

## **We need to go DEEPER: An online portal to improve reproducibility and accelerate research in deep learning for EEG analysis**

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**Context.** Deep learning (DL) has garnered a lot of attention recently for the analysis of electroencephalography (EEG) data across various domains such as epilepsy, sleep, brain-computer interfacing, and cognitive and affective monitoring [1]. In a recent review of the DL-EEG literature [1], we summarized the methodology and results of 154 papers to highlight interesting trends and uncover critical research avenues. However, whether DL consistently performs better than traditional EEG processing approaches remains to be systematically investigated. More urgently though, a large portion of the reviewed papers did not share code, use publicly available datasets, or report sufficient information to be readily reproducible. In a field such as DL where research moves very quickly, poor reproducibility is a major roadblock to fast developments.

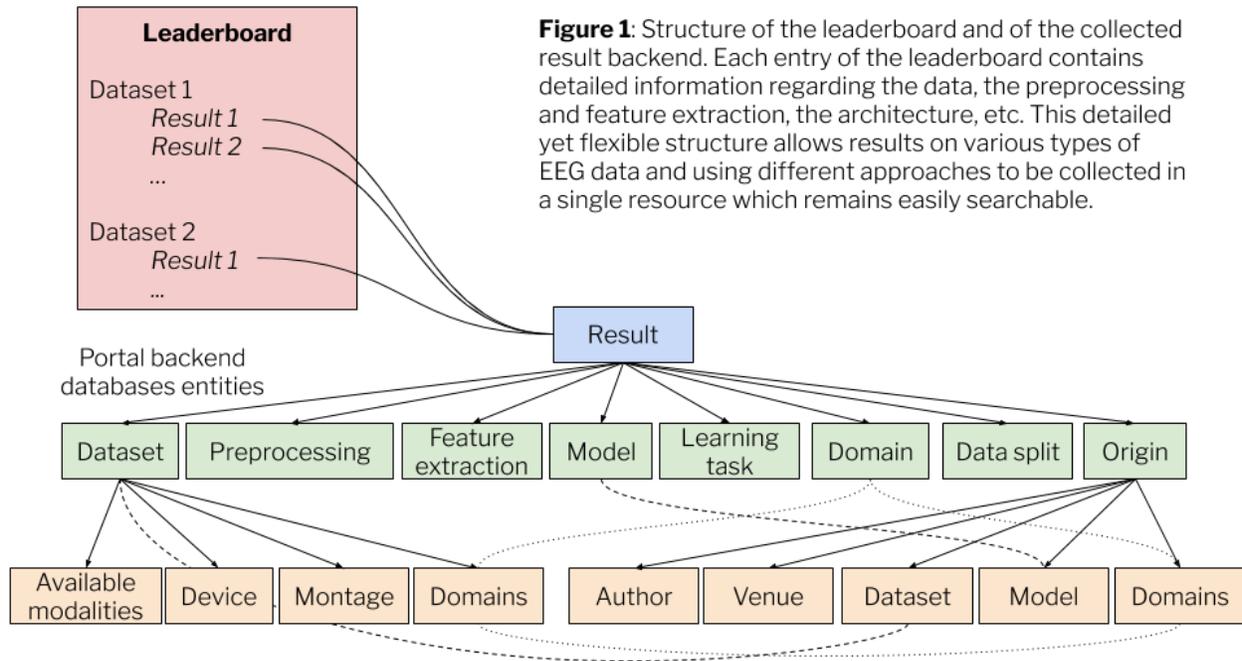
Concurrently, over the last few years, other fields leveraging DL (e.g., computer vision and natural language processing) have developed dramatically. This rapid pace of innovation was enabled by 1) the use of standard datasets, 2) model and code sharing, 3) standardization of reporting, 4) public leaderboards listing state-of-the-art results, and 5) open discussion platforms. Inspired by these practices, we present **DEEPER (Deep-learning EEG Portal to Encourage Reproducibility)**, an online portal to help accelerate DL-based EEG research.

**Objective.** DEEPER acts as the main resource for up-to-date results, code, algorithms and discussions around DL-EEG, integrating elements from initiatives and platforms such as ImageNet [2], Kaggle [3] and Github [4]. The portal aims to rally researchers, students and professionals interested in exploring DL models on EEG time series and fostering discussion among them. This initiative will improve reproducibility by centralizing results and resources, and by making result sharing a more transparent process.

**Technical description.** The portal is made up of the following main parts: 1) an evolving list of openly available EEG datasets, including a description, URL and reference for each dataset, 2) an easy-to-navigate leaderboard which allows sorting results using various criteria, 3) a forum to host discussions on implementation- and leaderboard-related topics, 4) an up-to-date list of all the published papers on DL-EEG [1], and 5) educational resources for DL-EEG. The leaderboard facilitates the exploration of results according to authors, datasets, architectures, reported performance, and includes links to the corresponding publications and code when available.

Once a public account of their work is published (e.g., through academic conferences, journals or preprint repositories), users can submit a thorough description of their approach through an online interface. Specifically, users log detailed descriptions of their results, architecture, preprocessing, code, dataset, cross-validation strategy, etc. (see Figure 1). This

information is then validated and included in the relevant leaderboard(s) by portal maintainers (the authors of this abstract) for other people to see and build on these results. Moreover, we propose a scoring mechanism to foster reproducibility in the field. According to this system, each entry to the portal receives points whenever other users report reproducing the original results. By providing higher visibility to high quality results, we encourage authors to ensure their experiments are reproducible.



**Significance.** By providing an up-to-date portal showcasing the latest results, papers and datasets, and by facilitating discussions and sharing among researchers in the field, DEEPER is geared toward accelerating research. It encourages reproducibility, both with data and code accessibility. It increases the trust in published results by showing whether these results have been reproduced and if so, by whom. As an open and free resource, DEEPER makes it easier to get started and participate in the field - be it for machine learning researchers interested in broadening the type of data they work with, or for EEG researchers looking to use the latest advancements in deep learning. Following the initial response of the community, we believe this model could easily be extended to also incorporate other modalities such as magnetoencephalography (MEG) and invasive EEG recordings.

- [1] Roy, Yannick et al. "Deep learning-based electroencephalography analysis: a systematic review." *arXiv preprint arXiv:1901.05498* (2019).
- [2] Deng, Jia, et al. "Imagenet: A large-scale hierarchical image database." *2009 IEEE Conference on Computer Vision and Pattern Recognition*. IEEE, 2009.
- [3] Kaggle: <https://www.kaggle.com/>
- [4] Github: <https://github.com/>