¹ A tutorial on Bayesian and Frequentist Event History Analysis for psychological

² time-to-event data

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Abstract

Time-to-event data such as response times, saccade latencies, and fixation durations are
ubiquitous in experimental psychology. To move beyond mean performance measures,
various distributional analyses have been proposed. Here we focus on one particular
distributional analysis known as discrete-time event history analysis, a.k.a. hazard
analysis, duration analysis, failure-time analysis, survival analysis, and transition analysis.
Across three tutorials that we make publicly available on Github and OSF, we illustrate
how to calculate and interpret descriptive statistics, and how to implement Bayesian and
frequentist regression models, using the R packages tidyverse, brms, and lme4. We discuss
how to manage inter-individual differences, implications for experimental design, and select
among various options when analysing time-to-event data using discrete-time survival
analysis.

Keywords: response times, event history analysis, Bayesian regression models

Word count: X

₂₇ A tutorial on Bayesian and Frequentist Event History Analysis for psychological

₂₈ time-to-event data

Introduction

₃₀ In experimental psychology, it is still standard practice to analyse response times

₃₁ (RTs), saccade latencies, and fixation durations using analysis-of-variance. However,

₃₂ differences in means conceal when an experimental effect starts, how long it lasts, and

₃₃ whether its onset is time-locked to other events. Such information is useful not only for

₃₄ interpretation, but also for cognitive psychophysiology and computational model selection

₃₅ (Panis, Schmidt, Wolkersdorfer, & Schmidt, 2020). In this tutorial we focus on a

₃₆ distributional method for analyzing time-to-event data that is known as discrete-time event

₃₇ history analysis (EHA), a.k.a. survival, hazard, duration, failure-time, and transition

₃₈ analysis (Allison, 1982, 2010; Singer & Willett, 2003). Across three tutorials that we make

₃₉ publicly available on Github and OSF, we illustrate how to calculate and interpret

₄₀ descriptive statistics, and how to implement Bayesian and frequentist regression models,

₄₁ using the R packages tidyverse, brms, and lme4.

₄₂ To apply EHA, one must be able to define the event of interest (e.g., a button press,

₄₃ saccade onset, fixation offset), time point zero (e.g., target stimulus onset, fixation onset),

₄₄ and measure the passage of time between time point zero and event occurrence in discrete

₄₅ or continuous time units.

₄₆ The shape of a distribution of waiting times can be described in multiple ways (Luce)

₄₇ Because waiting times can only increase, continuous-time EHA does not focus on the

₄₈ cumulative distribution function $F(t) = P(RT \leq t)$ and its derivative, the probability

₄₉ density function $f(t) = F(t)'$, but on the survivor function $S(t) = P(RT > t)$ and the

₅₀ hazard rate function $\lambda(t) = f(t)/S(t)$. The hazard rate function gives you the instantaneous

₅₁ rate of event occurrence at time point t, given that the event has not occurred yet.

52   Similarly, after dividing time in discrete, contiguous time bins indexed by t,

53 discrete-time EHA focuses on the discrete-time survivor function $S(t) = P(RT > t)$ and the

54 discrete-time hazard function $h(t) = P(RT = t| RT \geq t)$, and not on the probability mass

55 function and the cumulative distribution function. The discrete-time hazard probability

56 function gives you the probability that the event occurs (sometime) in bin t, given that the

57 event has not occurred yet in previous bins.

58   Statisticians and mathematical psychologists recommend focusing on the hazard

59 function when analyzing time-to-event data for various reasons. First, ... Second...

60   We focus on factorial within-subject designs in which a large number of

61 measurements are taken for a relatively small set of participants. Such so-called small-N

62 designs are ... (Smith and little)

63   We used R (Version 4.4.0; R Core Team, 2024)[1] for all reported analyses. Web links

64 are printed in bold.

Tutorial 1: Calculating descriptive statistics using a life table

66   To illustrate how to quickly set up life tables for calculating the descriptive statistics

67 (functions of discrete time), we use a published data set on masked response priming from

68 Panis and Schmidt (2016), available on **ResearchGate**. In their first experiment, Panis

69 and Schmidt (2016) presented a double arrow for xx ms that pointed left or right as the

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[1] We, furthermore, used the R-packages *citr* (Version 0.3.2; Aust, 2019), *dplyr* (Version 1.1.4; Wickham, François, Henry, Müller, & Vaughan, 2023), *forcats* (Version 1.0.0; Wickham, 2023a), *ggplot2* (Version 3.5.1; Wickham, 2016), *lubridate* (Version 1.9.3; Grolemund & Wickham, 2011), *papaja* (Version 0.1.2.9000; Aust & Barth, 2023), *patchwork* (Version 1.2.0; Pedersen, 2024), *purrr* (Version 1.0.2; Wickham & Henry, 2023), *RColorBrewer* (Version 1.1.3; Neuwirth, 2022), *readr* (Version 2.1.5; Wickham, Hester, & Bryan, 2024), *stringr* (Version 1.5.1; Wickham, 2023b), *tibble* (Version 3.2.1; Müller & Wickham, 2023), *tidyr* (Version 1.3.1; Wickham, Vaughan, & Girlich, 2024), *tidyverse* (Version 2.0.0; Wickham et al., 2019), and *tinylabels* (Version 0.2.4; Barth, 2023).

target stimulus with an onset at time point zero in each trial. Participants had to indicate the direction in which the arrow pointed using their corresponding index finger. Response time and accuracy were recorded on each trial. Prime type (neutral, congruent, incongruent) and mask type were manipulated. Here we focus on the subset of trials in which no mask was presented. The xx-ms prime stimulus was a double arrow with onset at -xx ms for the congruent and incongruent prime conditions.

Tutorial 2: Fitting Bayesian hazard models

Tutorial 3: Fitting Frequentist hazard models

Methods

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study.

Participants

Material

Procedure

Data analysis

Results

Discussion

References

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