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INSTITUTO DE SISTEMAS E ROBÓTICA
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Single trial detection of error-related potentials in brain-machine interfaces: A survey and comparison of methods

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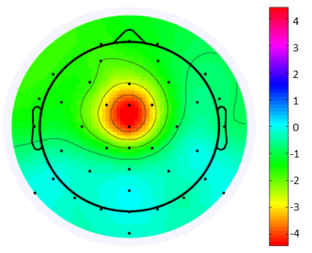
Introduction

Error-related Potential (ErrP) is an EEG potential elicited when humans perceive an error, naturally occurs without the user's explicit intention.

Objectives:

- Single trial detection of error-related potentials
- Generalization across sessions/subjects/tasks
- Learning from error during interaction



ErrP detection accuracies quite variable across studies.

Research Question: Does this variability depend more on classification pipelines or on the quality of elicited ErrPs?

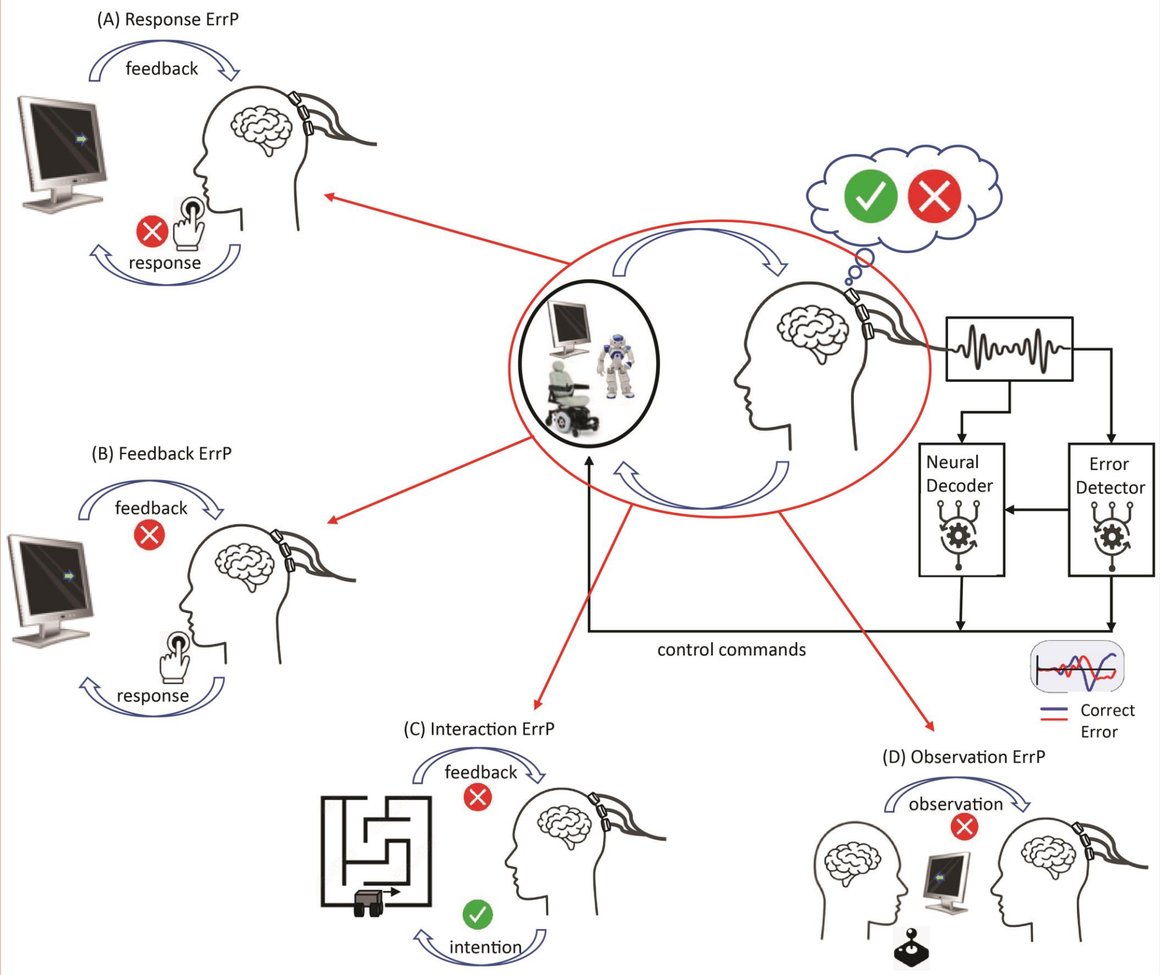


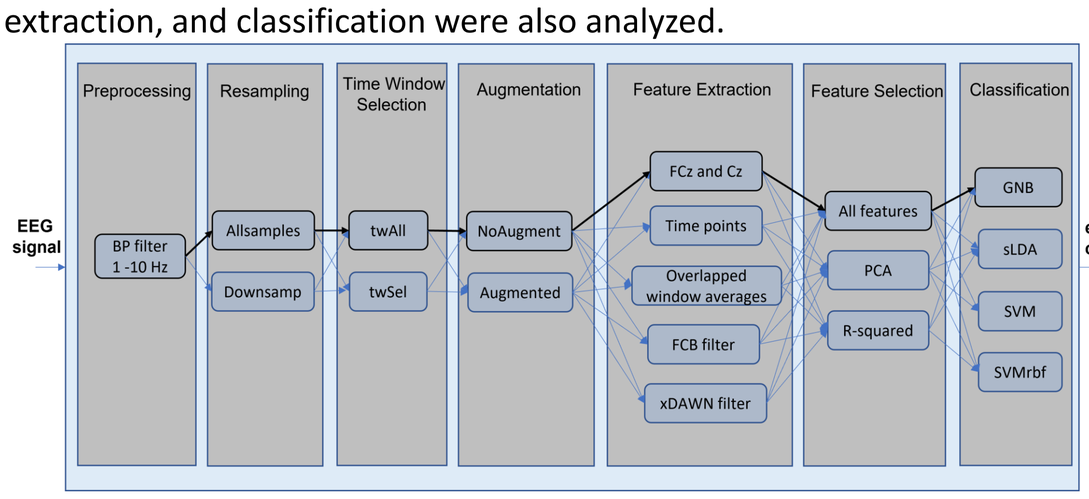
Figure: Integrating ErrPs into a closed-loop BCI system

Methods

11 datasets to compare several classification pipelines selected according to the studies where:

- ErrPs are detected online;
- Balanced accuracy is equal to or greater than 75%.

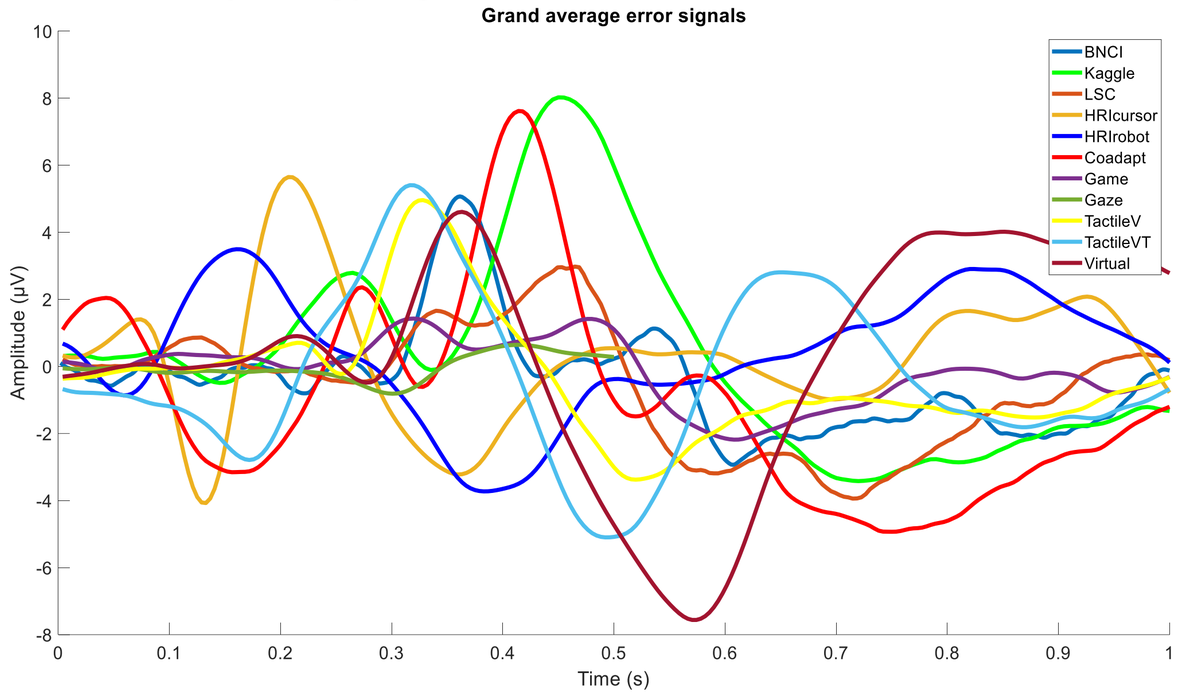
The effects of resampling, window selection, augmentation, feature extraction, and classification were also analyzed.

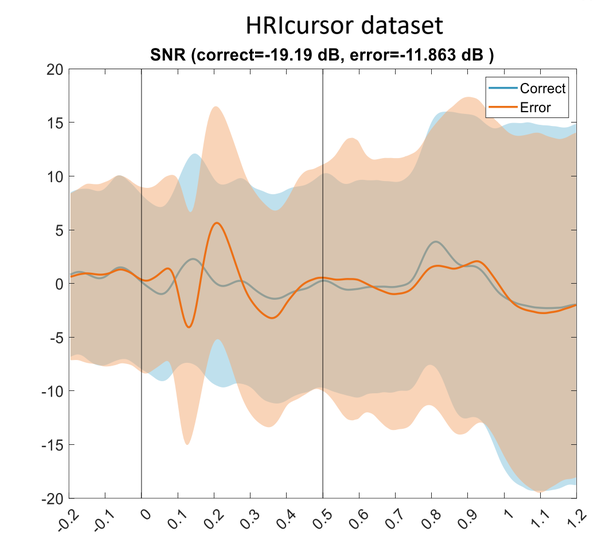


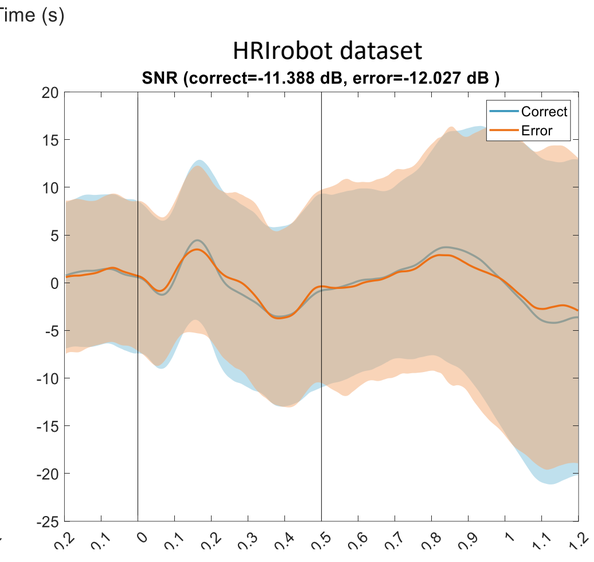
Results

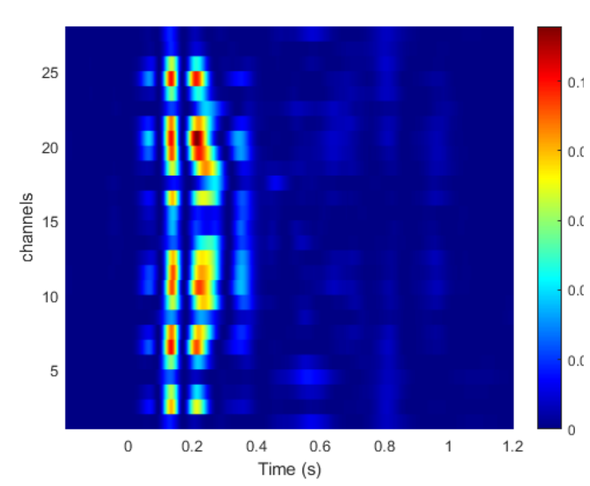
- The classification accuracy is highly dependent on user tasks in BCI experiments and on signal quality (in terms of ErrP morphology, signal-to-noise ratio (SNR), and discrimination (r-squared)).
- Shrinkage-regularized LDA is the most robust method for classification. FCB spatial features and overlapped window averages for feature extraction.
- There is a statistical correlation between accuracy and discriminability level ($p<0.001$), and correlation between accuracy and signal-to-noise ratio ($p<0.001$).

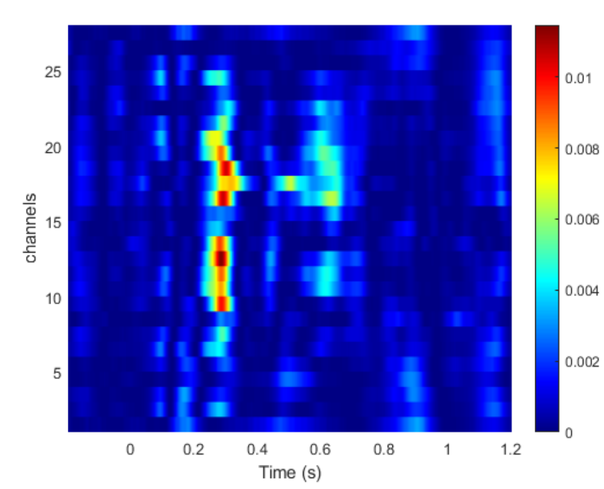
ErrP morphology, signal-to-noise ratio and discrimination











Ongoing/Future Work: Transfer learning approaches (data alignment, covariate-shift adaptation, Riemannian geometry, deep learning), data augmentation approaches (Generative Adversarial Networks)

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DS: Downsampling, WS: Window Selection, FS: Feature Selection, AUG: Augmentation.				FCzCz				FCB				xDAWN				Overlap				Timepoints			
				Bayes	sLDA	SVM	SVMrbf	Bayes	sLDA	SVM	SVMrbf	Bayes	sLDA	SVM	SVMrbf	Bayes	sLDA	SVM	SVMrbf	Bayes	sLDA	SVM	SVMrbf
DS	WS	FS	AUG																				
-	-	-	-	65.00	66.96	63.12	59.77	**71.70**	71.41	68.84	68.79	69.91	69.05	65.40	66.07	64.59	**72.35**	70.68	60.34	63.75	68.19	67.01	60.45
-	-	√ (r2)	-	65.16	67.71	63.58	61.00	**72.89**	**72.98**	69.26	70.25	69.80	70.42	66.56	67.63	65.79	**72.36**	69.67	62.17	62.74	67.37	63.16	60.12
-	-	√ (PCA)	-	64.63	67.33	62.88	59.84	66.44	67.18	63.64	62.77	67.09	68.37	64.62	64.85	63.72	**71.82**	68.55	60.12	61.59	64.17	59.66	57.72
√	-	-	-	64.86	67.82	63.88	59.78	71.32	**71.88**	68.82	68.50	69.72	70.25	65.98	66.10	64.42	**72.39**	70.65	60.29	63.82	69.39	67.28	60.45
-	√	-	-	65.14	67.08	63.19	61.13	**72.74**	**72.69**	69.19	70.64	69.27	69.06	64.58	66.31	65.01	**72.81**	70.56	61.99	63.42	69.22	66.89	61.03
-	-	-	√	64.56	66.76	61.99	59.20	70.93	71.17	67.95	67.55	68.72	68.28	64.35	64.93	64.41	**71.82**	69.55	59.33	63.77	67.84	66.26	59.86