

## Hebbian plasticity induced by temporally coincident BCI enhances post-stroke motor recovery

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### Supplementary Information: Permutation tests

#### Clinical evaluation

Permutation testing showed a significant improvement in FMA-UE score over time in the BCI-FES group ( $p = 0.040$ , effect size = 1.27) but not in the Random-FES group ( $p = 0.39$ , effect size = 0.53). A significant improvement was also observed in the NIHSS score over time in the BCI-FES group ( $p = 0.045$ , effect size = 1.06) but not in the Random-FES group ( $p = 0.44$ , effect size = 0.53).

Applying permutation tests separately to the subgroup of patients who started therapy in the acute and subacute phase, the differences showed an analogous pattern to that observed on applying an ANOVA. The BCI-FES group starting treatment in the acute phase showed a trend toward a difference ( $p = 0.070$ , effect size = 1.40), which was absent in the patients starting in the subacute phase ( $p = 0.16$ , effect size = 0.98). The difference was not significant in the Random-FES group starting treatment in the acute ( $p = 0.41$ , effect size = 0.98) or in the subacute phase ( $p = 0.40$ , effect size = 0.56).

#### TMS

Applying permutation tests to the TMS measurements, the improvements were significant for both groups: BCI-FES group ( $p = 0.040$ , effect size = 1.24); Random-FES group ( $p = 0.048$ , effect size = 0.82), with a greater increase over time in the BCI-FES than the Random-FES group ( $p = 0.040$ , effect size = 1.17).

#### High-density EEG

Comparing upper beta (15-23 Hz) oscillatory power, 0.5-1.5 s after the movement cue, between pre- and post-treatment, permutation tests showed the difference was also significant in the BCI-FES ( $p = 0.010$ , effect size = 1.77) but not in the Random-FES group ( $p = 0.44$ , effect size = 0.52).

Permutation testing showed a trend towards a difference between LRTC pre- and post-treatment in the BCI-FES ( $p = 0.095$ , effect size = 1.02) but not the Random-FES ( $p = 0.76$ , effect size = 0.16) group. On an individual level, all BCI-FES group patients showed an overall mean reduction in beta LRTC, compared with only one patient in the Random-FES group (Figure 7C).

EEG-EMG coherence in the time-frequency window in which spectral power changed from pre- to post-treatment in the BCI-FES group (0.5-1.5 s; 15-23 Hz), at the electrode location over the contralateral primary motor cortex at which the power difference was greatest (C2), differed significantly between pre- and post-treatment on permutation testing in the BCI-FES ( $p = 0.045$ , effect size = 1.72) but not the Random-FES ( $p = 0.95$ , effect size = -0.059) group.