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# A Novel Rhythmic Motor Imagery BCI with High Efficiency

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***Introduction:*** Conventional motor imagery (MI) tasks are often abstract, and the current decoding performance of MI-BCIs remains suboptimal. In our previous work, we demonstrated that both rhythmic movements [1] and rhythmic MI [2] can elicit brain activity at the task rhythm and its first harmonic. This novel electrophysiologic feature, which we summarized as steady-state movement-related rhythms (SSMRR), has been shown to facilitate higher decoding accuracy compared to conventional sensorimotor rhythm (SMR)-based decoding. Here, we aim to provide a preliminary validation that this more concrete rhythmic MI paradigm, with the SSMRR feature, can serve as a foundation for developing an efficient online BCI system even for naïve users.

***Materials and Methods:*** Thirty BCI-naïve subjects participated in the experiment (average age 22.03± 3.40 years, all right-handed, 15 female). Four kinds of rhythmic MI tasks (1.0Hz-Lefhand, 1.2Hz-Righthand, 1.4Hz-Lefthand, 1.6Hz-Righthand) were arranged in a block-randomized manner. As shown in figure 1(A), the subjects were instructed to perform rhythmic MI in sync with the video (as if they were controlling the hand in the video). Notably, we informed the subjects that they could associate themselves with the hand on the screen instead of explicitly imagining a hand in their mind, thereby reducing the cognitive load. The experiment consisted of three sessions, each comprising three runs with 40 trials per run. The offline session 1 followed the same design as in our previous work [2]. Session 2 and 3 were designed as online target-selection tasks. Task-discriminant component analysis (TDCA) [3] was employed for online decoding. The data from session 1 was used for initial TDCA training, and after each subsequent run, new data was integrated into the training process. Details of the offline electrophysiologic analysis followed the same methodology as in our previous work [2].

***Results and Discussions:*** As shown in figure 1(B), temporal and spectral-spatial patterns during the task can be clearly observed. By the end of the experiment, 30 BCI-naïve users achieved an average online accuracy of 79.33%±12.85% in the 4-class classification task (figure 1(C)). At the beginning of session 2, the accuracy was relatively low, primarily due to differences in paradigms between sessions. As new training data was accumulated in subsequent runs, the accuracy gradually improved.

***Significance:*** Based on the rhythmic MI paradigm and the SSMRR feature, we achieved nearly 80% accuracy in four-class online motor decoding among 30 BCI-naïve subjects. This novel BCI holds great promise as a new approach for device control and motor rehabilitation.

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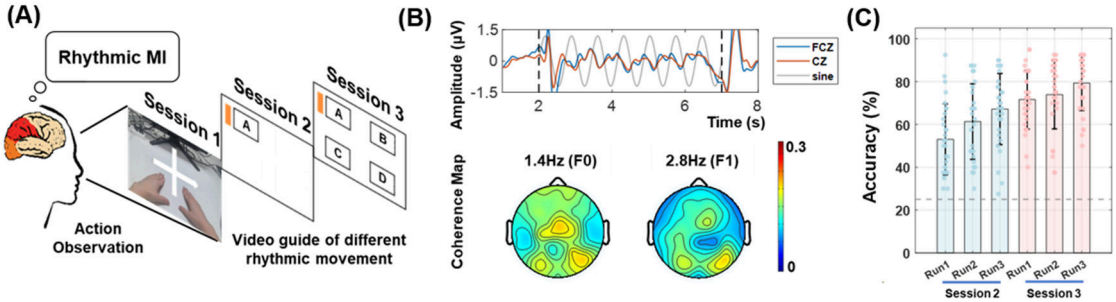


***Figure 1.*** **(A)** *The experimental paradigm. A/B/C/D represent video guides of four different rhythmic movements.* ***(B)*** *The group-level time-series of two selected channels and whole-brain coherence topology of the 1.4Hz-Lefthand MI task in session 3. The black vertical dashed lines in the upper figure indicate the begin and the end of the rhythmic MI. The sine wave at the task-related rhythm (the grey curve) was given as a reference.* ***(C)*** *The 4-class online decoding accuracies. The circular markers represent individual subjects, while the error bars indicate the standard deviation. The grey horizontal dashed line indicates the theoretical chance level (25%).*

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