Investigating early frequency effects in lexical decision making using pupil deconvolution

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The pupil dilation response is assumed to be a slow and indirect reflection of the latent cognitive events involved in task performance (Hoeks & Levelt, 1993). Conventional pupil deconvolution methods attempt to recover these events, promising a more precise study of cognitive processes (e.g., Wierda et al., 2012; Willems et al., 2015; Denison et al., 2020). We show that the assumptions made by the method are problematic when modelling data from psycholinguistic experiments such as lexical decision (LD) tasks and propose an extended model that combines generalized additive mixed models (Wood, 2017; van Rij et al., 2019) with Hidden semi-Markov models (Yu, 2010; Anderson et al., 2016) to address these problems.

The conventional model assumes that cognitive events all trigger a delayed pupil response (Hoeks & Levelt, 1993). The weighted sum of these individual responses is then believed to be reflected in the pupil dilation time course. Importantly, the conventional model is typically applied to averaged time courses, and thereby neglects the possibility that the timing between events and the shape of the response differs not just between subjects but also trials and events (cf. Wierda et al., 2012). However, accounting for trial-level variability is crucial for at least two reasons. First this is necessary for a precise recovery of latent events and thereby a detailed understanding of cognitive processing (cf. Anderson et al., 2016). Secondly, this enables the study of trial-level predictor variables, enabling for example the investigation of how continuous word frequency influences language processing.

We will compare the proposed extended model to the conventional method by applying both methods to the data from a LD experiment (N=26) in which we manipulated the frequency of words *and* nonwords (approximated by Google search result counts; Hendrix & Sun, 2020). We will explain how the extended model addresses the problems of the conventional deconvolution method, and show the results of the extended method: how the (early) cognitive events involved in lexical decisions are influenced by word and nonword frequency.

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