The Pros of using PAMMs: From Reaction Times to Response Dynamics

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Reaction times are an often-studied outcome variable in psycholinguistic research, as they provide insight into the processes underlying language comprehension and production. These data are most often analyzed using linear mixed-effects models (LMMs), or generalized additive mixed models (GAMMs) [1,2,3,4]. While these approaches can capture overall effects of predictors, they typically treat time as a dependent variable, thereby ignoring the question of *when* certain effects emerge during a response.

Piece-wise additive mixed models (PAMMs), on the contrary, model the *hazard rate*, i.e., the instantaneous probability that a response occurs at a given time, provided that it has not yet occurred, with non-linear effects that are allowed to vary during the response time window, while also incorporating random effects [5]. This makes it possible, for example, to examine how predictors such as word frequency, phonological neighborhood density and even predictors whose value changes during a trial such as the time relative to the uniqueness point influence auditory lexical decision during the whole response time window. Therefore, PAMMs show potential to be a useful addition to the psycholinguist's toolbox, but have been underutilized, as they have been applied to only a handful of studies thus far [6,7,8,9].

We evaluate PAMMs as a methodological alternative for analyzing reaction time data by applying them to the Massive Auditory Lexical Decision dataset [3] and by directly comparing them to commonly used approaches such as LMMs and GAMMs. We show how PAMMs provide a more detailed account of lexical processing by revealing how predictor effects evolve over time, which cannot easily be captured by traditional approaches. This difference is illustrated in Figure 1, where the GAM provides a time-averaged effect, while the PAMM reveals that the effect of log frequency is strongest early in the response process, where low-frequency words are associated with a reduced hazard, and diminishes at later time points.

We also provide guidance to psycholinguists by outlining the necessary steps to get a typical dataset into the proper data structure, model fitting, model evaluation and interpretation.

References

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Figure 1: The left panel shows the smooth effect of log frequency on mean response time estimated from a generalized additive model (GAM). The right plot shows the corresponding time-dependent effect estimated from a piece-wise additive mixed model (PAMM). Warmer colors indicate higher (log) hazard rates, reflecting an increased probability of responding, while cooler colors indicate reduced hazard. Clear, saturated regions indicate a significant effect.