Brain Signal Processing: Quantification of Motor Imagery Ability in Sport via EEG Event-Related Potential

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Abstract

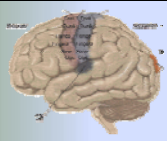
Using Electroencephalography Event-Related Potential (EEG-ERP) method for motor imagery (MI) ability analysis is suggested in this study. During actual movement (AM) or MI tasks, event-related desynchronization (ERD) of mu (8-13Hz) and β(18-25Hz) near primary motor cortex was found via trials averaging. MI has smaller ERD than AM, yet we may evaluate the vividness of the imagination by finding the correlation of MI and AM. The finding also implied the use of MI signal in Brain computed interface in the future practice.

Goal

-EEG feature extraction in both actual movement and motor imagery
-ERP Application: Ability of motor imagery in swimming ability quantification
-Real-time analysis of movement-related ERD real-time analysis

Experiment

Hardware: Single Channel of EEG headset




-Single electrode EEG
-C3 Channel in 10-20 International system
-Near the primary motor cortex.
-512Hz sampling frequency
-Transfer data to computer via Bluetooth

Fig1. Primary motor cortex and EEG headset

Experiment Setting: Neuroscience Research Paradigm

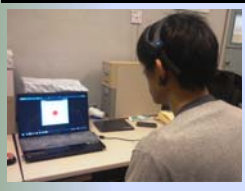
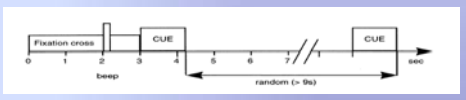



Fig2. (Left) The subject was directed to do the specific task.
(Right) Each session had 30 7s-duration trials.
Total 5 actual movement and 5 motor imagery sessions

Stage 1: Movement-related EEG feature extraction

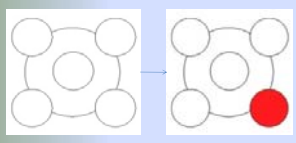
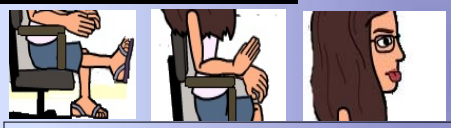
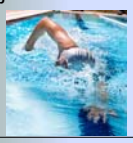
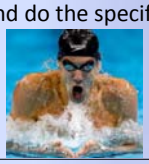



Fig3. Instruction to subject: red flash with beep sound in each trial.

Task: **Actual Movement** or **Imagination**		
Bottom	Upper	Central
Foot lifting	Hand raising	Tongue sticking out

Stage 2: Motor Imagery Application in Sport- Swimming

-Motor imagery ERP in sport science: Swimming movement
-Relationship between 'vividness' of motor imagery and EEG signal
-Subject instructed to imagine and do the specific swimming movement


Freestyle	Breaststroke	Back Stroke
Single hand -Left, right	Both hands, Single hand -Left, right	Single leg -Left, right

Motor Imagery → Actual Movement → Motor Imagery

Future Perspective

User-friendly movement-related EEG application: Real-time analysis

Eye Blink Artifact Removal: Adaptive Filter

Fig6. (left) Adaptive filter block diagram (middle) Eye blink template (right) Signal after filter

Association Area: Prefrontal lobe (F3 Channel)

	C3 Channel	F3 Channel
Pros	Near primary motor cortex	Dry electrode is available
Cons	With hair: need conductive gel	Association area is questionable

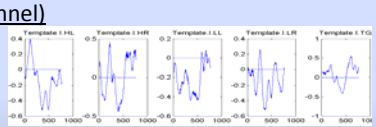


Fig7. Validation of association area

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Background

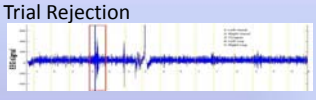
Movement Imagination

*I can **visualize** how I want the perfect race to go. I didn't have to fight the water. I could **feel** how I moved in it, how to be balanced. What might make me go faster or slower.*
(Michael Phelps, 22 Olympic medals winner)

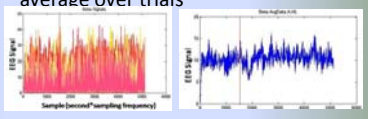
Motor Imagery means the imagination of movement which is applied in sport training and rehabilitation for motor skill improvement. The existing evaluation of imagination ability only bases on some questionnaires such as Sports Imagery Questionnaire (SIQ) and Vividness of Movement Imagery Questionnaire (VMIQ). However, this self-reported method is subjective depending on each individual subject. As a result, we tried looking at the brain signal and quantifying the motor imagery ability.

Data Analysis

1-Pre-processing:
Signal Epoch, Linear trends Removal
Trial Rejection

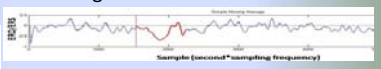


3-Ensemble Averages:
average over trials

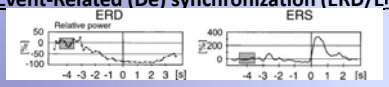


2-Band Pass: Finite Impulse Filter
EEG range: 0.5-45Hz
Movement related: ß-range(18-25Hz)

4-Linear Envelope:
Smoothing window



5-Event-Related (De) synchronization (ERD/ERS)



$$\mathrm{ERD/ERS} = \log\left(\frac{P_i}{R}\right)$$

where $P_i = \frac{1}{N}\sum_{i=1}^{N} y_{ij}^2$, $R = \frac{1}{k+1}\sum_{j=r_0}^{r_0+k} P_j$

6-Frequency-Time Analysis: Welch's power spectral density estimate

Result

Stage 1:

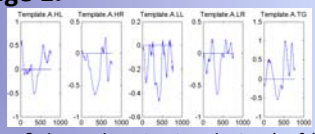
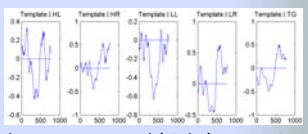



Fig4. β desynchronization during (Left)actual movement and (right) motor imagery

Stage 2:

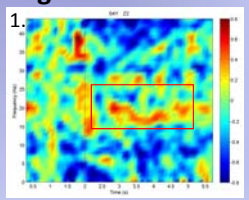
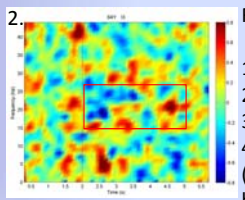
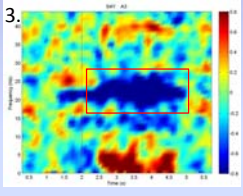
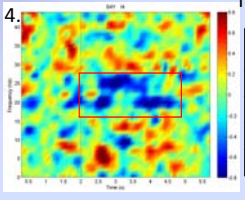





Fig5. ERD/ERS - time-frequency graph
1. Baseline (Z)
2. 1st Motor imagery (I1)
3. Actual Movement (A)
4. 2nd Motor Imagery (I2)
(Swimming- Freestyle left hand movement in a subject)

Correlation of tasks	r	p
A & Z	-0.0097	0.72
A & I1	0.3004	**<0.001**
A & I2	0.3829	**<0.001**
I1 & I2	0.3491	**<0.001**

Conclusion

The study suggested an EEG application in sport science to evaluate the MI ability. ERD correlation between AM and MI motor imagery implies the vividness of the imagination. As for the user-friendly practice in the future, the sensor location and real-time analysis should be taken into account.

Reference

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