Prediction of Central Neuropathic Pain in Subacute Spinal Cord Injury: Effects of EEG Dataset Size on Classifier Performance

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BACKGROUND

Central neuropathic pain (CNP) develops in more than 50% of people with spinal cord injuries (SCI) within a year post-injury [1]. We have shown that multichannel EEG classification can predict the risk of pain with an average accuracy of 80% [2,3]. The aim of this PhD project is to refine and validate the classification of patient EEG towards a clinical diagnostic tool that can predict patients' susceptibility to CNP. The existing classifier is based on a relatively small number of participants, for which results are often not repeatable when increasing datasets. This project has recruited a target 80 new participants across four groups in order to validate and improve classification accuracy.

METHODS

64-channel EEG recorded during cue-based motor imagery (MI) of upper and lower limbs; because of the known relationship between motor cortex over-activity and CNP [4]. All SCI participants are subacute para/tetraplegics with varying levels (C3-T12) and completeness of injury. Participants are divided into 4 groups:

- Able-bodied volunteers (AB)
- SCI participants with CNP (PwP)
- SCI participants who develop CNP (PdP)
- SCI participants who do not develop CNP (PnP) within 6 months of recording

Participants are considered to have CNP if diagnosed and larger than 4 on visual numeric scale (VNS).

We look at how increasing size of the original dataset using new data (Table 1.) affects classification performance.

Table 1. *Dataset sizes*

Group	Original Dataset	New Dataset	**Total**
PdP	8	15	**23**
PwP	10	20	**30**
PnP	10	12	**22**
AB	10	20	**30**

The original dataset was used to develop our predictive models [2,3]. The new dataset is used to increase the training set in order to test new performance.

Predictive models use a Support Vector Machine (SVM) classifier that utilises features based on Higuchi Fractal Dimensions (HFD) , a measure of signal complexity, during imagined movement. HFD features are extracted from smaller 2s windows, at each electrode position, for each repetition of MI (Figure 1.) recorded from all participants.

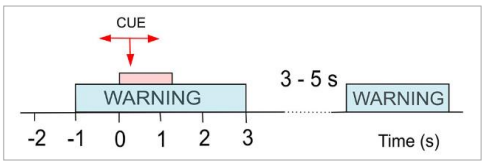

Figure 1 | Experimental setup for cue-based motor imagery (MI) tasks as used in both datasets. At t = −1 s a warning signal (a cross) appeared on a computer screen, followed by a cue (an arrow) at t = 0 s. The cue stayed on the screen until t = 1.25 s while the warning stayed until t = 3 s. Participants were asked to perform repetitive imagination of movement from t = 0 s until the warning disappeared at t = 3 s. Different arrows indicated motor imagery of different limbs.

RESULTS

HFD values range from 1 to 2.0 and are most frequently close to 1.85. HFD values are known to be lower in people suffering from neurological disorders as a result of slower processing leading to lower complexity (Figure 2a.). This complexity increases with presence of chronic pain, which we also observe in subacute CNP with a larger proportion of HFD features extracted from EEG data of PdP participants are at higher values (Figure 2b).

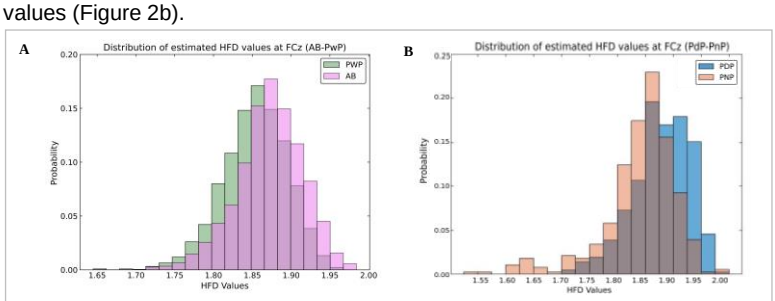

Figure 2 | Example distributions of HFD estimated from EEG data of participant groups **(A)** PwP and AB and **(B)** PdP and PnP at one electrode (FCz) during Leg (L) movement imaginations.

CLASSIFICATION PERFORMANCE

Classification focusses on MI during Leg movements as participants with CNP typically experience pain in their legs, i.e. below the level of injury. Performance is evaluated across time windows to determine whether different stages of MI provide more discriminatory features.

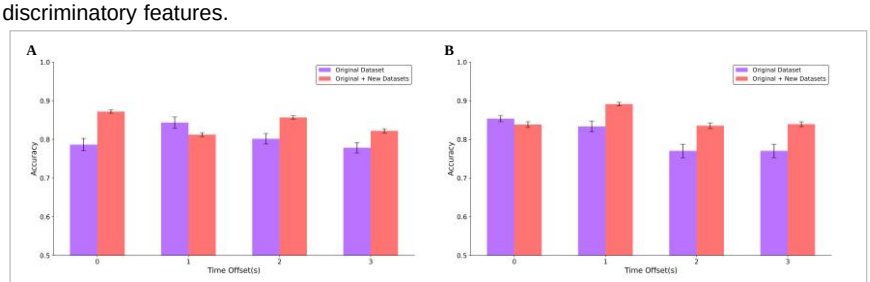

Figure 3 | Classification accuracy evaluated on **(A)** AB vs. PwP and **(B)** PdP vs. PnP using the original dataset and both the original and new dataset for Leg (L) MI data varies with 2 second temporal window offset (groups along the x-axis).

Average accuracy across four time windows increases from 80.3 ± 28.9 to 84.1 ± 28.3 (mean accuracy (%) ± std) when discriminating between AB-PwP (Figure 3a.), with only one time window decreasing. Additionally, **predicting the development of CNP in subacute SCI (PdP-PnP), on average, increases from 80.7 ± 25.5 to 85.1 ± 36.8.**

DISCUSSION

It is encouraging that accuracy remains high, and in general increases, when dataset size is increased, given that results are not often repeatable when using additional data recorded by different researchers. Further to increasing accuracy, by almost tripling the size of the dataset, we have also approximately halved our confidence intervals.

To further ensure generalisability of these classifiers, it will be important to increase number of EEG channels used to classify and assess features based on oscillatory EEG activity in order to avoid overfitting to this dataset.

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