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Power Priors for Replication Studies

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Abstract

In a replication study, researchers repeat an original study as closely as possible to see if new data yield similar results. However, there is no established way to quantify how "successful" a replication attempt was. We propose a novel power prior approach: The likelihood of the original study's data is raised to the power of α, and then used as the prior distribution for analyzing the replication data. The degree of compatibility between original and replication study is quantified by the posterior distribution and hypothesis tests related to the power parameter α. Inferences for other parameters, such as effect sizes, dynamically borrow information from the original study. The degree of borrowing depends on the conflict between the two studies. An application to data from the Reproducibility Project: Cancer Biology illustrates the advantages and limitations of the method.

Exploring these limitations also led to two new theoretical results about power priors, which we will also present: First, we give the asymptotic posterior distribution of α based on the commonly assigned beta prior on α. Counterintuitively, when the replication data perfectly mirror the original data, the posterior of α does not converge to a point mass at $\alpha = 1$ but approaches a distribution that hardly differs from the prior. This implies that a complete pooling of original and replication data is impossible when beta priors are assigned to α. Second, we explore the connection between power priors and hierarchical models and find that power prior inferences with beta priors on α align with hierarchical model inferences using a generalized beta prior on the relative heterogeneity variance I^2 known from meta-analysis. The connection illustrates that power prior modeling is unnatural from the perspective of hierarchical modeling since it corresponds to specifying priors on a relative rather than an absolute heterogeneity scale.

Keywords: Bayes factor, Bayesian hypothesis testing, Bayesian parameter estimation, borrowing, hierarchical models, historical data, meta-analysis, power priors, replication studies

References

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