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A non-invasive EEG-based Brain-Machine Interface for the control of myoelectric prostheses

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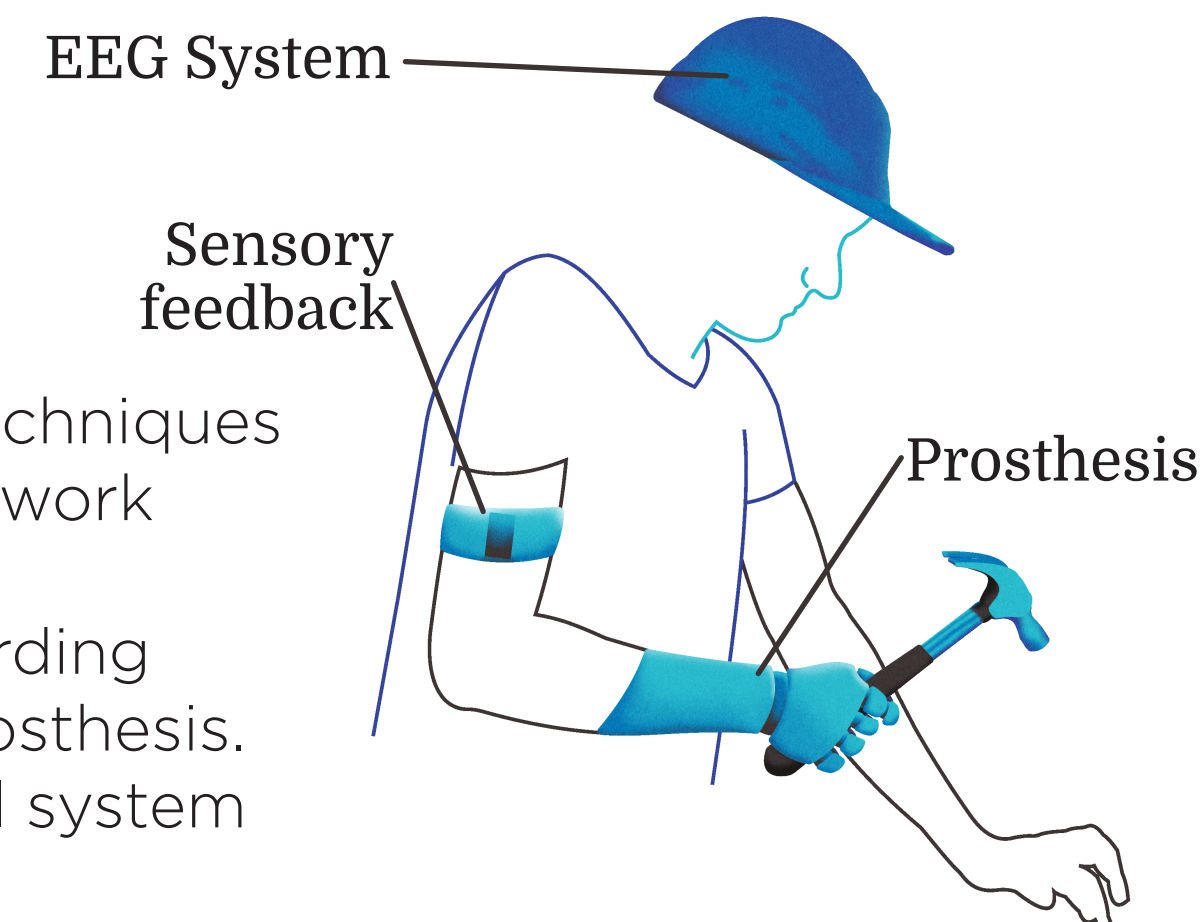


Highlights

- While both amputees and able-bodied subjects were reaching close performances regarding the classification of the type of movement, the latter were performing better than the amputees during real-time control.
- There were no significant differences between the estimation performances using motor execution and motor imagery based EEG data; meaning the system could potentially be transposed to people with tetraplegia.
- The performances and distinction between movements were quite stable along the sessions, it might indicate that more sessions are needed to see an effect.
- Removing 32 electrodes out of 64 create a loss of around 1% in the performance.

Introduction

- A large extent of the literature is dedicated to the control of robotic arms using invasive brain-machine interfaces (BMI) for people with tetraplegia.
- There are fewer examples reporting the use of non-invasive techniques for the control of prosthesis by people with amputation like the work we are presenting here.
- Our system combines an electroencephalography (EEG) recording system and a sensory feedback device to control a MyoBock prosthesis.
- We studied the control performance of this BMI based control system when used by amputees and able-bodied people.



Materials and Methods

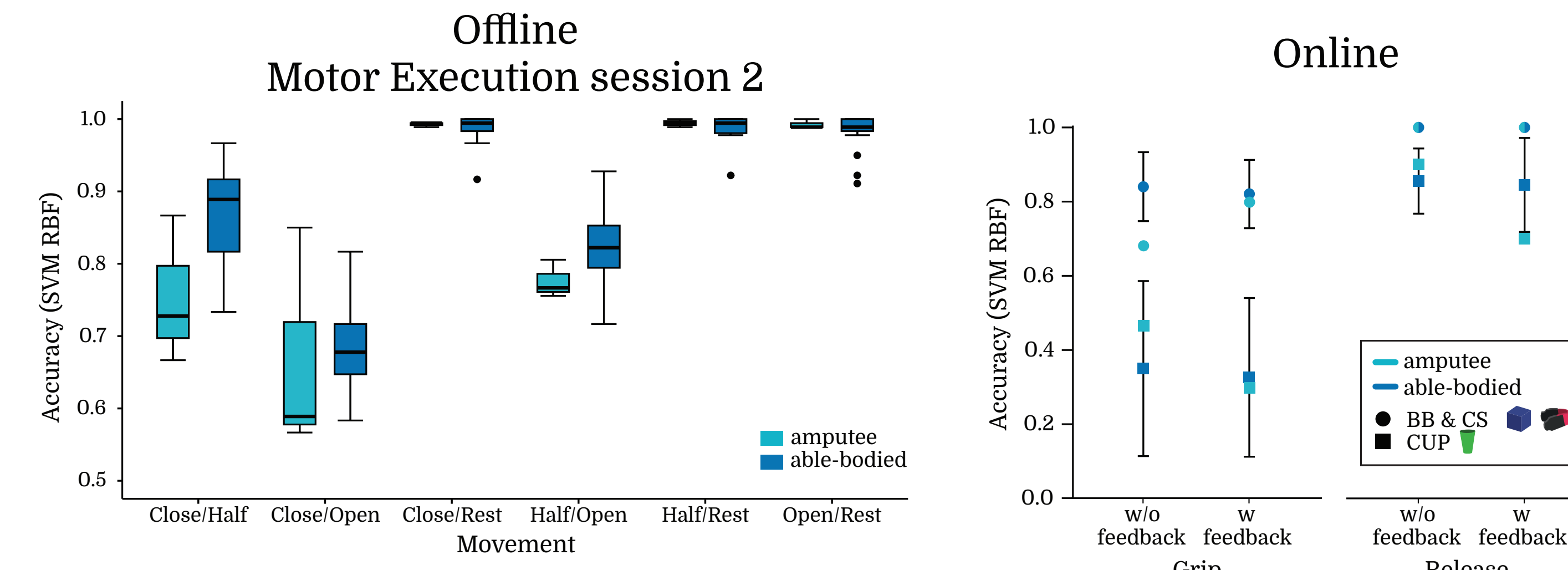
- 3 experimental sessions were conducted with able-bodied (n = 19) and trans-radial amputees (n = 4).
- The subjects performed a sequence of Grasping-Moving-Releasing with three objects in Motor Execution (ME) and Motor Imagery (MI).
- 2 feature extraction pipelines were used :
 - Common Spatial Patterns + Wavelet Decomposition
 - Riemannian Geometry
- Four types of movements were classified : Close, Half, Open and Rest leading to six one-vs-one classification models.
- The class distinctiveness metric (Lotte & Jeunet, 2018) was computed.



	Able-bodied	Amputees
Session 1	MI + ME with dominant hand	MI + ME with original prosthesis
Session 2	MI + ME with modified prosthesis + real-time test	
Session 3	MI + ME with modified prosthesis + sensory feedback + real-time test	

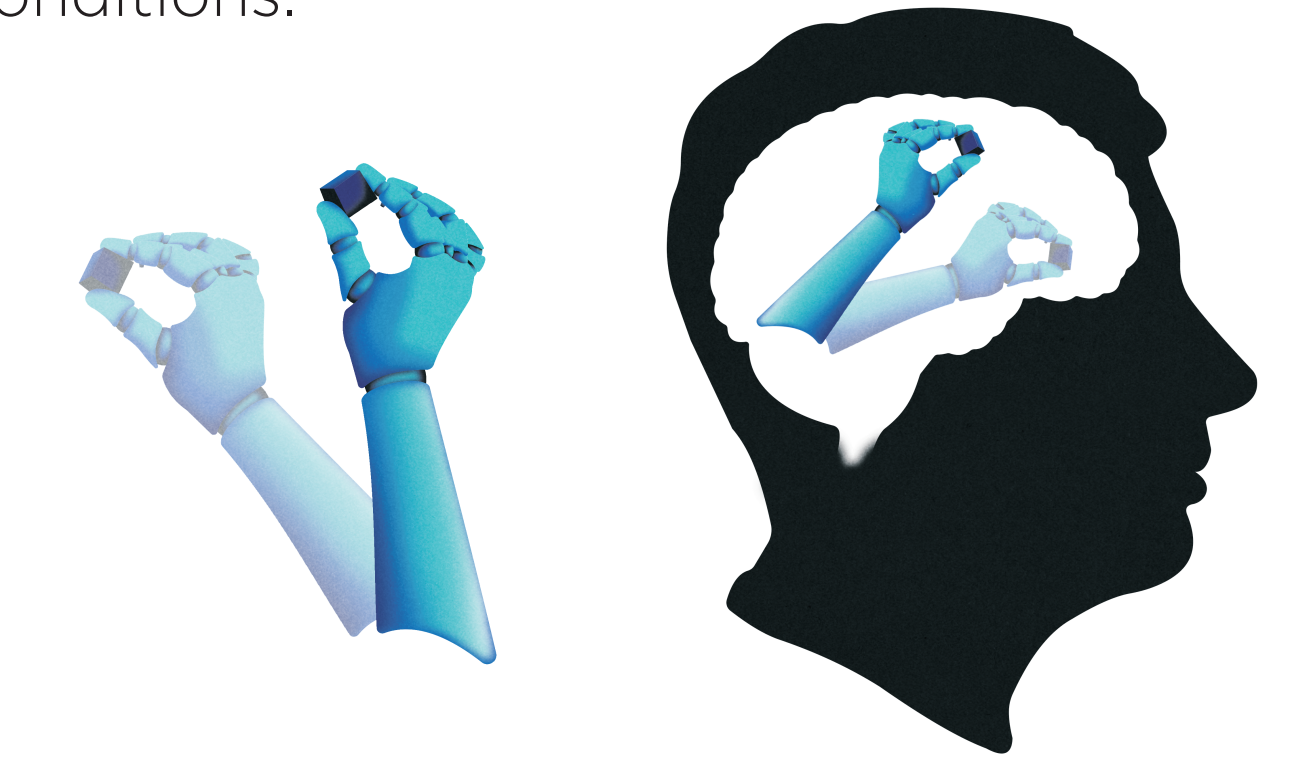
The able-bodied are performing better than the amputees

The different EEG systems used for each group could explain the difference. This has also been observed during real-time control of the modified prosthesis using EEG data.



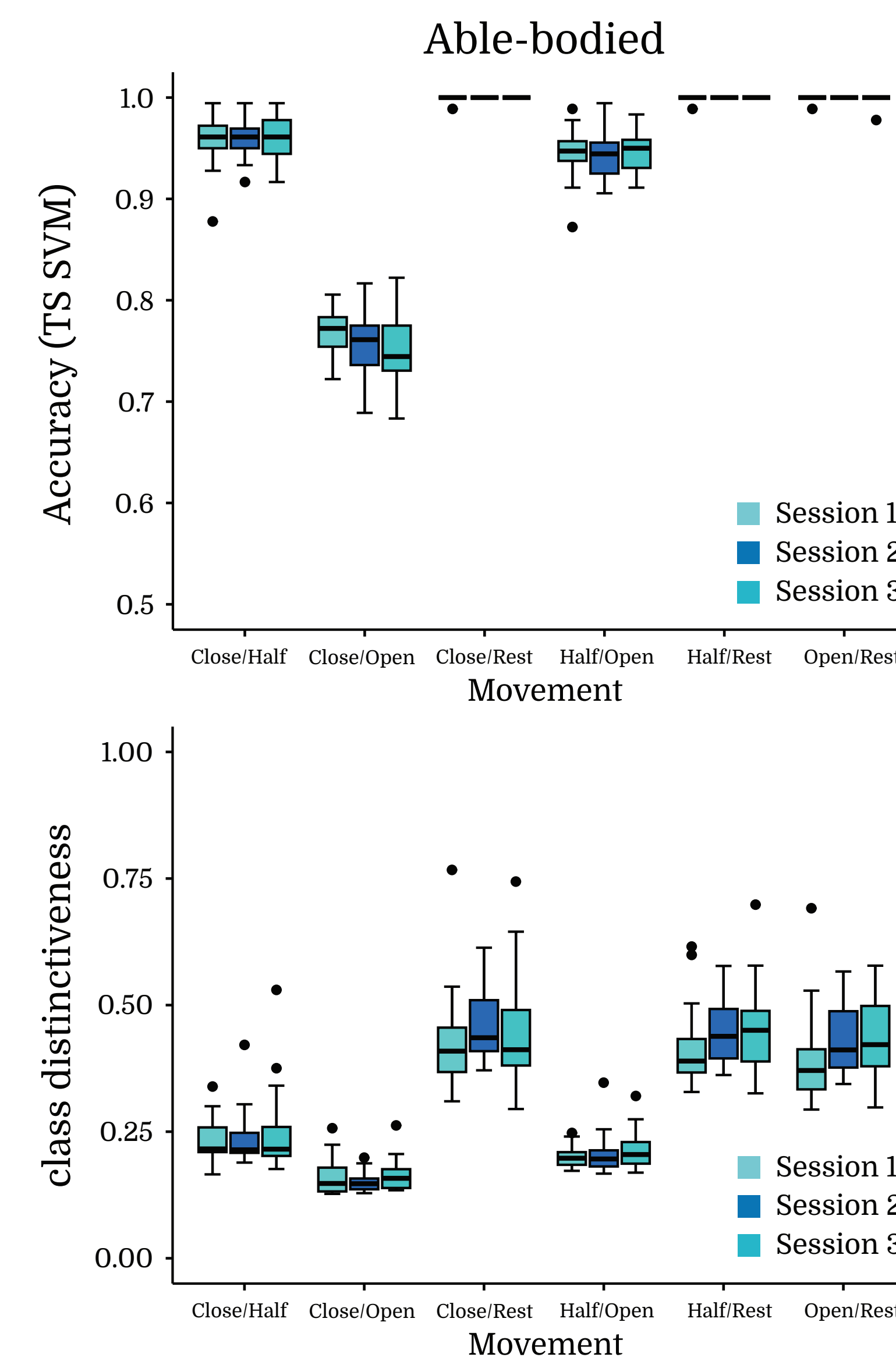
No significant difference between Motor Execution and Motor Imagery in terms of performance

While there are neurological differences in the execution and the imagination of movements (even more in amputees), we observed no differences in the performances between the two conditions.



Performance and class distinctiveness remain stable over time

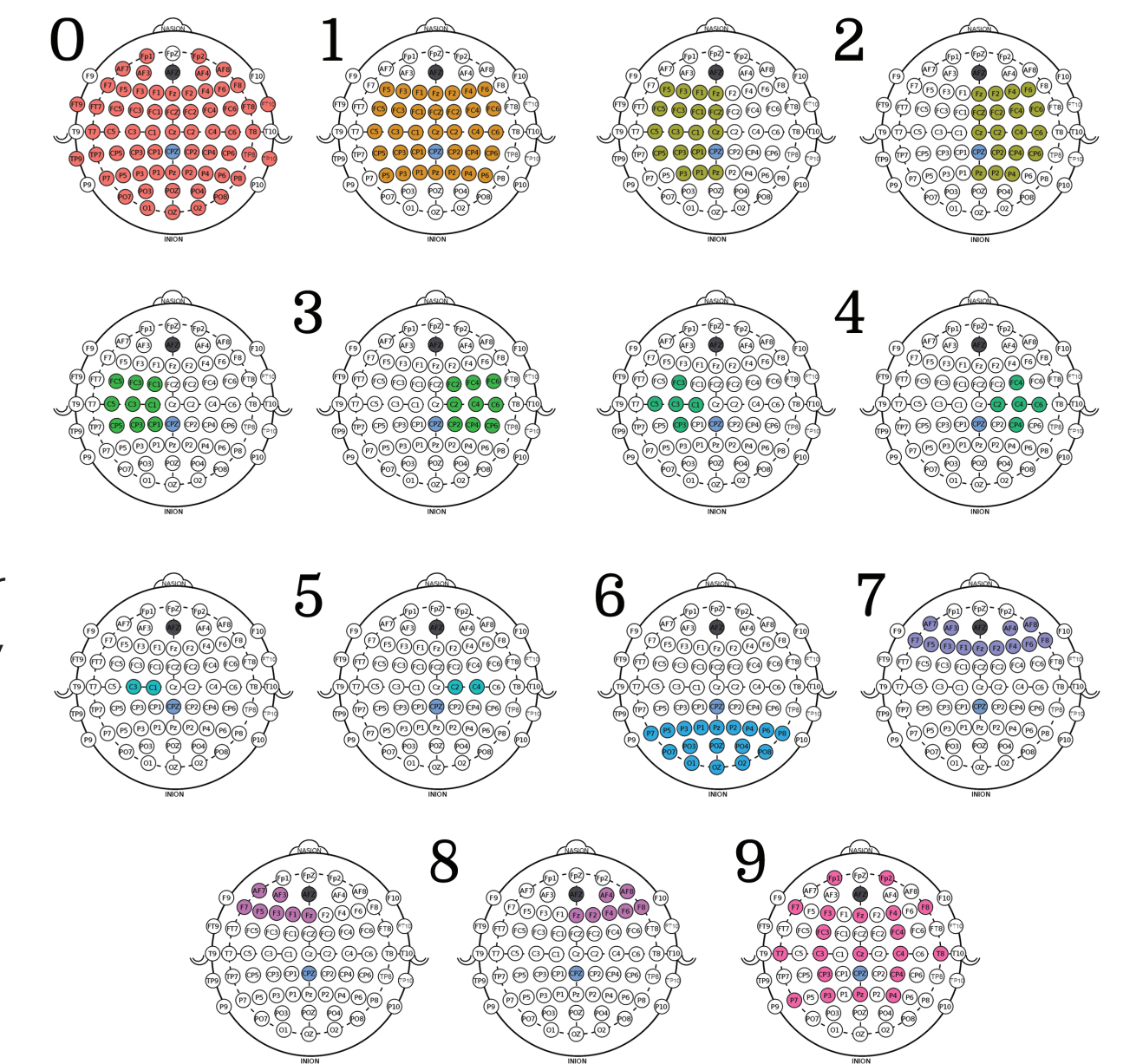
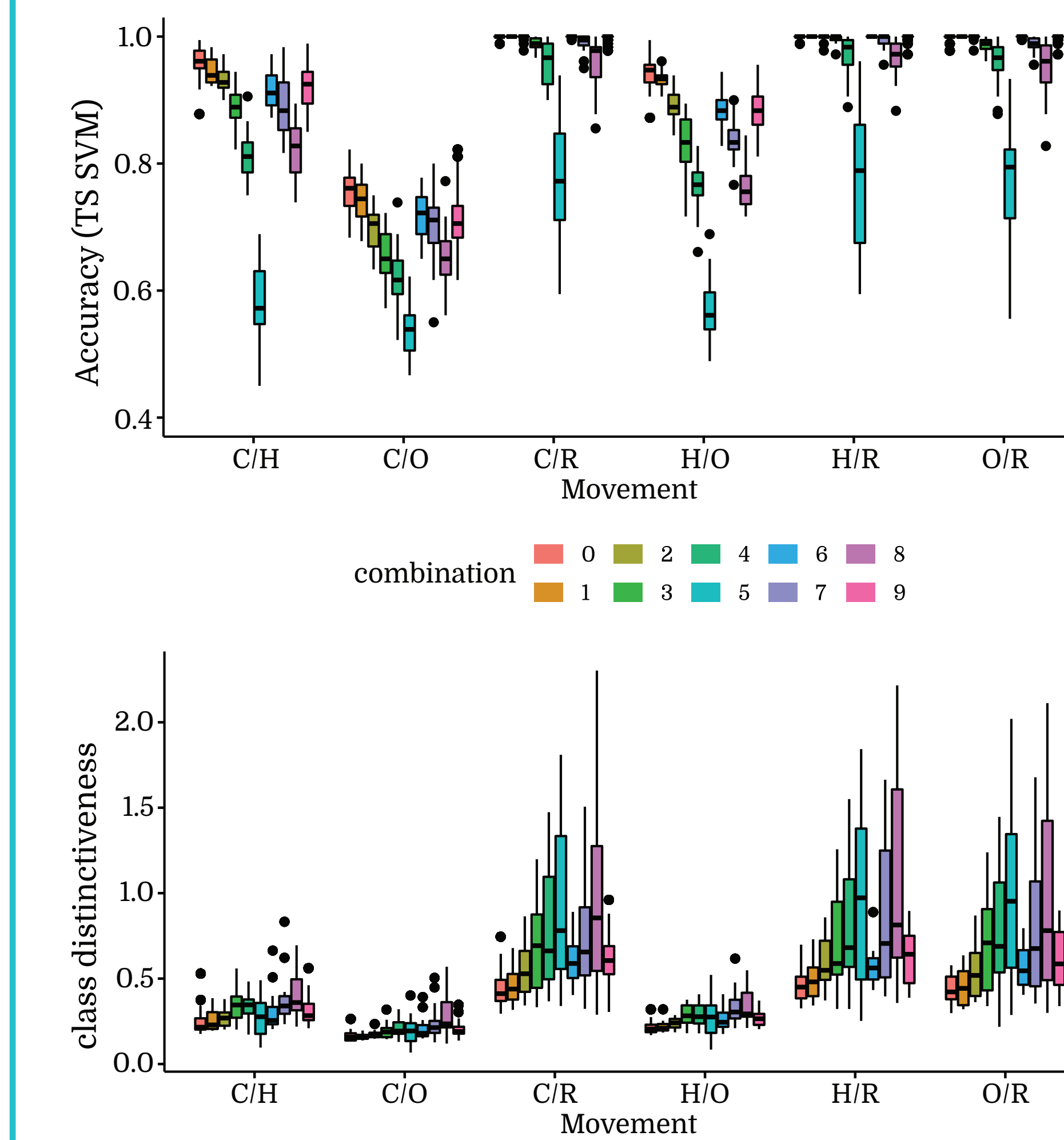
We observe a slight increase of the distinctiveness over time for the models where a movement is compared with Rest. This increase has no impact on the performance.



Removing half of the electrodes only lead to a decrease of ~1% in the performance

On the other hand, removing electrodes improve class distinctiveness. This dichotomy could indicate a tendency for the algorithms to overfit the data.

As expected, choosing electrodes over the sensorimotor cortex leads to better performances compared to frontal or parietal areas but those choices do not decrease drastically the performance.



Loss of accuracy compared to the performance with 64 electrodes

Session	S1	S2	S3
Comb. 1	1,1%	0,8%	0,7%
Comb. 2	2,8%	3%	2,7%
Comb. 3	5,9%	6%	5,8%
Comb. 4	10,5%	10,8%	10,6%
Comb. 5	30,4%	31,4%	29,2%
Comb. 6	3,6%	2,5%	2,7%
Comb. 7	5,8%	5,7%	4,8%
Comb. 8	9,7%	9,6%	10%
Comb. 9	3,5%	2,2%	2,7%

Conclusion

- The able-bodied participants outperformed the amputees in the conducted experiments. The difference was consistent even during real-time control of the modified prosthesis.
- There was no significant difference in performance between ME and MI tasks. It needs to be investigated for other types of amputations (congenital or transhumeral for example).
- The performance and class distinctiveness of the models remained stable over time. It is possible that more sessions are needed to see a significant improvement in the performance.
- Removing half of the electrodes and focusing on the sensorimotor cortex resulted in only a marginal decrease of approximately 1% in performance, a first step toward the development of a system that can be used in an ecological setting.

Acknowledgments

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To access my PhD thesis on the control of prosthetic hands using non-invasive BMIs Scan the QR code :

