Enhancing EEG-Based Brain-Computer Interfaces for Inner Speech Decoding: A Novel Feature Extraction Method Using the Inter-Trial Coherence Framework.

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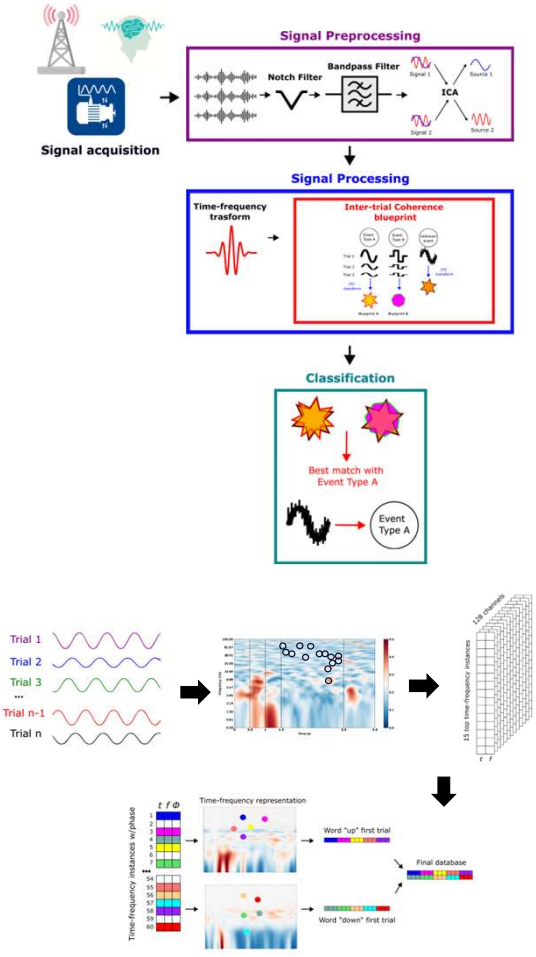
INTRODUCTION

Inner speech decoding through EEG signals is a promising yet challenging area in BCIs. **The goal is to translate neural activity into communicable forms like text or audio**. However, current systems **face low classification accuracy, largely due to the lack of representative features** for distinguishing between classes. This issue stems from the low signal-to-noise ratio (SNR) in EEG signals, which complicates the extraction of meaningful information.

In this work, we propose a **novel methodology using the Inter-Trial Coherence (ITC) framework to extract consistent features** from inner speech EEG signals across multiple trials, aiming to improve classification accuracy.

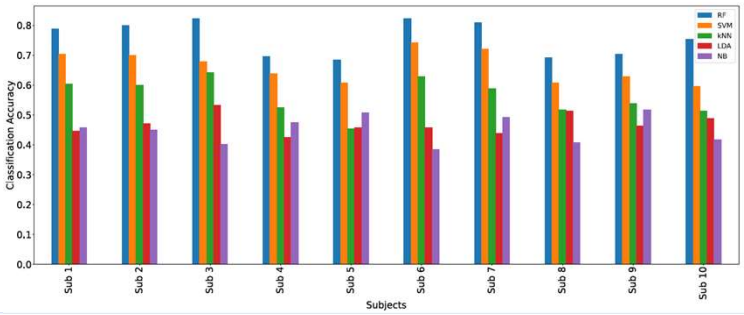
MATERIALS AND METHOD



RESULTS AND DISCUSSION

This study evaluated five classification algorithms—Random Forest (RF), Support Vector Machine (SVM), k-Nearest Neighbors (kNN), Linear Discriminant Analysis (LDA), and Naive Bayes (NB)—**for inner speech decoding. RF achieved the highest overall accuracy (75.70%), followed by SVM (66.25%) and kNN (56.08%).** RF also demonstrated the highest accuracy for individual subjects and recording sessions, highlighting its robustness. In contrast, LDA and NB showed the lowest performance, with accuracies of 46.91% and 45.12%, respectively.

	RF	SVM	kNN	LDA	NB
Sub 1	0.7875	0.7042	0.6042	0.4458	0.4583
Sub 2	0.8000	0.7000	0.6000	0.4708	0.4500
Sub 3	0.8222	0.6792	0.6417	0.5333	0.4028
Sub 4	0.6958	0.6375	0.5250	0.4250	0.4750
Sub 5	0.6833	0.6083	0.4542	0.4583	0.5083
Sub 6	0.8231	0.7413	0.6285	0.4577	0.3842
Sub 7	0.8083	0.7208	0.5875	0.4375	0.4917
Sub 8	0.6917	0.6083	0.5167	0.5125	0.4083
Sub 9	0.7042	0.6292	0.5375	0.4625	0.5167
Sub 10	0.7542	0.5958	0.5125	0.4875	0.4167
AVG	0.7570	0.6625	0.5608	0.4691	0.4512



CONCLUSIONS

This study introduced a novel feature extraction methodology using Inter-Trial Coherence (ITC) to enhance the accuracy of inner speech decoding in EEG-based Brain-Computer Interfaces (BCIs). **The Random Forest classifier achieved the highest average accuracy (75.70%), outperforming other classifiers and the state-of-the-art.** ITC proved to be a more effective feature extraction method compared to traditional approaches, even with a limited dataset. While the results are promising, **limitations such as dataset size and the need for real-time processing still need to be addressed**. **Future work** should focus on refining feature extraction methods to make them more **generalizable** across subjects and sessions and improving computational efficiency for real-time applications.

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BIBLIOGRAPHY

[1] Lopez-Bernal, D., Balderas, D., Ponce, P., & Molina, A. (2022). A state-of-the-art review of EEG-based imagined speech decoding. Frontiers in human neuroscience, 16, 867281.
[2] Lopez-Bernal, D., Balderas, D., Ponce, P., & Molina, A. (2023, November). Inner speech classification using inter-trial coherence framework for feature extraction. In 2023 19th International Symposium on Medical Information Processing and Analysis (SIPAIM) (pp. 1-6). IEEE.
[3] Lopez-Bernal, D., Balderas, D., Ponce, P., & Molina, A. (2024). Exploring inter-trial coherence for inner speech classification in EEG-based brain–computer interface. Journal of Neural Engineering, 21(2), 026048.