Non-Linear modelling of EEG event durations: A simulation approach

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Event related potentials (ERP) have been an essential part of Electroencephalography (EEG) analysis since its early days. Common practice is to average over many trials to get an estimate of the underlying brain response. However, many experiments contain events of variable length (e.g. due to differences in reaction times, fixation duration, stimulus duration, etc.). These varying durations are rarely considered, be it due to a lack of analysis tools or plain unawareness, in the worst case leading to biased or even nonsensical inferences about the nature of the brain. This is further complicated by the fact that varying event durations often co-occur with temporal overlap of different ERPs. For example, the brain response to a stimulus is directly followed by the response to a button press,

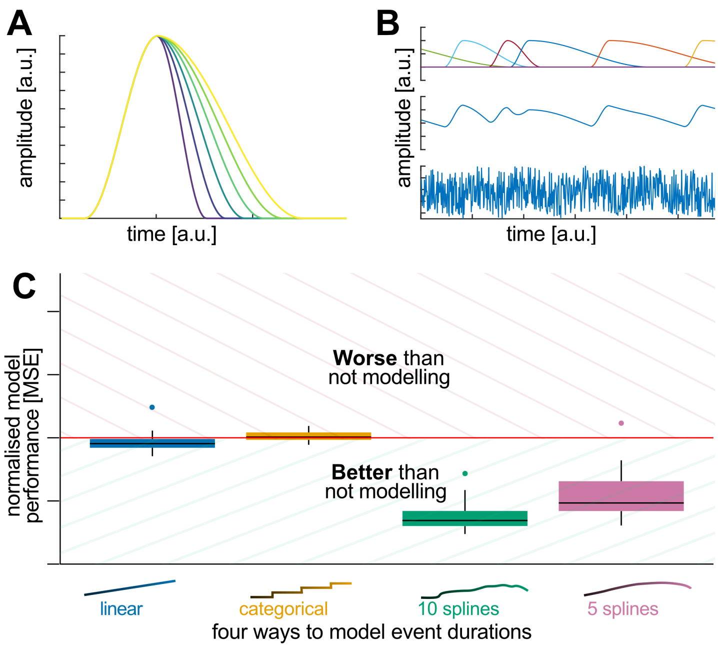

Figure 1: Ground truth ERP of one simulation showing different event durations (A); Isolated ERPs (B.top), continuous simultion without (B.middle) and with (B.bottom) noise; Model performance as compared to not modeling event duration. Event duration was modeled linearly (blue), categorical/ step-wise (yellow), non-linear with 10 splines (green), and with 5 splines (green).

Here, we systematically test approaches to model such duration effects. We simulated continuous EEG data consisting of overlapping ERPs with a duration effect (Fig. 1.B). Then, we applied regression methods to the simulated data and systematically explored how event duration affects the resulting ERPs and how to adequately model them. To account for temporal overlap, we used deconvolution-based overlap correction as implemented in the unfold-toolbox ([1], [2]) and investigated its additional influence on the performance of ERP estimation.

We find that modelling event durations as binned or linear predictors performs poorly. However, non-linear effects using spline regression seem to be able to capture the main patterns and are thus a promising candidate for application to real-world data (see Fig. 1.C).

In a second step, we applied our approach to a real P300 dataset ([3]). In the P300, event duration is defined by the time it takes for participants to decide whether a presented stimulus is a *target* or *non-target*. We analyzed the data in three different ways to assess the influence of both overlap and the interaction between overlap and reaction time on the ERP. 1) we modeled ERP in the traditional way, disregarding both overlap and reaction time. 2) We used a model where only overlap was modelled. And 3) we used a model incorporating both the influence of overlap and reaction time.

As expected, we found a significant difference between target and non-target in the traditional approach (p ¡ 0.001). Similarly, we found a significant difference between conditions when modeling overlap but not reaction time (p ¡ 0.001). However, when modeling both overlap and reaction time, no significant difference between conditions remains (p = 0.22). The duration effect might have confounded most of the P300 effect.

At first sight, this finding is very surprising, as it implies that the famous P300 stems (at least in some cases) from a mere difference in reaction time. If true, this would directly contradict prominent theories about the function of the P300 ([5]). However, reaction time and overlap as a source of the P300 is not necessarily new, the P300 as a result of overlap to button press responses has been proposed as a potential confound before ([4], [6]).

References

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