Meta-analysis: Shortcomings and potential

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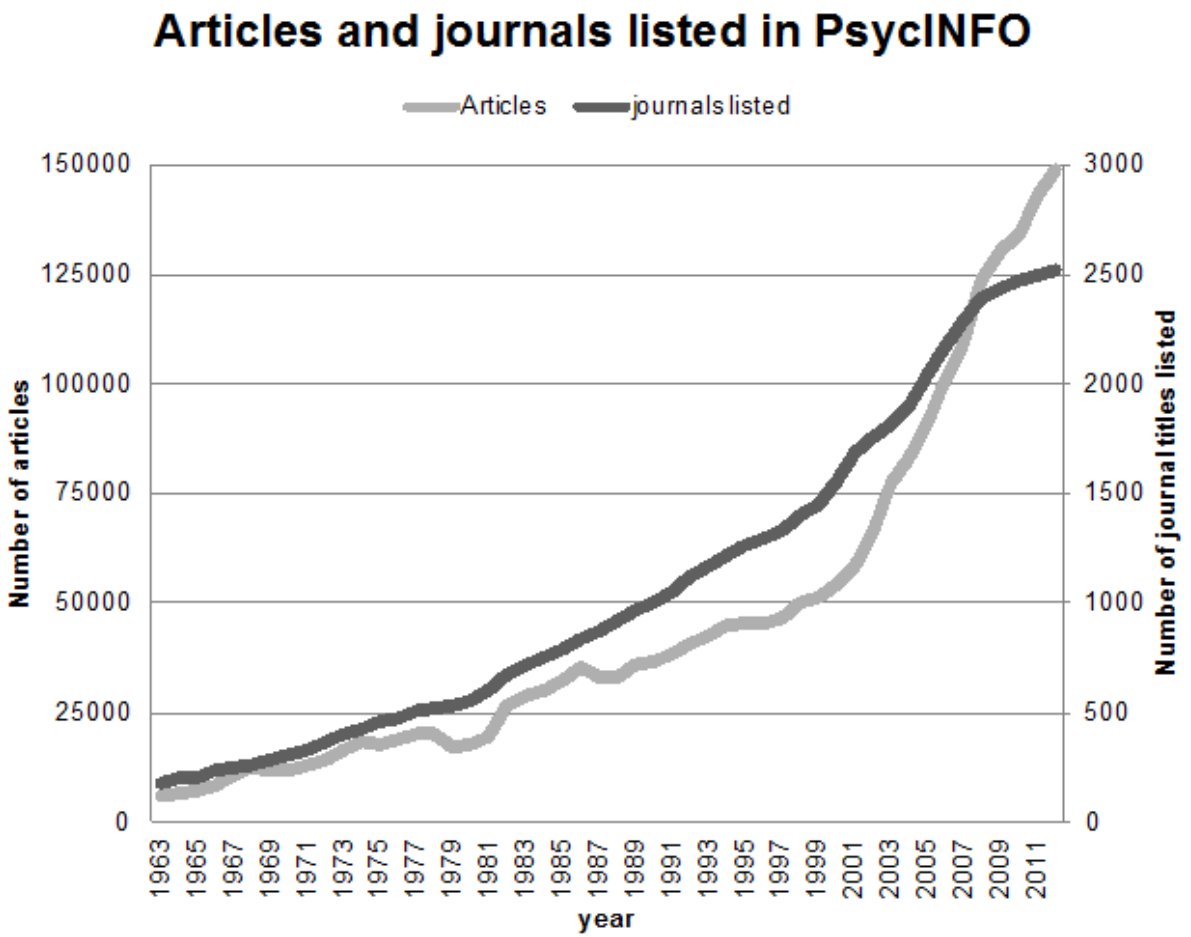
Overview

1. Meta-analysis
2. Publication bias
3. Replication research and meta-analysis: Snapshot method
4. Other chapters of dissertation
5. Software

Meta-analysis

- Meta-analysis is "the statistical synthesis of the data from separate but similar studies leading to a quantitative summary"



Meta-analysis

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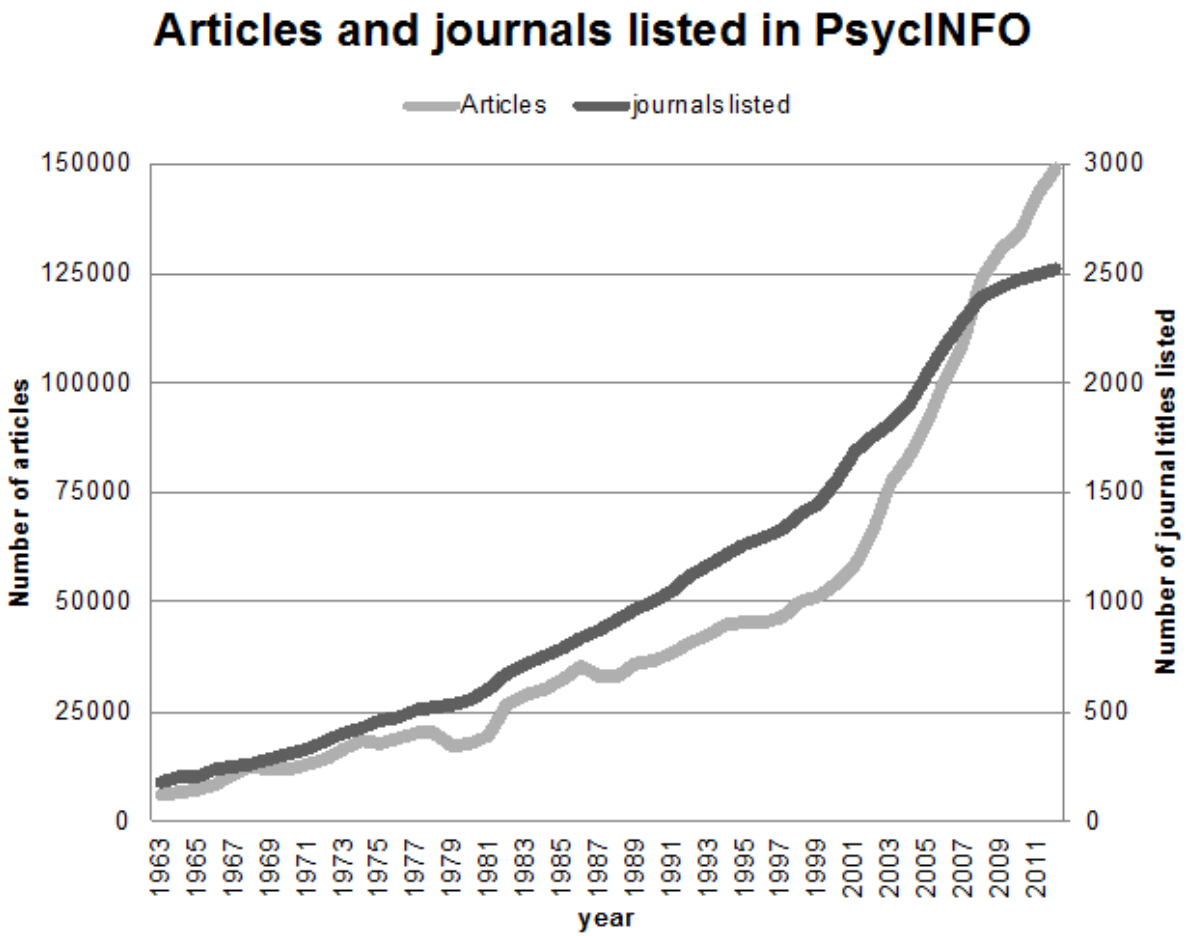
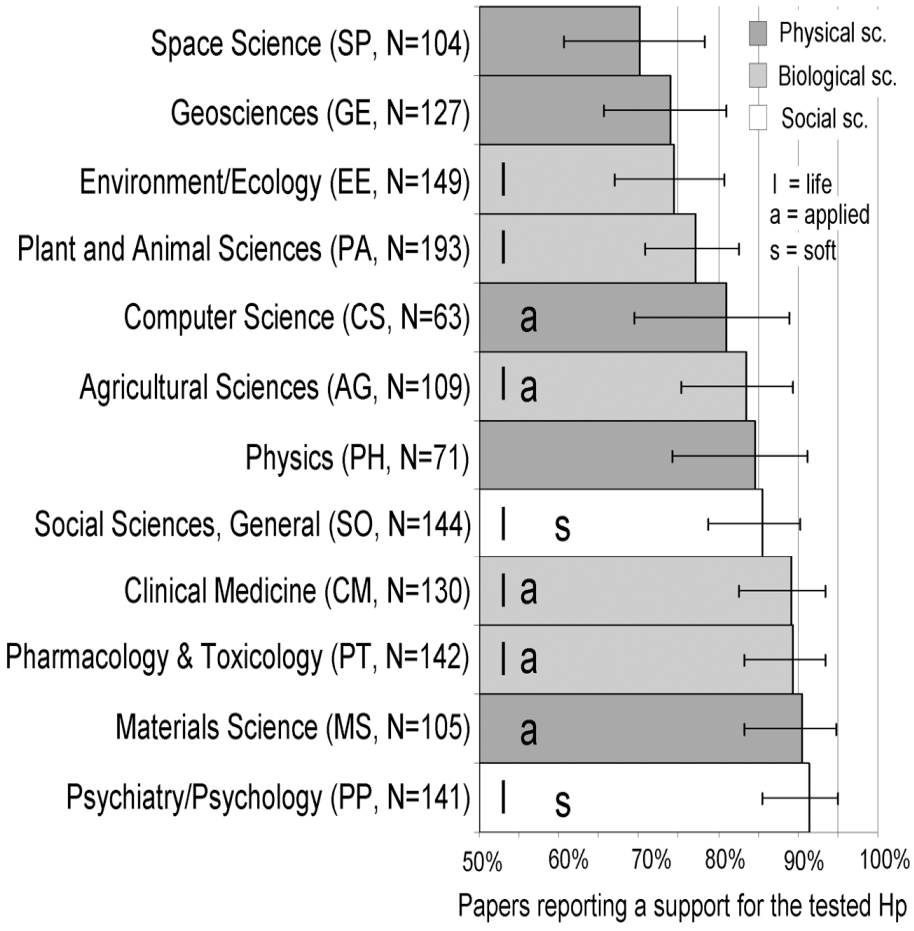


- But... what is the quality of the studies we are combining?

Publication bias

- Publication bias is "the selective publication of studies with a significant outcome"
- ≈90% of main hypotheses are significant in psychology
- But this is not in line with average statistical power (about 20-50%)
- Consequences:
  - Overestimation
  - False impression



Adapted from Fanelli (2010)

Replications and meta-analysis: The problem

- Example of a common problem (independent samples t-test):

	Cohen's d	t-statistic
Original	0.5	$t(78) = 2.24$, $p = .028$
Replication	0.23	$t(170) = 1.5$, $p = .135$

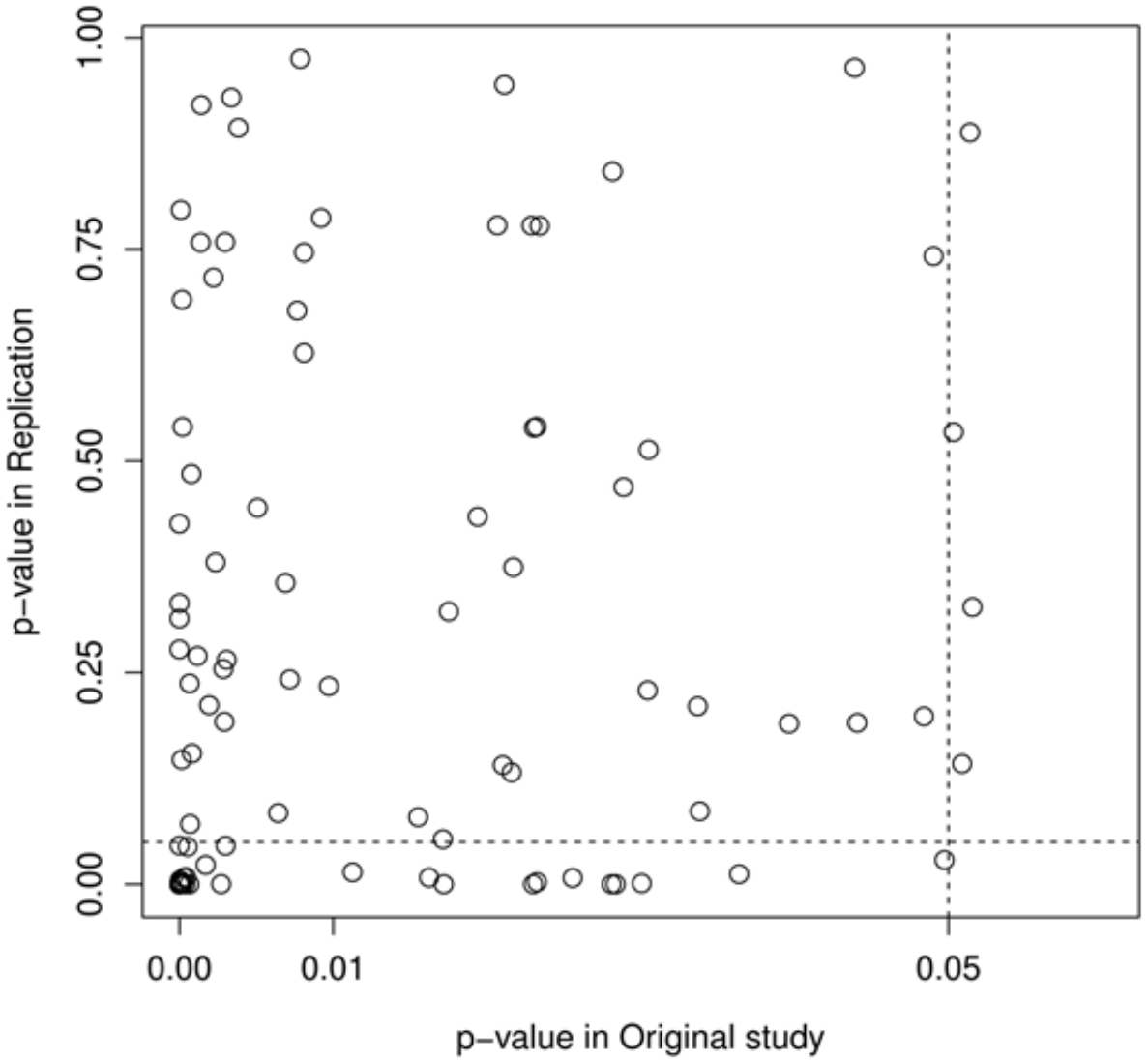
What to conclude?!

Questions considered relevant:

- Does an effect exist? (0 or not)
- What is the magnitude of effect size? (best guess)

Replications and meta-analysis: The problem

- Distribution of *p*-values in Reproducibility Project: Psychology
  - Significant original and nonsignificant replication in 63.9%



Replications and meta-analysis: The problem

- Significant results are overrepresented in the literature
- Published effect sizes are therefore most probably overestimated
- Replicability projects in psychology (RPP) and economics (EE-RP) confirmed that effect sizes are overestimated:
  - RPP: $r = 0.403$ vs. 0.197
  - EE-RP: $r = 0.506$ vs. 0.303
- **Conclusion:** We should take statistical significance of original study into account

Snapshot method

- **Snapshot** Bayesian Hybrid Meta-Analysis Method
  - Assume four effect sizes (zero, small, medium, large) $\rightarrow$ *snapshots*
- Snapshot **Bayesian** Hybrid Meta-Analysis Method
  - Compute posterior probability of these four effects $\rightarrow$ *Bayesian*
- Snapshot Bayesian **Hybrid** Meta-Analysis Method
  - Take statistical significance of original study into account $\rightarrow$ *hybrid*
- Snapshot Bayesian Hybrid **Meta-Analysis** Method
  - Combine original study with replication $\rightarrow$ *meta-analysis*

Snapshot method: Basic idea

- Density of the replication is "normal" pdf because no selection:

$$f_r = f(y = y_r; \theta)$$

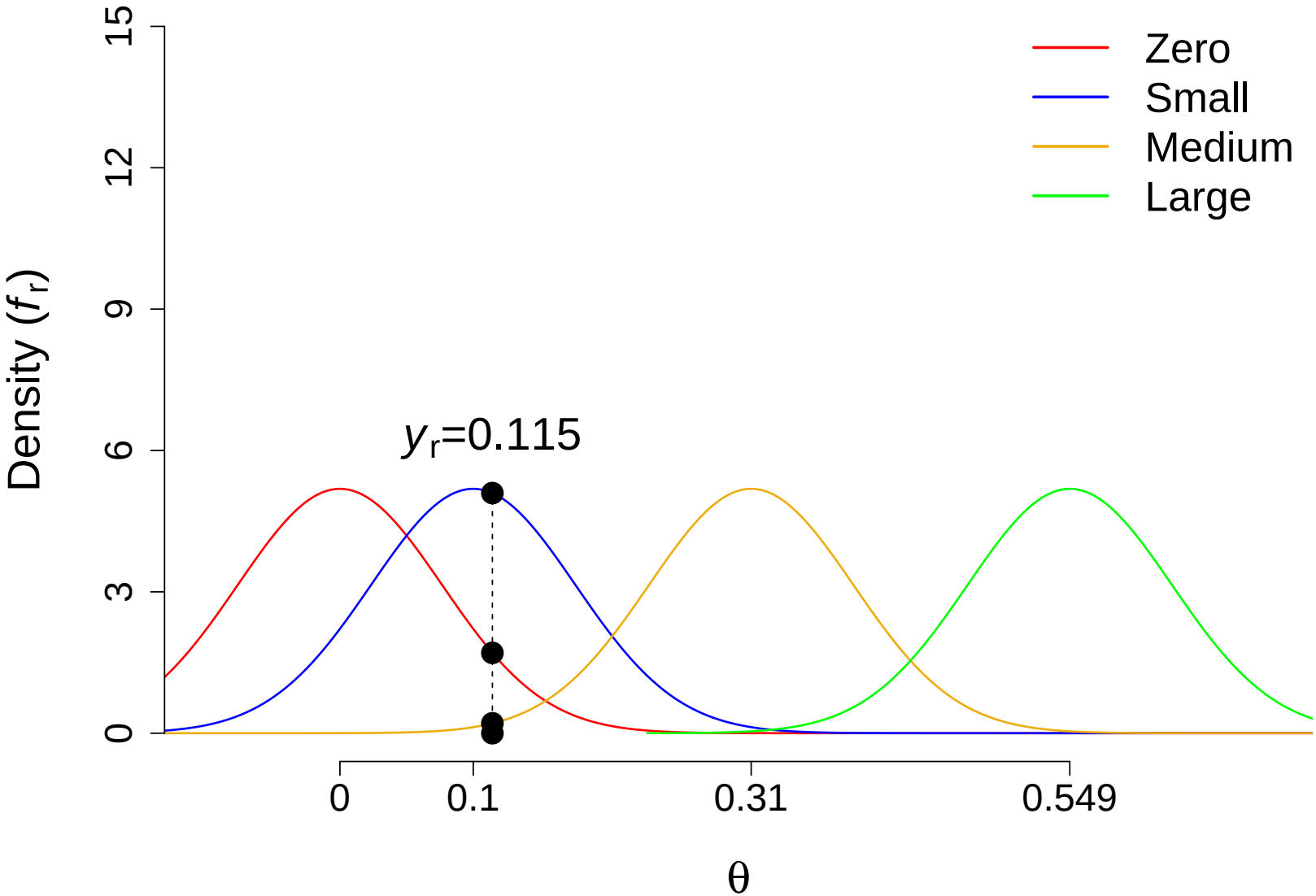
- Density of the original study is pdf *conditional on effect size being statistically significant*:

$$f_o = \frac{f(y = y_o; \theta)}{P(y \geq y_{cv}; \theta)}$$

- Assumptions:
  - Original study is statistically significant
  - Both studies estimate the same effect (fixed-effect)

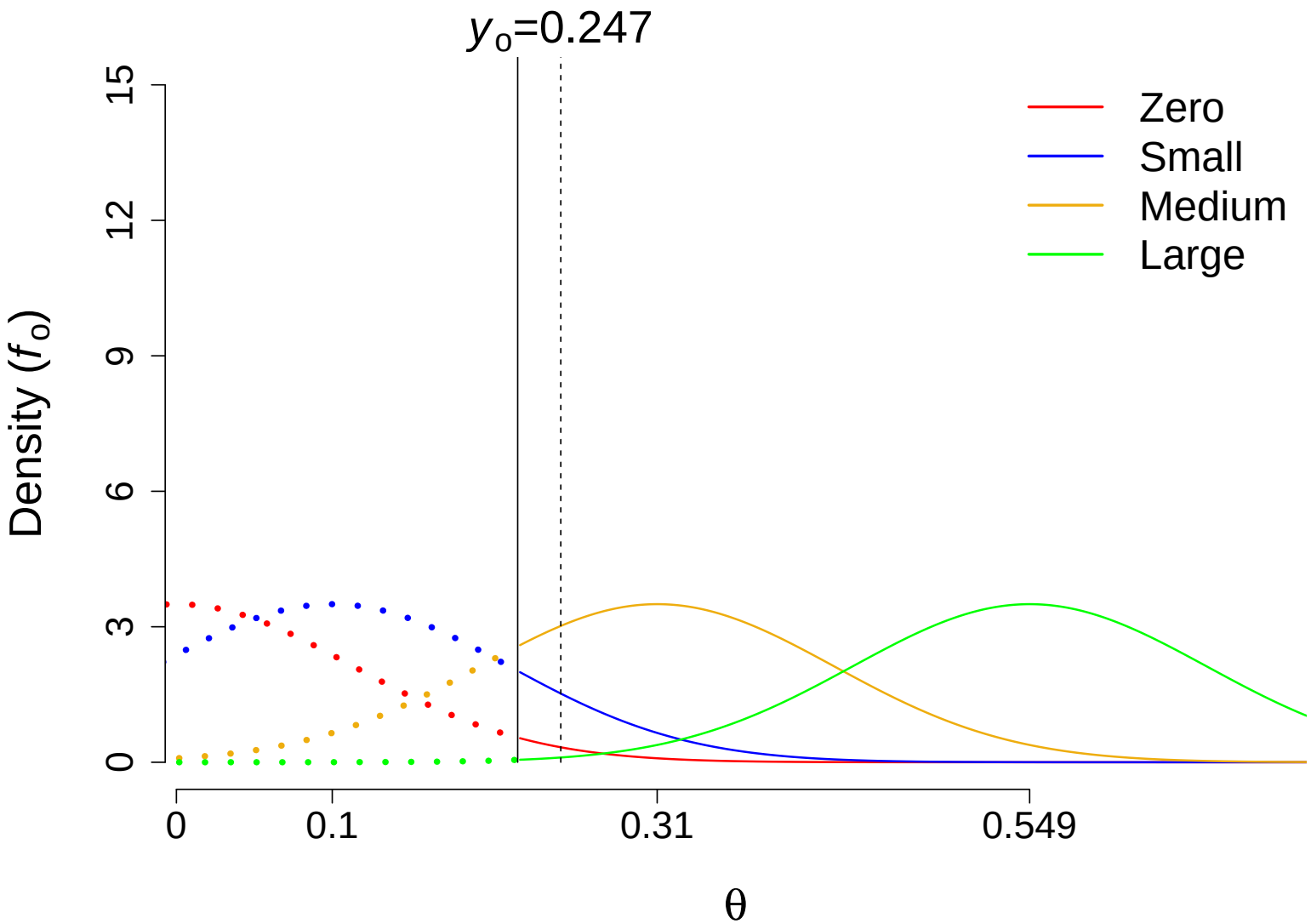
Snapshot method: Basic idea

- Densities replication: $d = 0.23$, $t(170) = 1.5$, $p = 0.135$



Snapshot method: Basic idea

- Densities original study (naïve): $d = 0.5$, $t(78) = 2.24$, $p = 0.028$



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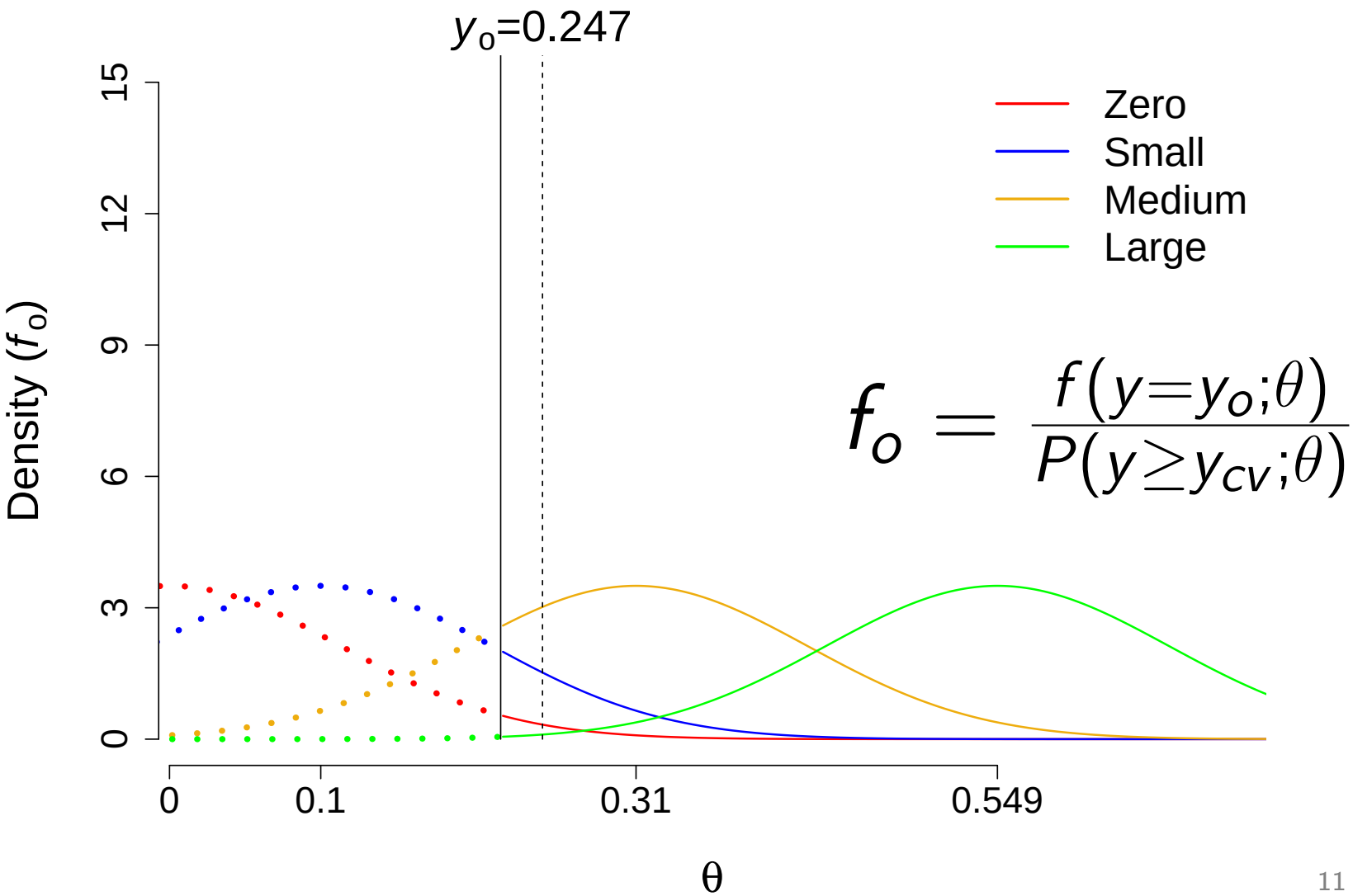

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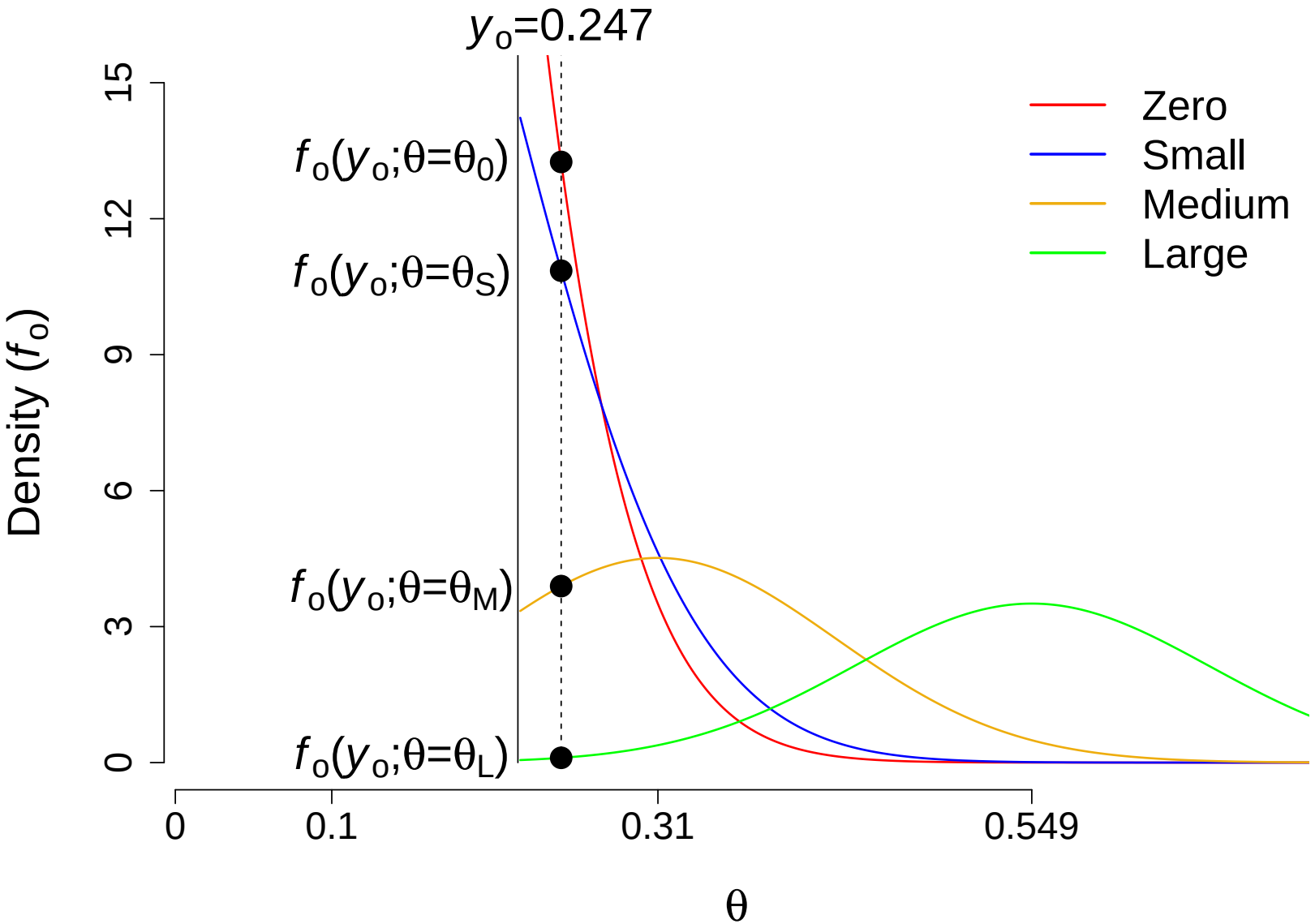

Snapshot method: Basic idea

- Combined likelihood:

$$L(\theta) = f_o(\theta) \times f_r(\theta)$$

- Posterior probabilities assuming a uniform prior for each snapshot are computed with:

$$\pi_x = \frac{L(\theta = x)}{L(\theta = \theta_0) + L(\theta = \theta_S) + L(\theta = \theta_M) + L(\theta = \theta_L)}$$

- Advantages of the method:
  - Easy and insightful
  - Easy (re)computation posterior for other (than uniform) prior:

$$\pi_x^* = \frac{p_x \pi_x}{p_0 \pi_0 + p_S \pi_S + p_M \pi_M + p_L \pi_L}$$

Snapshot method: Example

- Example of a common problem (independent samples t-test):

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- Applying snapshot method:

	Zero	Small	Medium	Large
Naïve	0.063	0.866	0.071	0
Snapshot				

Snapshot method: Example

- Example of a common problem (independent samples t-test):

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Original	0.5	$t(78) = 2.24$, $p = .028$
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- Applying snapshot method:

	Zero	Small	Medium	Large
Naïve	0.063	0.866	0.071	0
Snapshot	0.287	0.703	0.01	0

- Evidence of zero effect increased; best guess = small effect

Application: RPP and EE-RP

- Initiatives to study the replicability of psychological and economic research
- **RPP:** Studies from JPSP, Psychological Science, and Journal of Experimental Psychology: 67 out of 100 studies were included
- **EE-RP:** Experimental research from the American Economic Review and Quarterly Journal of Economics: 16 out of 18 studies were included
- "High-powered" replication of a key effect

Application: RPP and EE-RP

- Probability of strong evidence (π_x >.75; BF >3) using snapshot method

	Zero	Small	Medium	Large	Unknown
EE-RP	0	0.062	0.312	0.438	0.188
RPP	0.134	0.03	0.045	0.164	0.627

- **Conclusions:**
  - Studied effects larger in EE-RP than in RPP
  - Only few studies have strong evidence for zero effect in RPP (13.4%)
  - Often not enough information for determining magnitude of effect size in RPP (62.7%)

Conclusion and discussion: Snapshot method

- Methods *should* take statistical significance of original study into account
- We developed such a method within a Bayesian framework
- An analytical study showed that huge sample sizes ($N \approx 1000$) are needed to distinguish zero from small effect
- Determining sample size of replication with snapshot method akin to computing required sample size with power analysis

Other chapters of my dissertation

- Chapter 7 $\rightarrow$ Snapshot method
- Chapters 2, 3, and 5 $\rightarrow$ *P*-uniform and *p*-uniform*
- Chapter 4 $\rightarrow$ Meta-meta-analysis on publication bias in psychology and medicine
- Chapter 6 $\rightarrow$ Hybrid method
- Chapter 7 $\rightarrow$ Multi-step estimator for estimating between-study variance in a meta-analysis (together with Dr. Dan Jackson)
- Chapter 8 $\rightarrow$ Assessing properties of methods for constructing a confidence interval for the between-study variance (together with Dr. Wolfgang Viechtbauer)

Software

- R package `puniform` on CRAN for applying proposed methods

- Web applications:
  - https://rvanaert.shinyapps.io/p-uniform/
  - https://rvanaert.shinyapps.io/p-uniformstar/
  - https://rvanaert.shinyapps.io/snapshot/
  - https://rvanaert.shinyapps.io/hybrid/

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