Identifying Children with Developmental Coordination Disorder Using Motor Imagery-based Functional Connectivity Features

基於運動想像任務的功能性連接特徵辨識發展協調障礙兒童

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1 Background

Developmental Coordination Disorder (DCD) affects approximately 5-6% of school-aged children, leading to poor motor skills and impairing daily life activities. Traditional diagnosis methods rely heavily on behavioral assessments, such as the Movement Assessment Battery for Children (M-ABC2)[1], which lack a neuroscience-based foundation. Recent research has confirmed that Motor Imagery (MI) training can help children with DCD improve their motor skills. Concurrently, Brain-Computer Interface (BCI)[2] have emerged as innovative diagnostic in neurodevelopmental disorder research, and EEG-based functional connectivity analysis[3] represents a promising approach within these frameworks.

Keywords:
- Developmental Coordination Disorder
- Motor Imagery based Brain-Computer Interface
- Functional Connectivity

2 Objectives

This study aims to:

1. Develop a MI-BCI system for identifying children with DCD
2. Validate the efficacy of Motor Imagery-based Functional Connectivity as a discriminative feature in TD/DCD classification
3. Establish a neuroscience-informed, objective diagnostic methodology for DCD

3 Methodology

Participants
- 57 TD (M-ABC2: 78.6±7.4), 23 DCD (M-ABC2: 48.0±12.7)
- Age: TD (10.4±0.9), DCD (10.3±0.7)
- Ethically approved by NTHU IRB (11004HT042)

EEG Data Collection
- equipment: Curry 8, Neuroscan Synamps 2, 30-channel Quik-Cap
- Sampling rate: 1000 Hz, 24-bit A/D conversion

Figure 1. Experimental Paradigm

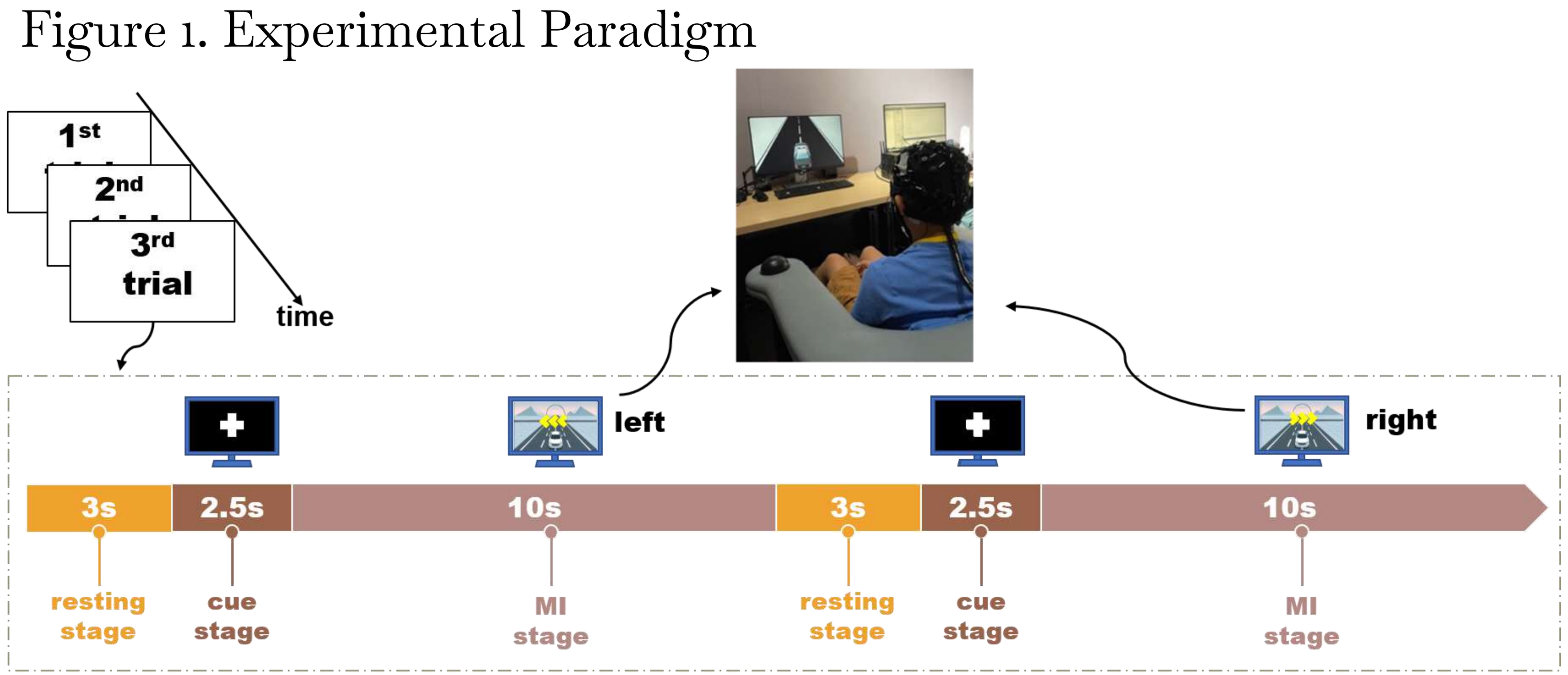
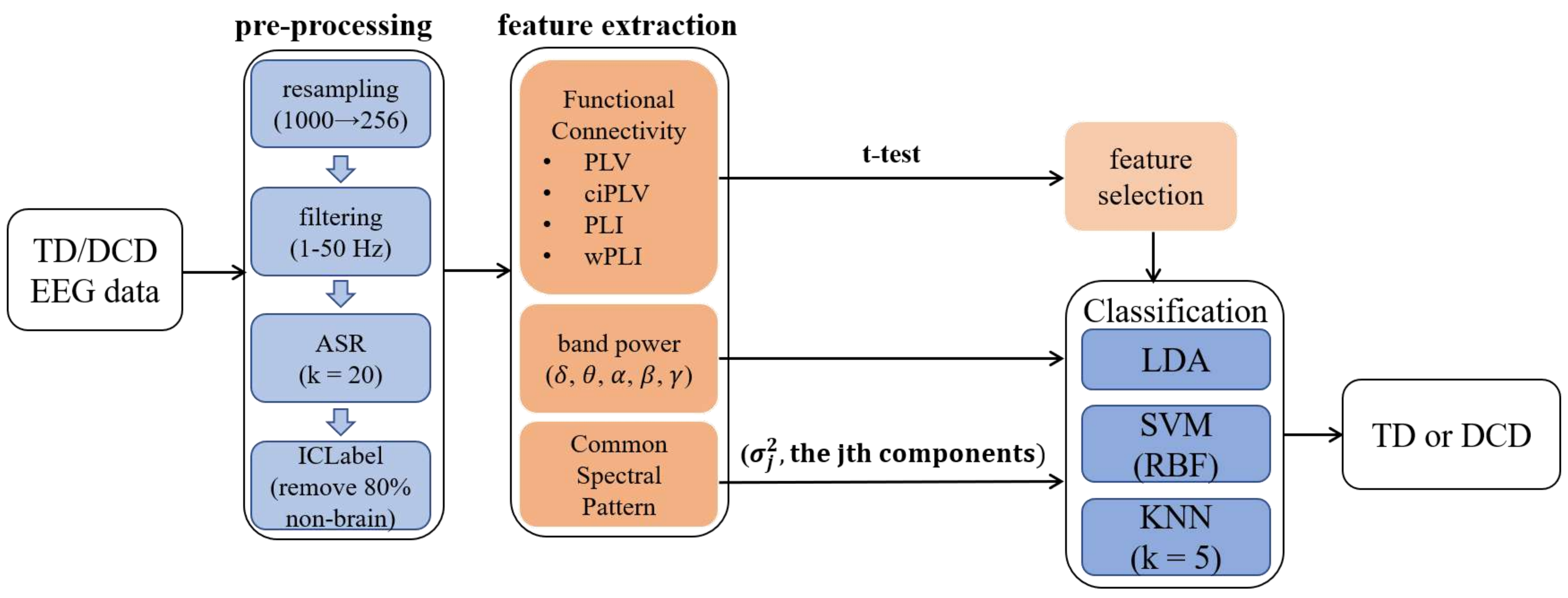


Figure 2. MI-BCI System Overview



4 Results

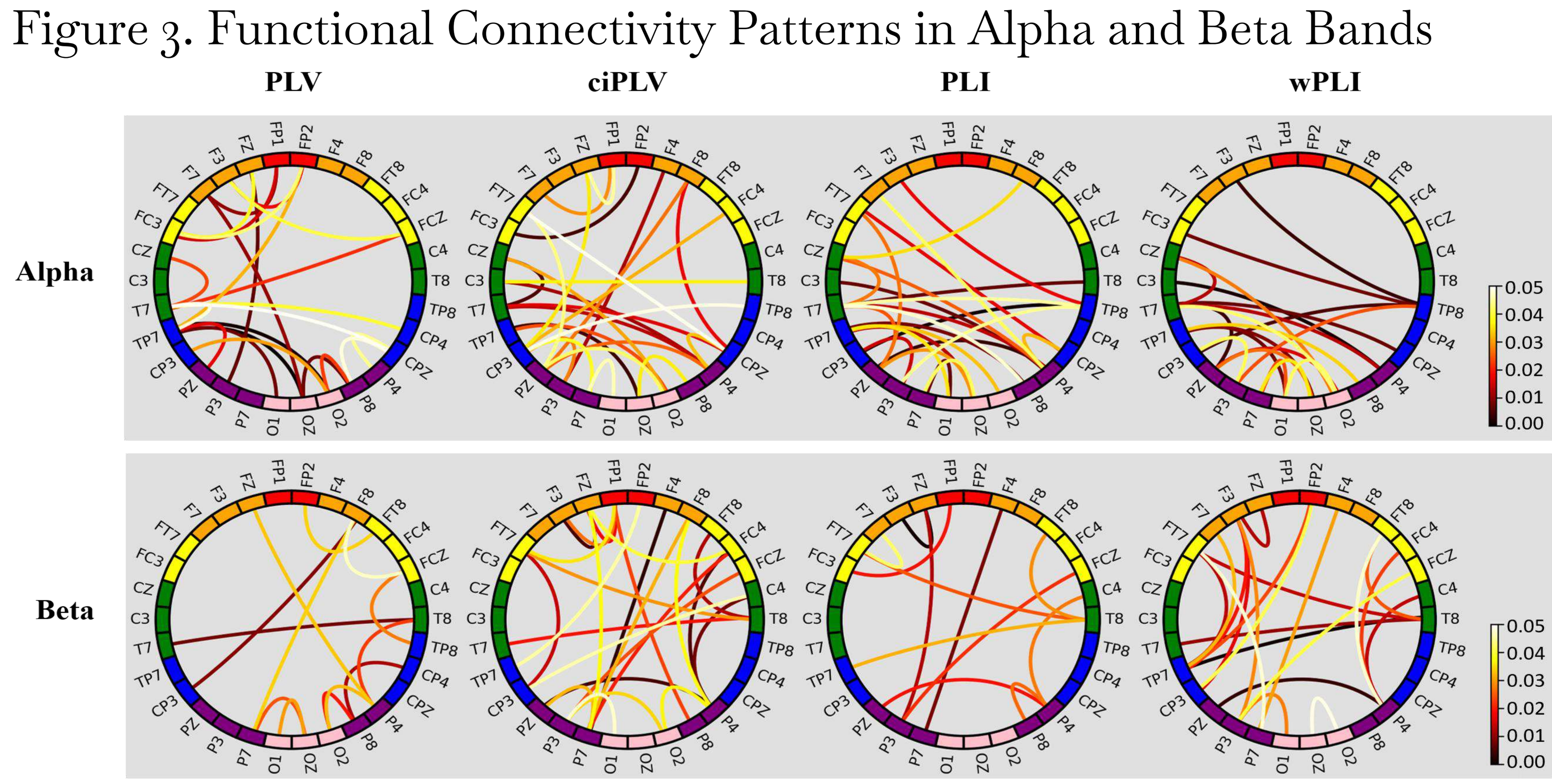
Among the tested features, Mu and Beta functional connectivity demonstrated the highest classification performance across models, with an accuracy of 0.89±0.03 and F1 score of 0.85±0.04 (Table 1) using the SVM classifier.

As shown in Figure 3, these connectivity patterns in Mu and Beta bands exhibited significant differences ($p < 0.05$) between DCD and TD groups, particularly in the contralateral motor-related cortical regions during right-sided MI tasks.

Table 1. Accuracy and F1 Score of Different Features

Features		LDA	SVM	KNN
CSP	-	0.58±0.03 *(0.20±0.12)*	0.58±0.03 *(0.27±0.12)*	0.54±0.05 *(0.23±0.13)*
Band Power	Mu	0.64±0.06 *(0.50±0.09)*	0.58±0.02 *(0.08±0.08)*	0.55±0.05 *(0.41±0.08)*
	Beta	0.62±0.07 *(0.48±0.10)*	0.58±0.03 0.06±0.07	0.55±0.05 *(0.42±0.07)*
Functional Connectivity	Mu	0.76±0.04 *(0.71±0.04)*	0.87±0.02 *(0.83±0.03)*	0.81±0.02 *(0.76±0.03)*
	Beta	**0.85±0.02** ***(0.81±0.03)***	**0.89±0.03** ***(0.85±0.04)***	**0.83±0.04** ***(0.79±0.05)***

Figure 3. Functional Connectivity Patterns in Alpha and Beta Bands



5 Conclusions

This study developed a MI-BCI system that effectively identifies children with DCD through functional connectivity patterns, achieving high classification performance. The significant differences in Mu and Beta connectivity between DCD and TD groups establish a promising foundation for an objective, neuroscience-informed diagnostic approach. Future work will focus on validating these findings in larger datasets and exploring the potential of this system for early intervention assessment.

6 References

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