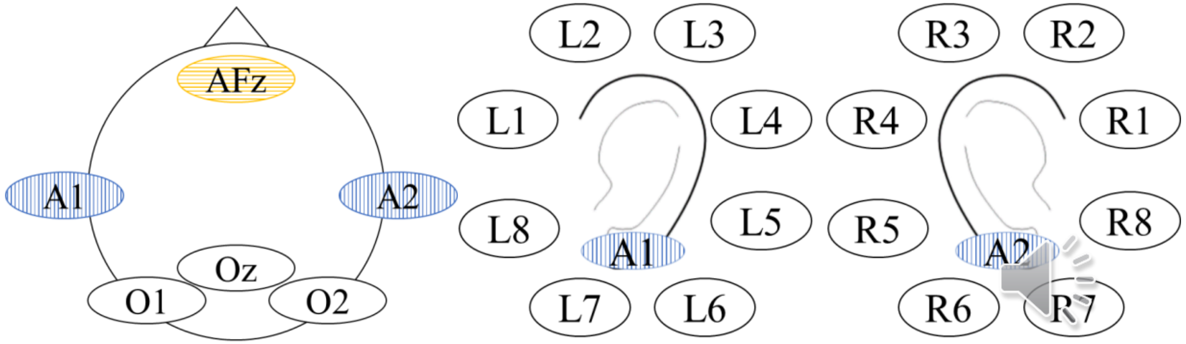
Sampling Frequency : 2,000 *Hz*

Band-pass filter : 0.5 — 70 *Hz*



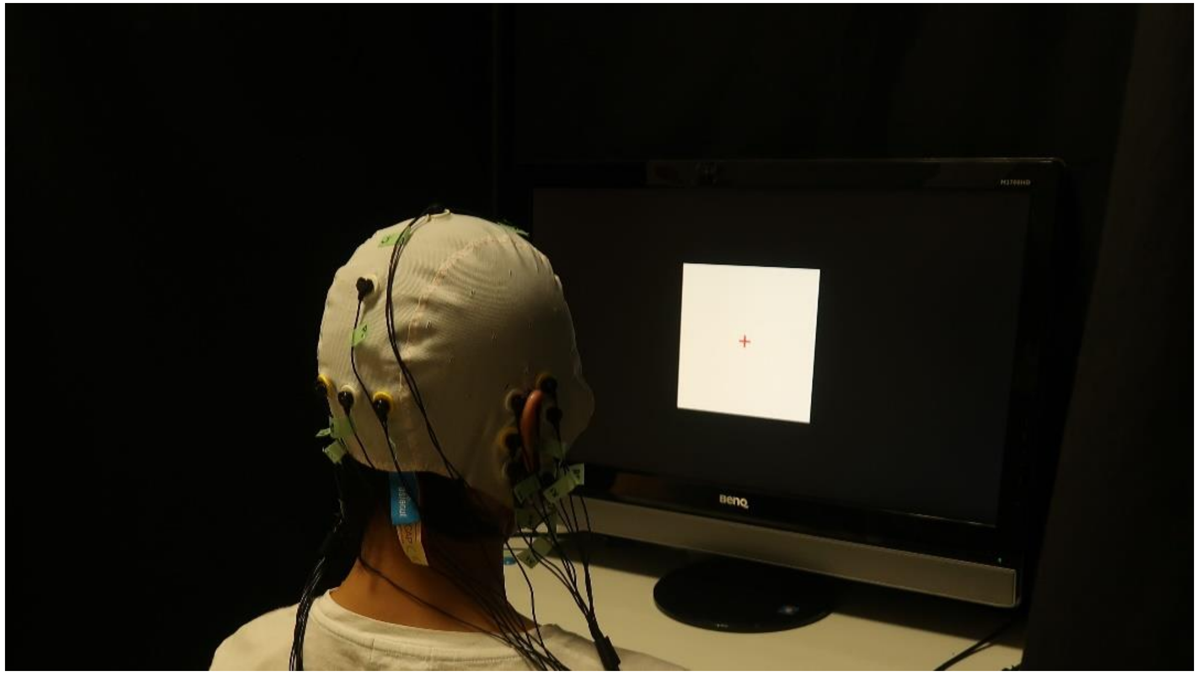
Electrode Positions

Electrode	: Oz, O1, O2, both ear arounds
GND	: AFz
REF (around left ear)	: left earlobe (A1)
REF (around right ear)	: right earlobe (A2)
REF (on head)	: mean of A1 and A2

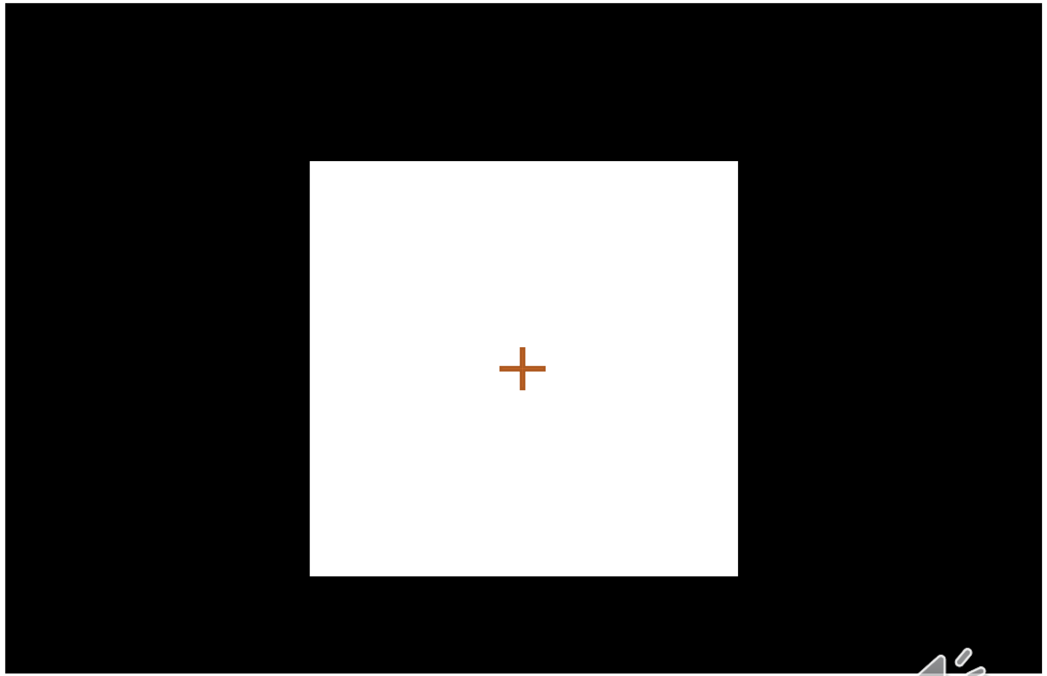


Visual flashing stimulus task

The display (27 inch) was placed 50 cm in front of the subject, and the subject was instructed to rest his eyes during breaks, to gaze at the crosshairs during stimulus presentation, and to limit eye blinking.



Experimental Scene

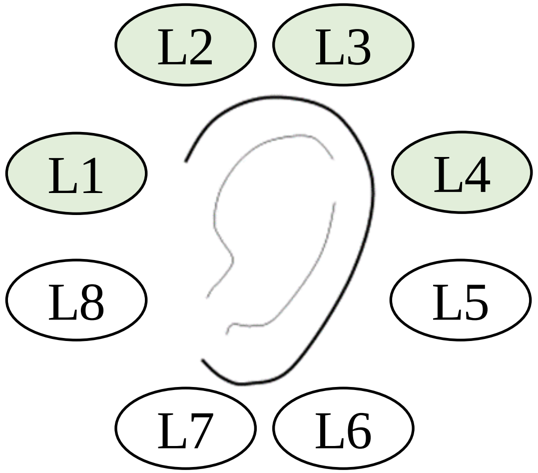


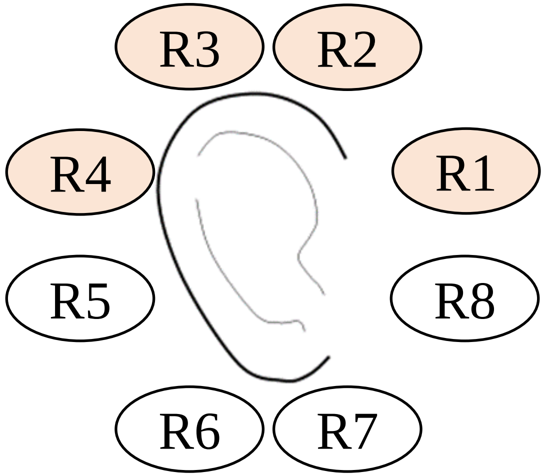
visual flashing stimulus

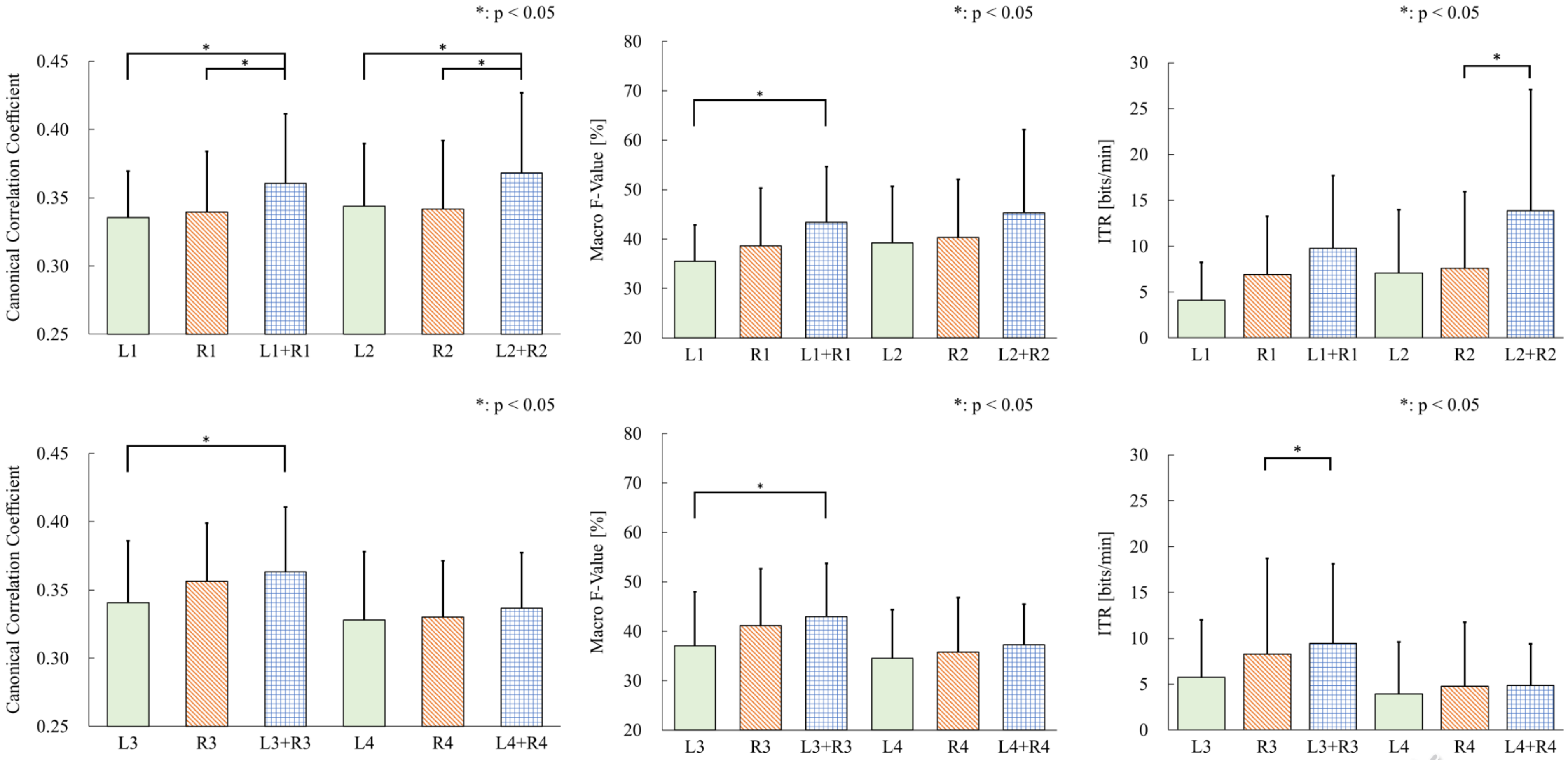
Analysis

Extracting data	Extraction of 1 second data length for use in CCA
Band-pass filter	Apply 4 - 35 Hz Band-pass filter
Normalization	Application of robust z-score to reduce the influence of left-right differences in amplitude values during measurement
Adding to both each ear position	Add and average data with identical left and right numbers around both ears
CCA	Calculation of Canonical Correlation Coefficient (CCC)

Results: upper of ear EEG



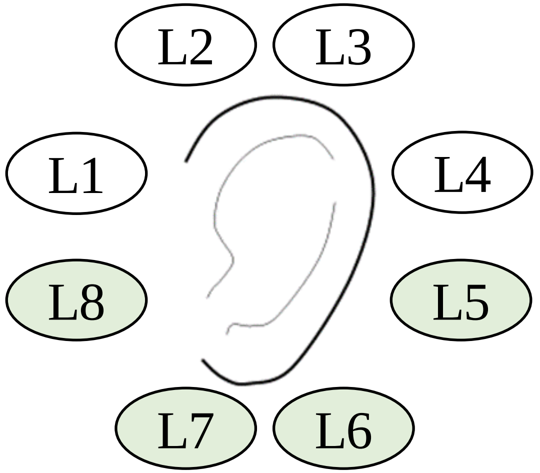


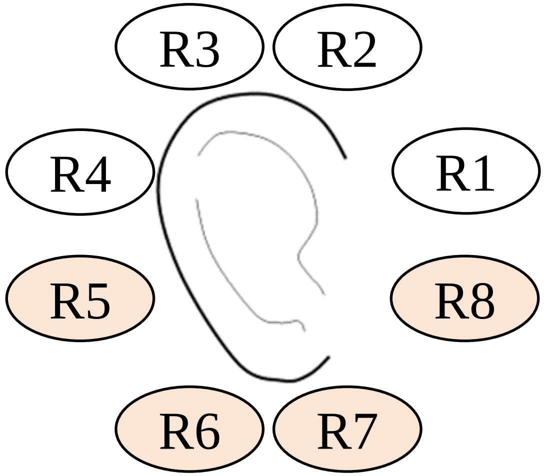


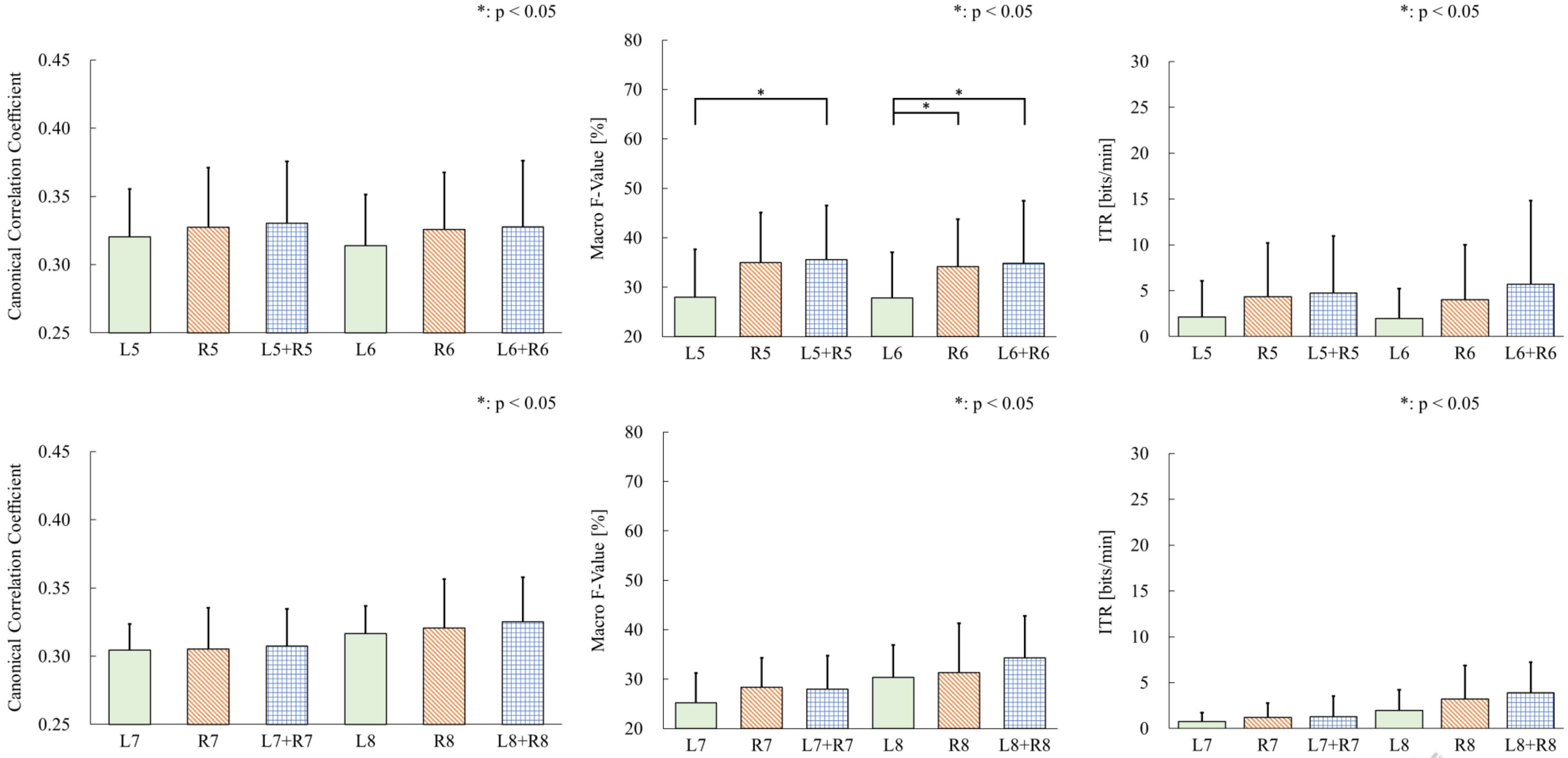
CCC, Macro F-values and ITRs for the upper ear (Mean ± SD)

When the results were added together, a **significant improvement** was observed in some cases

Results: lower of ear EEG



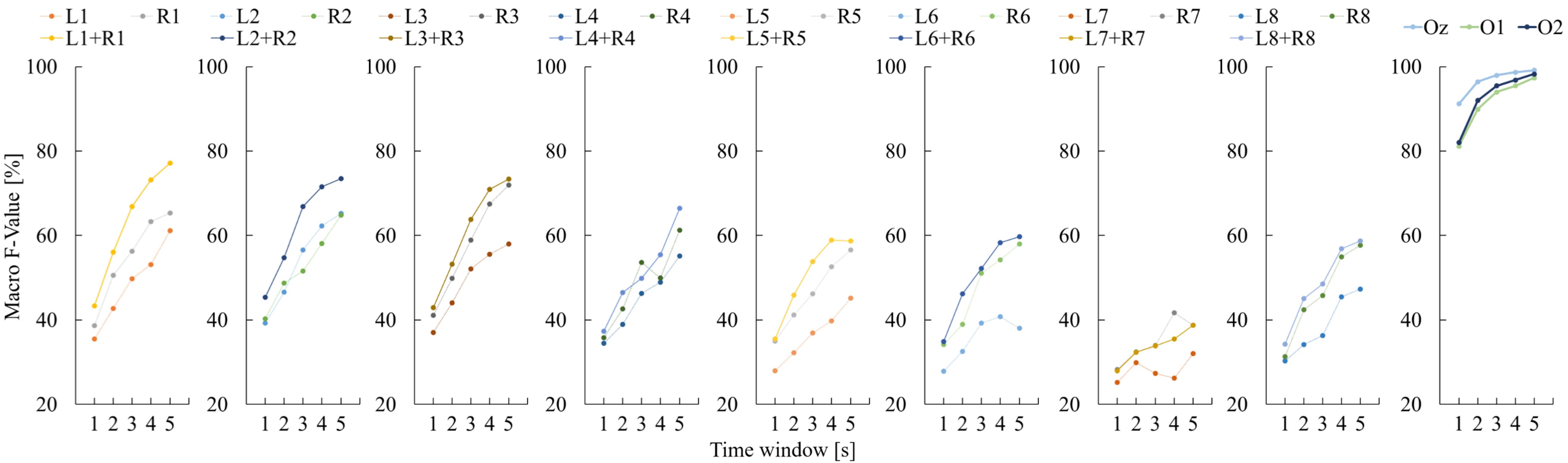




CCC, Macro F-values and ITRs for the lower ear (Mean ± SD)

Significantly higher results for electrode-to-electrode addition at **Macro F-value**

Discussion: Using Time window length



Each time windows of Macro F-values for the around ear and head (Mean)

- The addition and averaging of the electrodes attached to the control site yielded stable and high results
- The accuracy was overwhelmingly lower when compared to the head

Discussion: Benefits and Future Challenges

Usefulness when compared to previous study

Previous Study (Sun et al.[6])

- Accuracy was **43.75** % when the method was pre–trained with the participants' data.

In this study

- The estimated F-value was **45.33** % when the method **wasn't pre-trained** the data.

No learning required and **higher accuracy** than single channel induction

Future Issues

A large sample is needed because of the small number of subjects of 14 people and their young age

[6] Y. Sun et al., "Cross-subject fusion based on time-weighting canonical correlation analysis in SSVEP-BCIs," *Measurement*, vol.199, 111524(2022)

Conclusion

Purpose

The time-series data were compared with monopolar induction by holding the target sites around both ears and adding up the time-series data

Results

- The best CCC was 0.37 ± 0.06 of L2+R2
- The best Macro F-value was 45.33 ± 16.84 % of L2+R2
- The best ITR was 13.86 ± 13.22 *bits/min* of L2+R2
- Addition tended to be higher in the upper part of the ear

In the future

we will examine the detailed electrode placement, time window length, and algorithms to improve the accuracy of measurements around the ear

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