BCI Assistance in Simple Hand Movements to Enable IMC/CMC-Based Rehabilitation for Post-Stroke Patients

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Objective

Utilize intermuscular coherence (IMC) and corticomuscular coherence (CMC) as features to an online BCI for the purpose of developing a motor rehabilitation therapy for stroke survivors.

Background

- In recent years work has been done on the addition of alternative signals such as EMG to traditionally EEG based brain machine interfaces (BCI's). These are known as hybrid BCI's.
- Intermuscular coherence (IMC) and corticomuscular coherence (CMC) are measures of connectivity and synchronization of neural pathways within the body and are calculated using the cross power spectrum of EEG-EMG or EMG-EMG pairs.
- In particular, according to Colamarino et. al. 2021, CMC and IMC show promise in classification for post-stroke motor rehabilitation

Methods

- Binary classification was done on hand open/hand closed movements
- Recording of EEG signals was done according to the 10-20 international system, and EMG signals were be recorded for extensor digitorum and flexor digitorum superficialis muscles
- IMC and CMC were calculated and averaged over 3 frequency bands (alpha, beta, gamma)
- A k-nearest neighbors model was utilized to classify selected features into the two movement classes

$$\text{CMC}_{xy}(f_j) = |S_{xy}(f_j)|^2$$

$S_{xy}(f_j)$ = cross-power spectrum
f_j = characteristic frequency

$$\text{IMC}_{xy}(f_j) = \frac{|S_{xy}(f_j)|^2}{|S_{xx}(f_j)| \cdot |S_{yy}(f_j)|},$$

$S_{xy}(f_j)$ = cross power spectrum
$S_{xx}(f_j)/S_{yy}(f_j)$ = autospectra of muscle signals

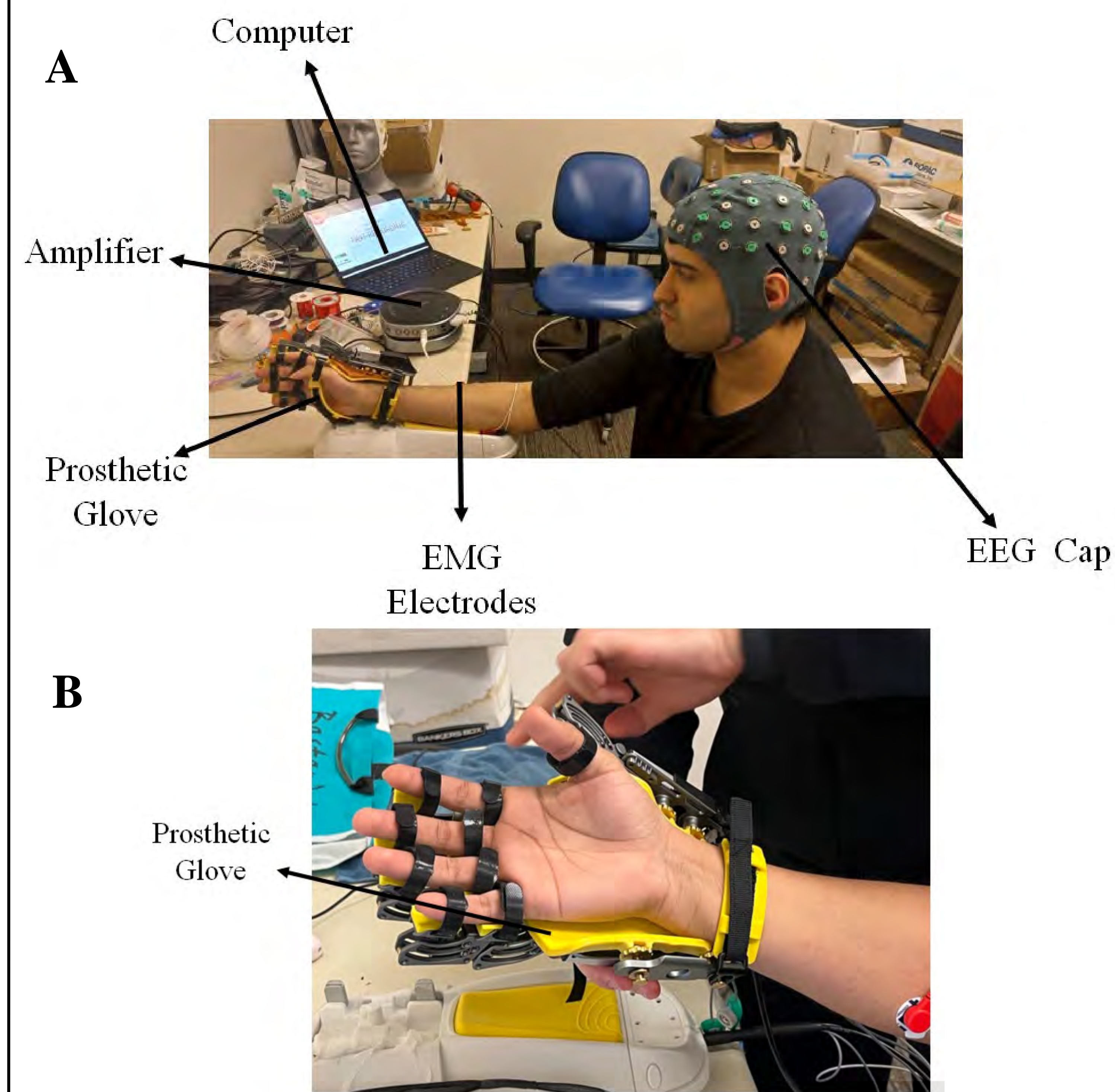*Figure 1. Equations used to calculate the IMC and CMC off different EMG-EMG and EEG-EMG pairs*

Figure 2. Testing of the BCI in real time
A. The full BCI setup including the exoskeleton hand, EEG cap, EMG electrodes, Amplifier, and computing device (laptop)
B. "Hand of Hope" Exoskeleton hand from Rehab-Robotics Company Ltd.

Hand exoskeleton was utilized in order to assist hand closed movement and complete proprioceptive feedback loop

Results

- **Utilizing both IMC and CMC the model was able to classify between flexion/rest and extension/rest with 95 100% accuracy**
- **Utilizing IMC, the model was able to distinguish between flexion and extension with a validation accuracy of 80.4% and a test accuracy of 83.3%**
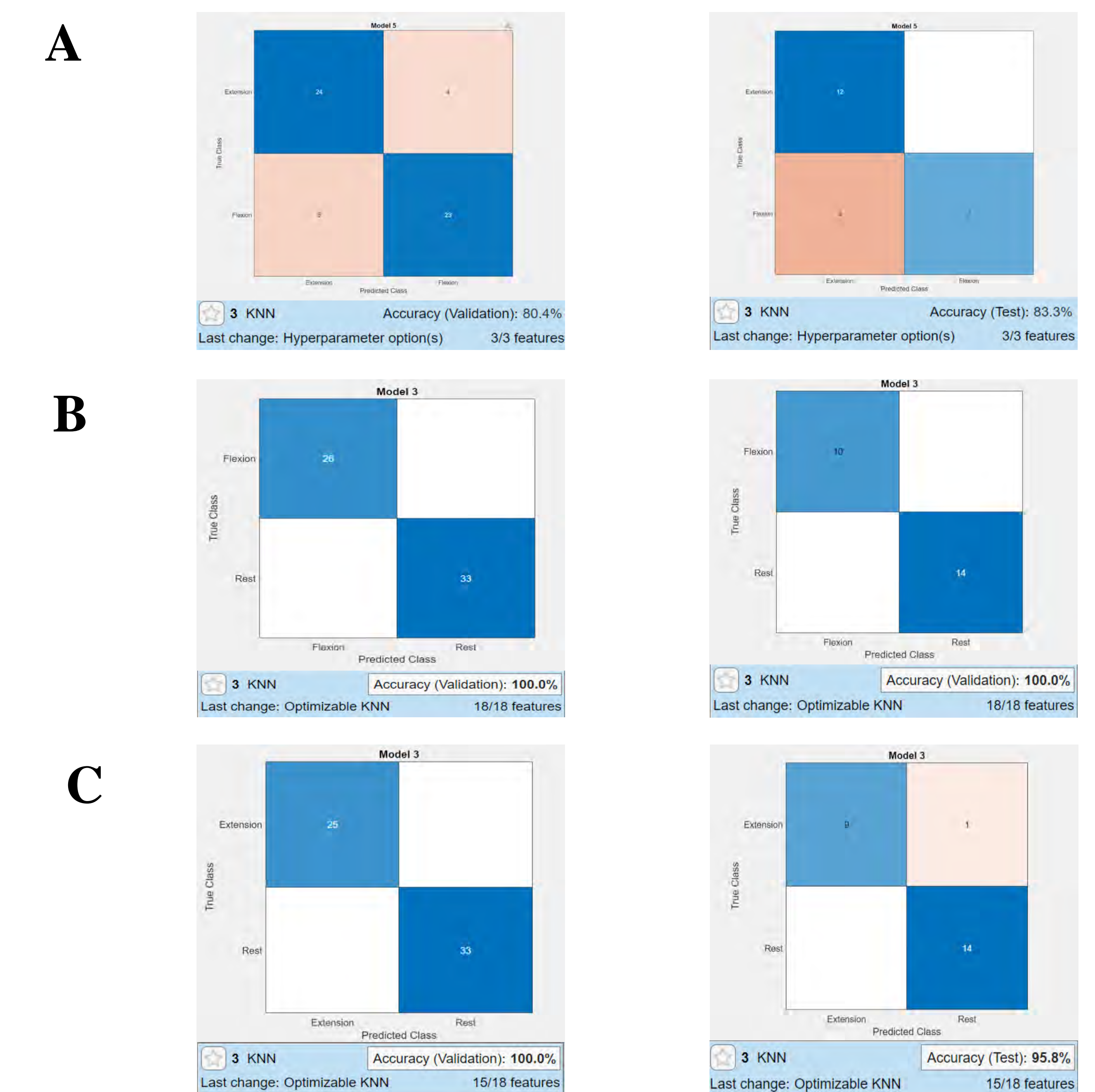

Figure 3. Validation and testing confusion matrices for extension/flexion (A), flexion/rest(B), extension/rest(C)

Conclusion

- **The BCI was able to successfully utilize IMC to classify extension/felxion movements to a reasonable degree of accuracy**
- **Further studies should be done on the use of CMC in this specific application. In particular the positioning and relaxation of the hand/arm may need to be adjusted.**