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# Neural correlates of continuous feedback processing during the execution of a 2D driving task

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*Introduction:* Recent research of our group unveiled strong modulations akin to an error-related negativity (ERN) and error positivity ($P_e$) in the electroencephalogram (EEG) when faced with a continuous deviation of feedback from the intended target [1]. To answer two open questions – whether these modulations were induced in part by periodic visual input, and if the ERN- and $P_e$-like scalp potentials arise independently from each other in a phase-lock with the underlying error signal – we proposed a new paradigm. Within EEG measurements in 10 participants, we argue that the modulations are indeed feedback-related and that our observed potentials arise independently at distinct phases of the feedback-target deviation.

*Material, Methods, and Results:* EEG signals (60 channels, 10-10 system) of ten participants (7 female, 1 left-handed) have been recorded in pairs as one participant (Operator) executed 2D steering tasks while the other (Observer) observed their performance. Consecutively, four paradigm conditions were presented in 3 3.5-minute runs each. During the winding road condition, participants observed a self-driving car moving perfectly along a winding road while the Operator steered along. In three control conditions (full, erroneous (distinct/indistinct)), the Operator had first full, then limited steering control and was instructed to always stay on the white centerline. During erroneous control conditions, the car was then automatically moved away from the centerline as soon as it steered too close, leading to continuous deviations from the road. Following eye artifact removal and removal of front-most electrodes [2], bandpass-filtering (0.2-10Hz), and bad channel interpolation, data were re-referenced to their common average and epoched around [-3,3]s of a local maximum in deviation from the road (see Fig. 1).

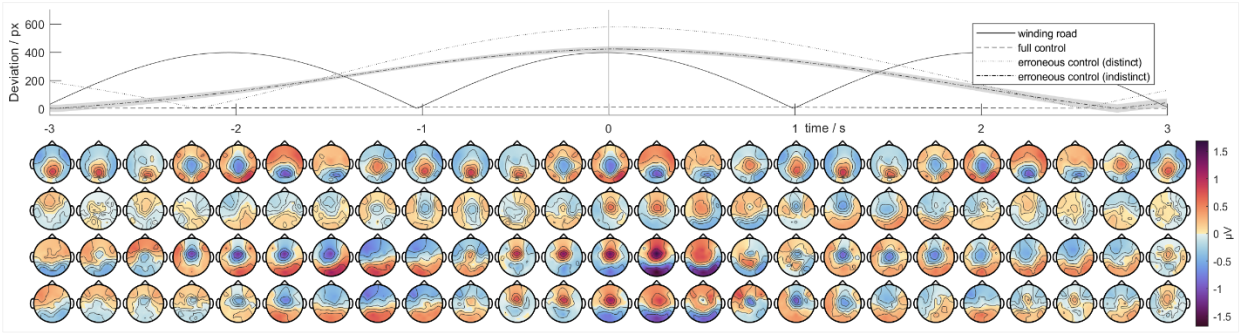


***Figure 1.*** *Grand average car deviation from the road* ***(top)*** *and grand average topographical maps* ***(bottom)*** *for the four conditions* winding road, full control, erroneous control (distinct/indistinct) *from top to bottom.*

*Discussion:* For all conditions, we observed clear modulations above parieto-occipital (winding road) and fronto-central (control) areas in the EEG corresponding to modulations in the feedback-target deviation, implying that the processes modulating with the visual input and the feedback processing are indeed distinct. Further, temporal distances of around 2s between ERN- and Pe-like scalp topographies promote that these correlates lock to distinct phases in the deviation signal, rather than a common event, as usually seen in discrete error processing literature [3].

*Significance:* The existence of neural correlates to continuous rather than discrete inputs demanding error/feedback processing, as well as the clear scalp topographies observed, promote new prospects regarding the instant correction of brain-computer interface tasks involving fine-tuned feedback control. As a next step, algorithms for classification or regression of the continuous feedback signal from the EEG may be worth exploring.

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