Markov-switching models enable precise recovery of cognitive events from trial-level pupil dilation time courses

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Pupil dilation time courses are assumed to be a slow and indirect reflection of the latent cognitive events involved in task performance. Additive models of pupil dilation can be used to recover these events through deconvolution, promising a more precise study of cognitive processes. To this end, the conventional deconvolution method assumes that cognitive events all trigger a delayed pupil response. The weighted sum of these individual responses is then believed to be reflected in the pupil dilation time course.

Importantly, the conventional method typically assumes the same shape for the pupil responses elicited by all events. Additionally, the method is usually applied to averaged time courses. Thus, it neglects the possibility that the timing between events and the shape of the response differs not just between subjects but also between trials and even different cognitive events. However, accounting for trial and event-level variability is crucial to achieve precise recovery of latent events and thereby a detailed understanding of cognitive processing. Moreover, accounting for trial-level variability is necessary when investigating how trial-level predictors (e.g., continuous word frequency) influence cognitive processes involved in task performance.

To ensure a precise recovery of latent cognitive events, we propose an extended model that combines generalized additive mixed models with Hidden semi-Markov models. We will show that despite the added complexity the model recovers parameters accurately and that the risk of overfitting is minimized through efficient and automatic regularization. Finally, we will apply this model to data from a lexical decision experiment in which participants processed words and two types of non-words which differed in their frequency (approximated with Google result counts), to investigate the cognitive events involved in lexical decisions and how they are affected by word type and frequency manipulations.