Correcting for publication bias in a meta-analysis with *p*-uniform*

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Message

- Publication bias is omnipresent in science
- Publication bias $\rightarrow$ overestimation of effect size in meta-analysis
- The publication bias method *p*-uniform overestimates effect size in case of between-study variance in true effect size
- The improved and extended method *p*-uniform*:
  1. eliminates overestimation due to between-study variance
  2. is a more efficient estimator than *p*-uniform's estimator
  3. enables estimating and testing of the between-study variance

Overview

1. Publication bias
2. From *p*-uniform to *p*-uniform*
3. Simulation study
4. Conclusion and discussion

Publication bias

- Publication bias is “the selective publication of studies with a significant outcome”
- Overwhelming evidence for publication bias:
  - 95% of published articles contain significant results in psychology (1/40!)

From *p*-uniform to *p*-uniform*: *p*-uniform

- Only considers significant effect sizes and discards others
- Distribution of *p*-values at the true effect size is uniform
- Only significant effect sizes, so conditional probabilities:

$$q_i = \frac{1 - \Phi\left(\frac{y_i - \mu}{\sigma_i}\right)}{1 - \Phi\left(\frac{y_{cv} - \mu}{\sigma_i}\right)}$$

- Tests for uniformity are used to evaluate whether q_i are uniformly distributed

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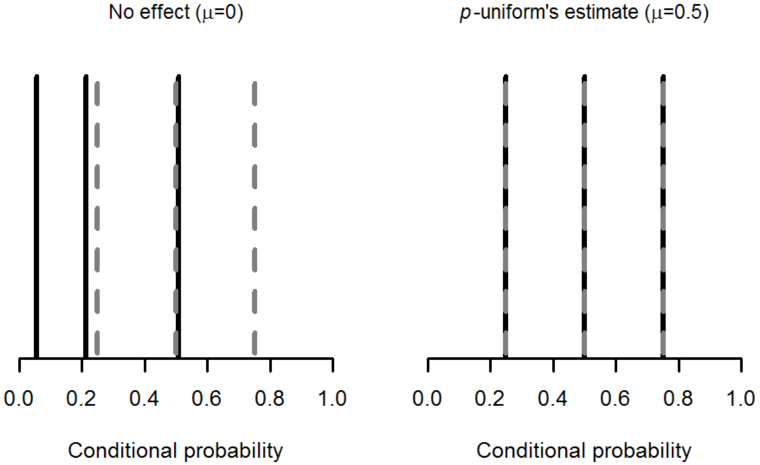
- Assumptions:
  - Homogeneous true effect size
  - All significant effect sizes have an equal probability of getting included in a meta-analysis

From *p*-uniform to *p*-uniform*: *p*-uniform

- Example with three observed effect sizes ($\mu = 0.5$):

$t(48)$=3.133, p=.0029; $t(48)$=2.646, p=.011; $t(48)$=2.302, p=.025



From p-uniform to p-uniform*: p-uniform*

- *P*-uniform* considers the significant **and** nonsignificant effect sizes

- Now effect sizes not only conditional on significance but also on nonsignificance

- Maximum likelihood estimation is used $\rightarrow$ truncated densities

Significant	Nonsignificant
$q_i^* = \dfrac{\phi\left(\frac{y_i-\mu}{\sqrt{\sigma_i^2+\tau^2}}\right)}{1-\Phi\left(\frac{y_{cv}-\mu}{\sqrt{\sigma_i^2+\tau^2}}\right)}$	$q_i^* = \dfrac{\phi\left(\frac{y_i-\mu}{\sqrt{\sigma_i^2+\tau^2}}\right)}{\Phi\left(\frac{y_{cv}-\mu}{\sqrt{\sigma_i^2+\tau^2}}\right)}$

- Likelihood function: $L(\mu, \tau^2) = \prod q_i^*$

From *p*-uniform to *p*-uniform*: *p*-uniform*

- Confidence intervals and testing hypotheses
- We also implemented several methods of moments estimators
- Important assumption:
  - Probability of including a significant and nonsignificant effect size in a meta-analysis is assumed to be constant (but may differ from each other)

Simulation study: Method

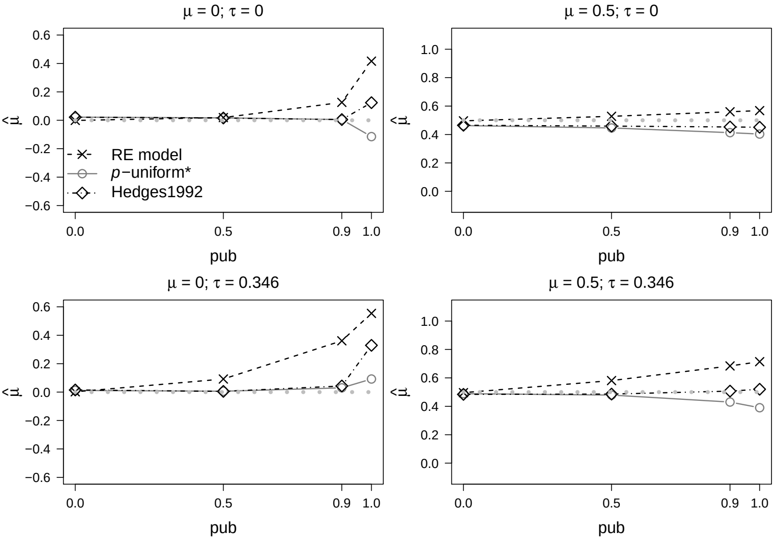
- **Goal:** Evaluate performance of *p*-uniform* and compare to other methods

- Effect size measure is standardized mean difference with 50 as sample size per group

- Conditions:
  - $\mu = 0; 0.2; 0.5$
  - $\tau = 0; 0.163; 0.346 \rightarrow I^2 = 0\%; 40\%; 75\%$
  - Number of studies (k) = 10; 30; 60; 120
  - Extent of publication bias (pub) = 0; 0.5; 0.9; 1

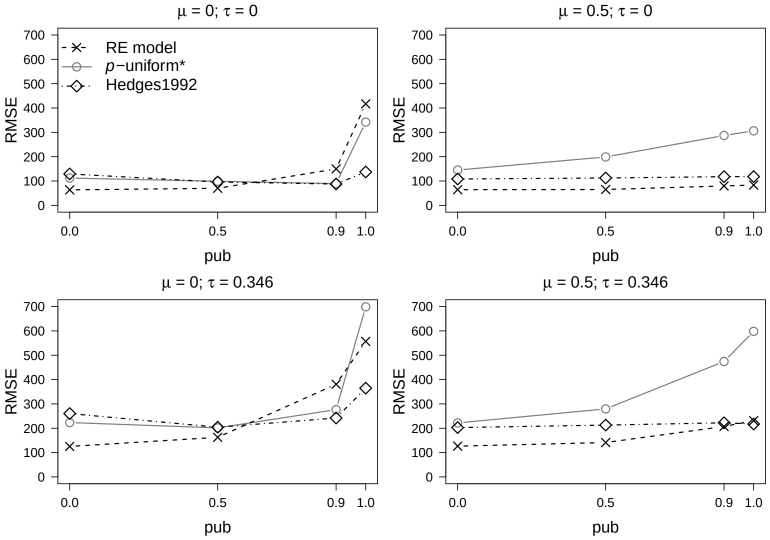
- Included methods:
  - *p*-uniform*
  - random-effects model $\rightarrow$ Paule-Mandel estimator for τ^2
  - selection model approach by Hedges (1992) $\rightarrow$ cut-off at α=.05

Simulation study: Estimating μ



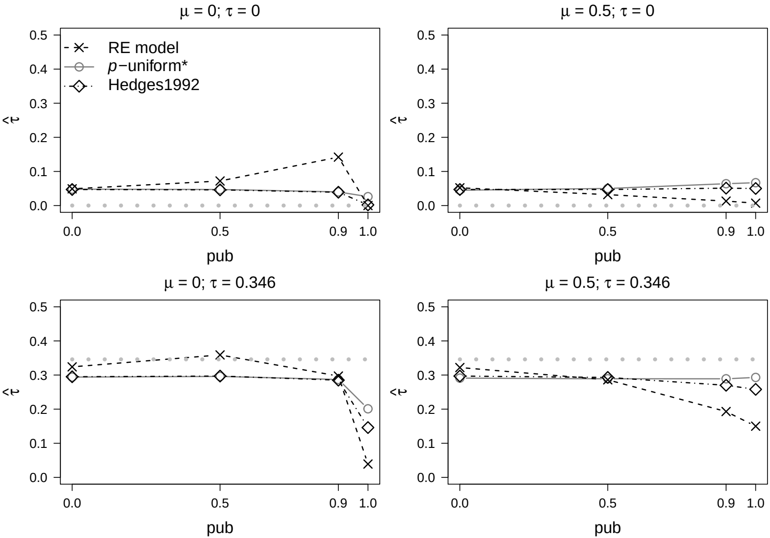
- Random-effects model overestimates μ if $pub > 0$
- Bias of p-uniform* and Hedges1992 is largest if $pub = 1$

Simulation study: RMSE Estimating μ



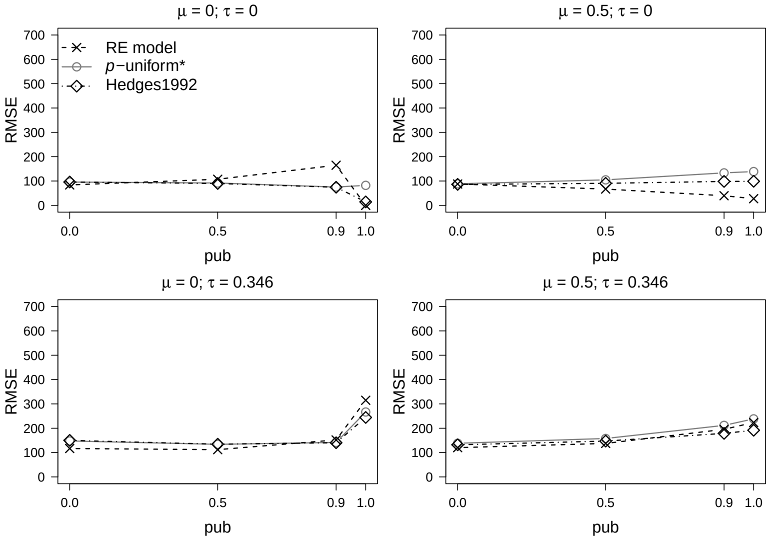
- RMSE of all methods increased as a function of τ and *pub*
- RMSE of *p*-uniform* generally larger than Hedges1992

Simulation study: Estimating τ



- RE model overestimates τ if $\tau = 0$ and underestimates if $\tau > 0$
- *P*-uniform* less negatively biased than Hedges1992 if $\tau > 0$

Simulation study: RMSE Estimating τ



- RMSE of all methods increased as a function of *pub* if $\tau > 0$
- RMSE of *p*-uniform* generally slightly larger than Hedges1992

Conclusion and discussion

- *P*-uniform* is an improvement over *p*-uniform, because
  1. eliminates overestimation due to between-study variance
  2. is a more efficient estimator than *p*-uniform's estimator
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- Random-effects model had the best statistical properties in the absence of publication bias

- Statistical properties of *p*-uniform* and the selection model approach by Hedges (1992) were comparable

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- Recommendations:
  - report results of *p*-uniform* and selection model approach by Hedges (1992) in any meta-analysis
  - be reluctant when extreme publication bias is expected with only significant effect sizes

Conclusion and discussion

- Software:
  - *p*-uniform*: R package `puniform` and web application https://rvanaert.shinyapps.io/p-uniformstar
  - Hedges' (1992) selection model approach: R package `weightr` and web application https://vevealab.shinyapps.io/WeightFunctionModel
- Future research:
  - Violations of the assumption of equal probabilities of significant and nonsignificant effect sizes for getting published
  - *P*-uniform*'s publication bias test
  - Consequences of *p*-hacking

Thank you for your attention