Passive BCI for Dementia Onset Detection and Cognitive Intervention Monitoring

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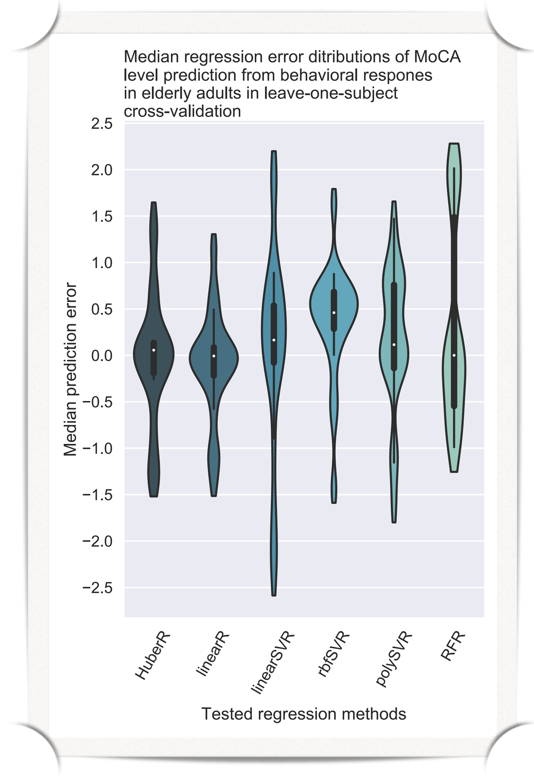
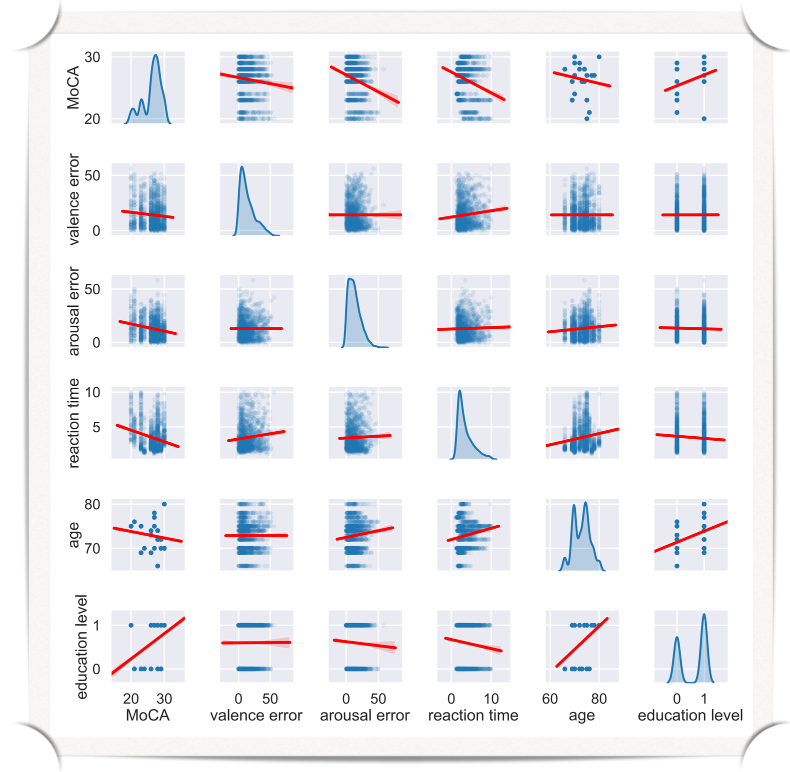
Abstract

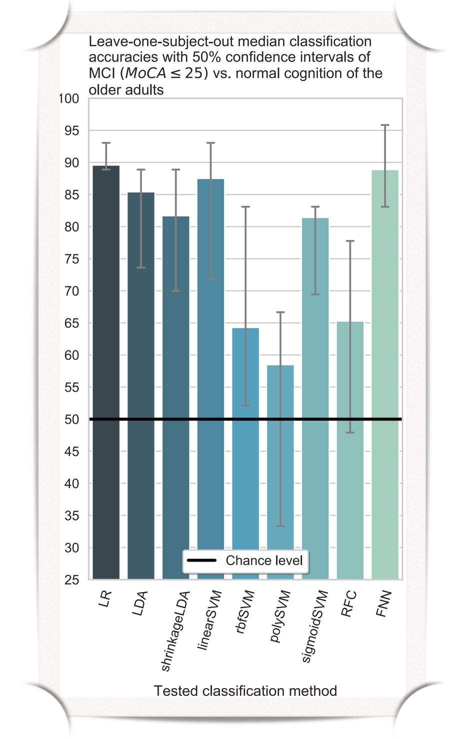
The poster presents a practical application of machine learning (ML) in the so-called `AI for social good' domain and in particular concerning the problem of a dementia onset prediction. An increase in dementia cases is producing a significant medical and economic weight in many countries. Approximately 47 million older adults live with a dementia spectrum of neurocognitive disorders, according to a recent report of the World Health Organization (WHO), and this number will triple within the thirty years. This growing problem calls for possible application of AI-based technologies to support early diagnostics for cognitive interventions and a subsequent mental wellbeing monitoring as well as maintenance with the so-called 'digital-pharma' or 'beyond a pill' therapeutical strategies. The poster presents our study results of EEG brainwave responses analysis in a BCI-based emotional stimulus and working implicit memory learning task. We focus on the advancement of digital biomarkers for dementia progress detection and monitoring. We discuss a range of machine-learning-resulting accuracies with encouraging results using classical shallow and deep learning approaches for automatic discrimination of normal cognition versus a mild cognitive impairment (MCI). The classifier input features consist of an older adult emotional valence and arousal EEG responses, as obtained from a group of 35 older adults participating voluntarily in the reported dementia biomarker development project. The presented results showcase the inherent social benefits of artificial intelligence (AI) utilization for the elderly and establish a step forward to advance machine learning (ML) approaches for the subsequent employment of simple BCI-based EEG examination for MCI and dementia onset diagnostics.



Results: Median errors of the tested regression methods for MoCA score predictions using various methods.

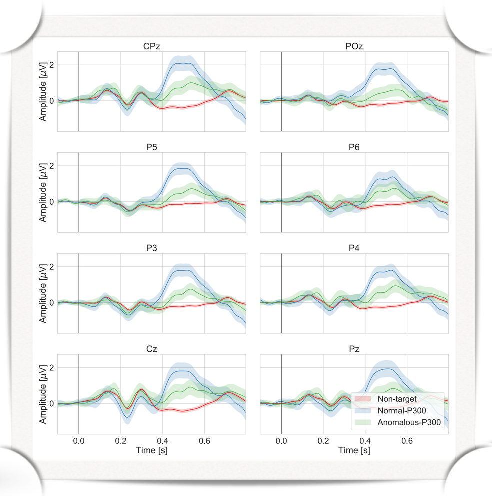


Results: Pairwise scatter plots with features used for MoCA score regression or MCI classification with clear linear dependencies.

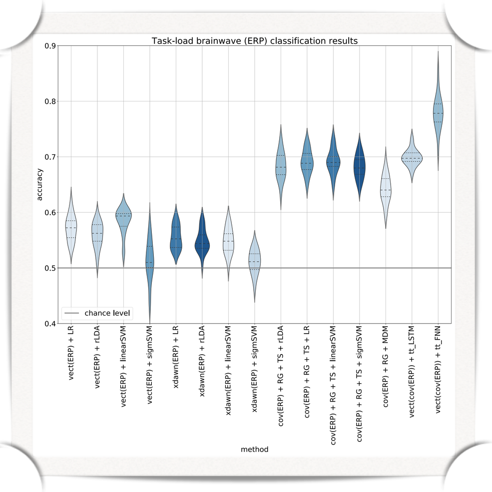


Results: Median **c**lassification results of various classifiers tested in our project. Fully connected deep neural network (FNN) and linear regression (LR) resulted with accuracies round 90%.

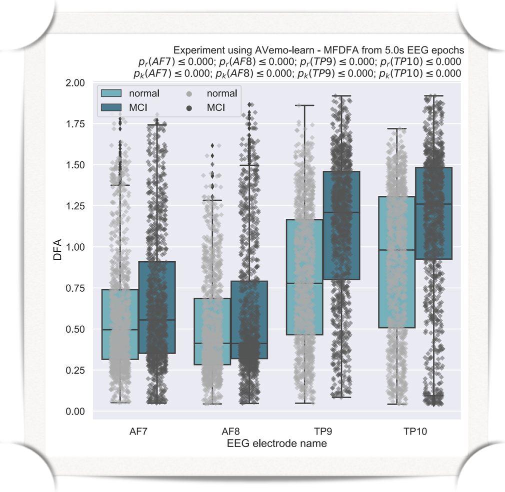
EEG Results



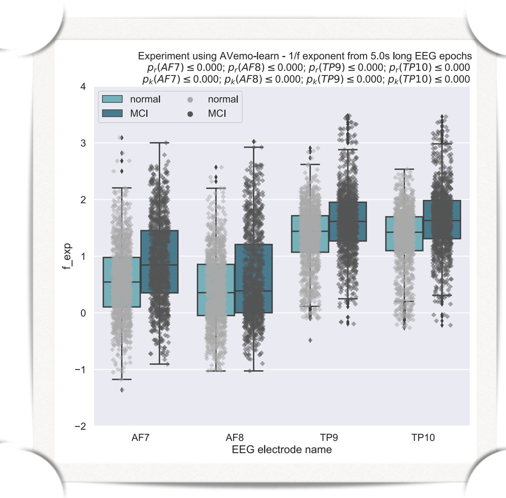
Results: Auditory (amplitude modulated) P300 latency responses to easy (normal-P300; real sound; blue), difficult (anomalous-P300; virtual; green) and ignored (non-target; red) spatial auditory stimuli.



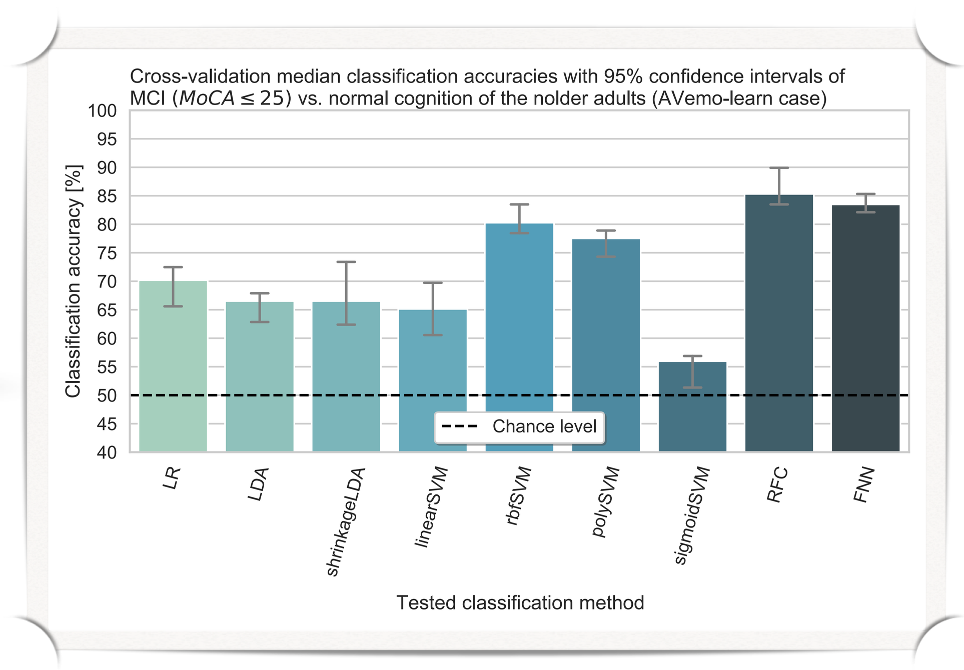
Results: Median classification accuracy results (white dots within percentile ranges) depicted together with result distributions (a chance level of 0.5 representing 50% of binary classification cases depicted with bold gray line).



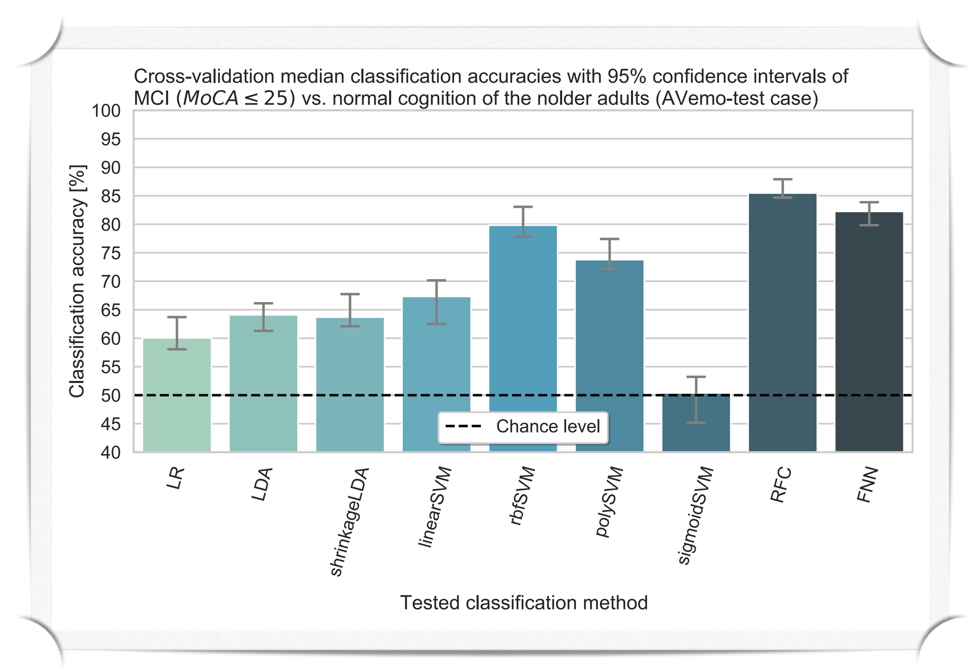
Results: Multi-fractal DFA analysis results for MCI and normal elderly with significant statistical differences of the distributions as evaluated with ranksums (p_r) and Kruskal-Wallis (p_k) tests.



Results: Spectral 1/f slope exponent analysis results for MCI and normal elderly with significant statistical å of the distributions as evaluated with ranksums (p_r) and Kruskal-Wallis (p_k) tests.



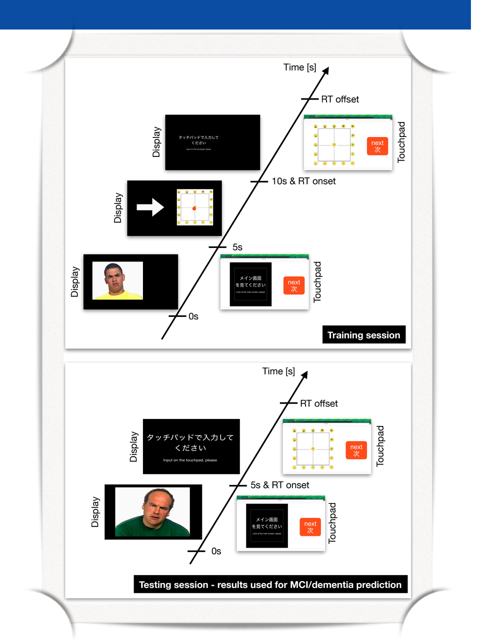
Results: Median classification results of various classifiers tested in our project in he working-implicit-visuospatial-memory learning task and using EEG complexity (MFDFA and 1/f exponent) features. Random forest and FNN classifiers resulted with accuracies round 95%.



Results: Median classification results of various classifiers tested in our project in he working-implicit-visuospatial-memory testing task and using EEG complexity (MFDFA and 1/f exponent) features. Random forest and FNN classifiers resulted with accuracies round 95%.

Methods

We conducted experiments with human subjects with guidelines and approval of the RIKEN Ethical Committee for Experiments with Human Subjects in the Center for Advanced Intelligence Project (AIP). In the experimental session, 35 elder participants (number of females = 22; mean age = 73.5 years old; age standard deviation of ±4.85 years; recruited from Silver Human Resources Center and Honobono Laboratory). Each subject experiment consisted of 72 video presentation trials (5~7 seconds each) with 24 different emotion categories. Behavioral response of valence and arousal working implicit memory-based responses together with reaction times and EEG were recorded.

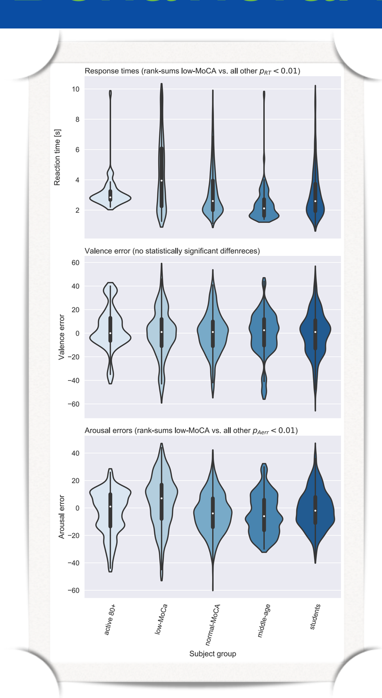


Methods: Working-implicit-visuospatial-memory learning (top) and testing (bottom) paradigms.

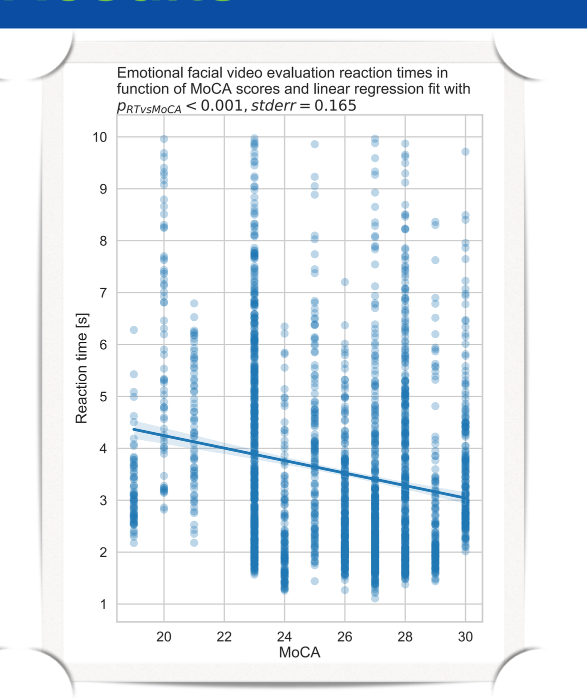
Conclusions

- The study resulted in MCI pathology prediction from behavioral and EEG responses in the spatial- and implicit-working-memory task of emotional valence and arousal levels estimation together with reaction times in simple video clips watching task.
- In the study involving older adults with known MoCA scores, we were able to evaluate several shallow learning classifiers.
- The prediction of MCI (usually MoCA of 25 has been considered as mild cognitive impairment (MCI) stage already, while above this threshold an elderly adult cognition has been evaluated as standard) in the simple emotional faces evaluation task resulted in robust and small errors.
- The successful application of such AI/ML-based dementia onset prediction shall lead to a healthcare cost lowering benefiting the aging societies.
- We also acknowledge the potential limitations of the current approach as we only infer human-error-prone MoCA scores-based MCI stages, which are only proxy estimators of dementia.
- AI-based dementia estimators, if used without proper evaluation, might also pose a danger of misuse or abuse; thus, proper ethical standards will need to be in place too.
- In the next step of our research project, we plan to evaluate the developed methods with a larger sample of ordinary versus SCI/MCI, or even dementia diagnosed members of the society.

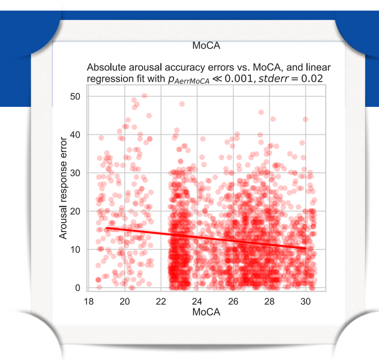
Behavioral Results



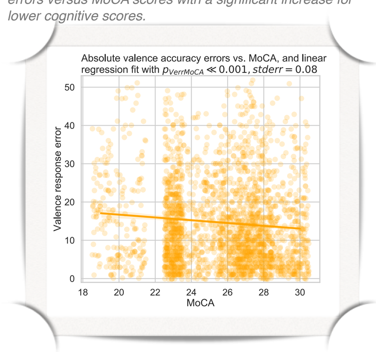
Results: Reaction times (top), valence (middle) and arousal (bottom) errors with statistically significant median differences of low-MoCA (MCI) group.



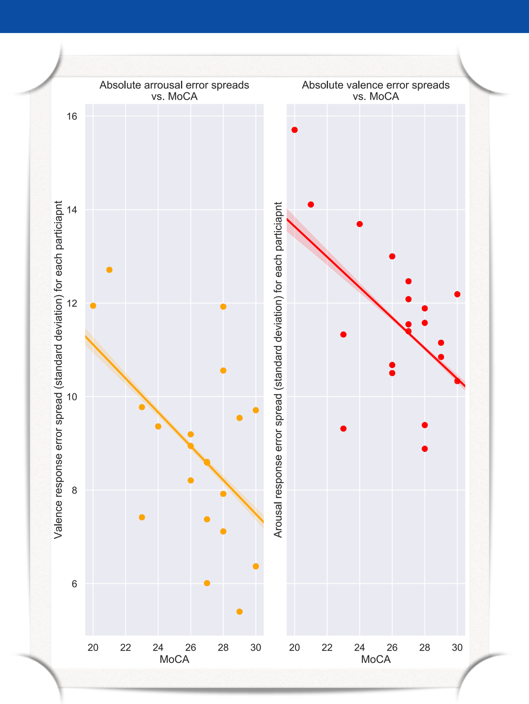
Results: Linear regression of reaction times versus MoCA scores with a significant slowing for lower cognitive scores.



Results: Linear regression of the working-implicit-visuospatial-memory learning-based arousal judgement errors versus MoCA scores with a significant increase for lower cognitive scores.



Results: Linear regression of the working-implicit-visuospatial-memory learning-based valence judgement errors versus MoCA scores with a significant increase for lower cognitive scores.



Results: Linear regression of the working-implicit-visuospatial-memory learning-based median for each subject arousal and valence judgement errors versus MoCA scores further confirming the error increases for lower cognitive scores.

References

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