Meta-analyzing non-preregistered and preregistered studies

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Preregistered studies and meta-analysis

- More and more preregistered studies in psychology (and other fields)
- Preregistered studies are less likely to be affected by publication bias

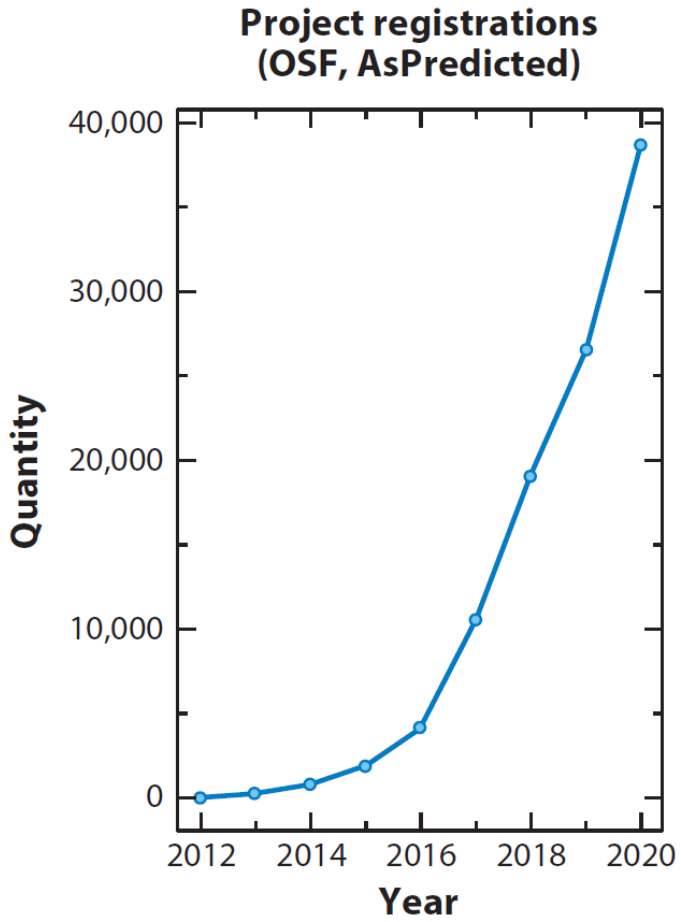

Figure adapted from Nosek et al. (2022)

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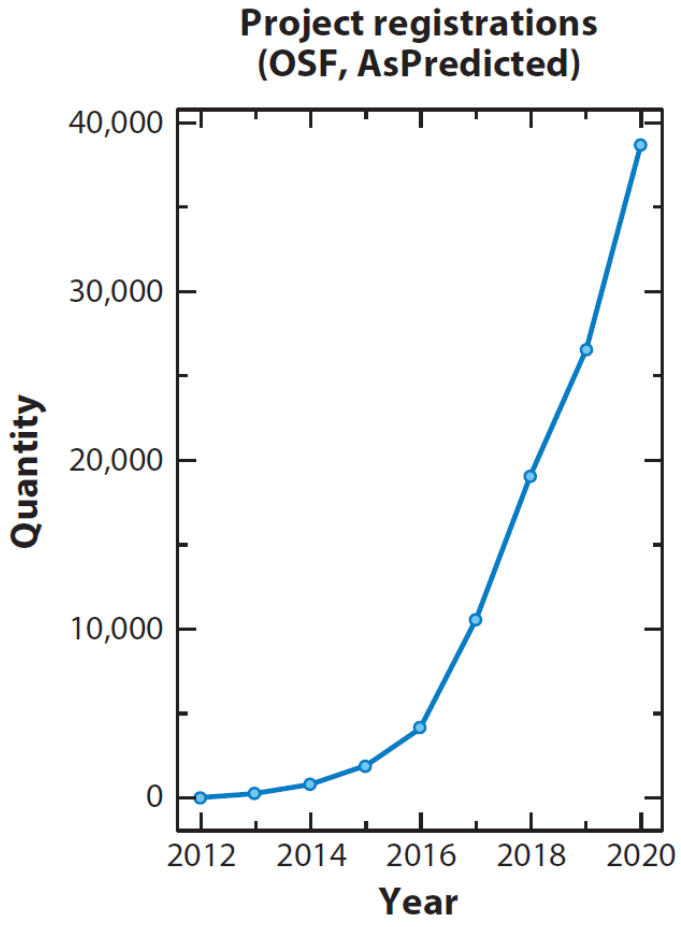

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Question:

How to meta-analyze data that contain non-preregistered and preregistered studies?

Potential analysis approaches

1. Ignoring possible publication bias in non-preregistered studies
2. Ignoring that preregistered studies may be less affected by publication bias
3. Discarding all non-preregistered studies
4. Including type of study in a meta-regression analysis

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1. Ignoring possible publication bias in non-preregistered studies
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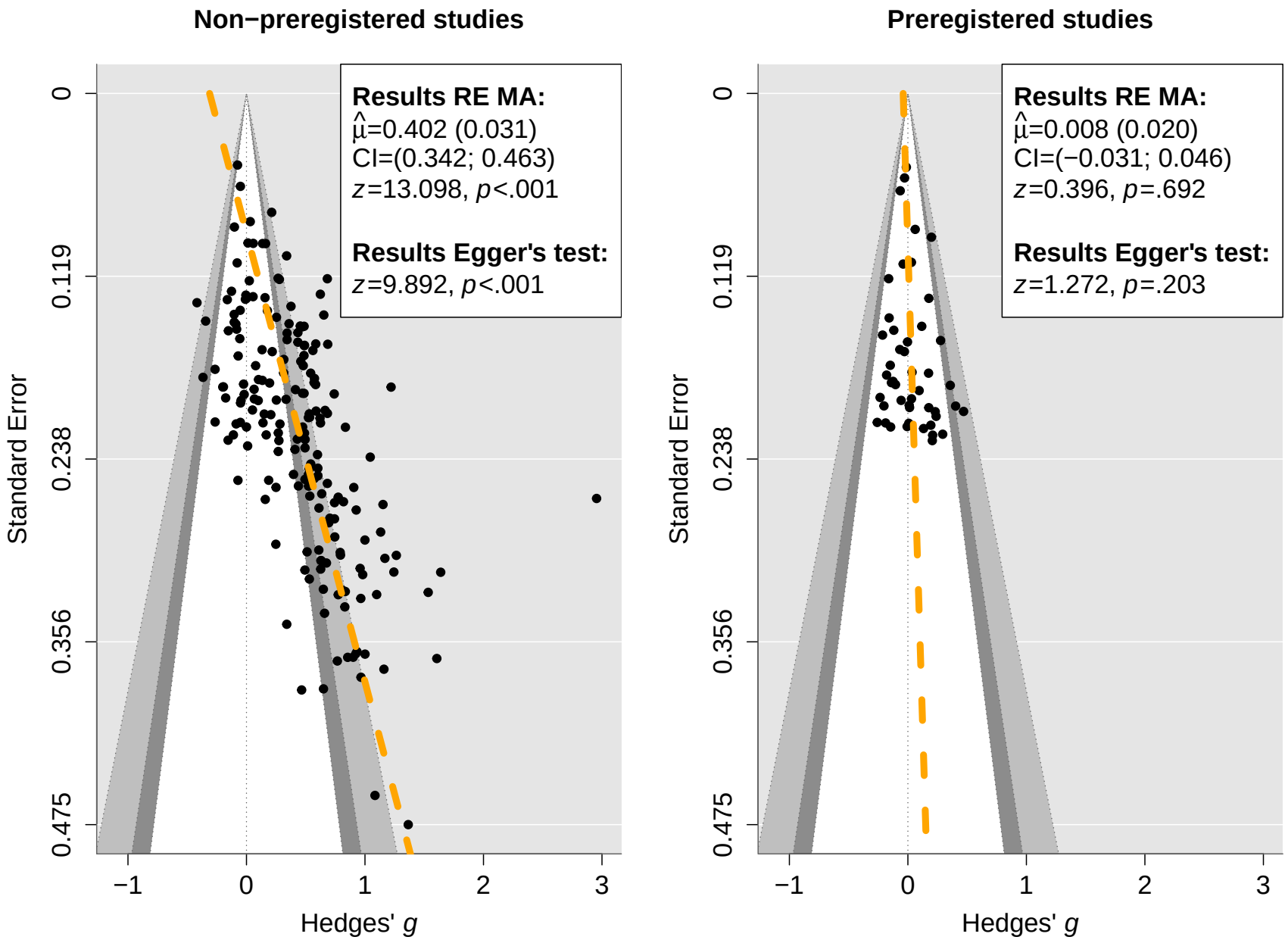
3. Discarding all non-preregistered studies
4. Including type of study in a meta-regression analysis
5. Applying the Hybrid Extended Meta-Analysis (HYEMA) method that treats preregistered and non-preregistered studies differently

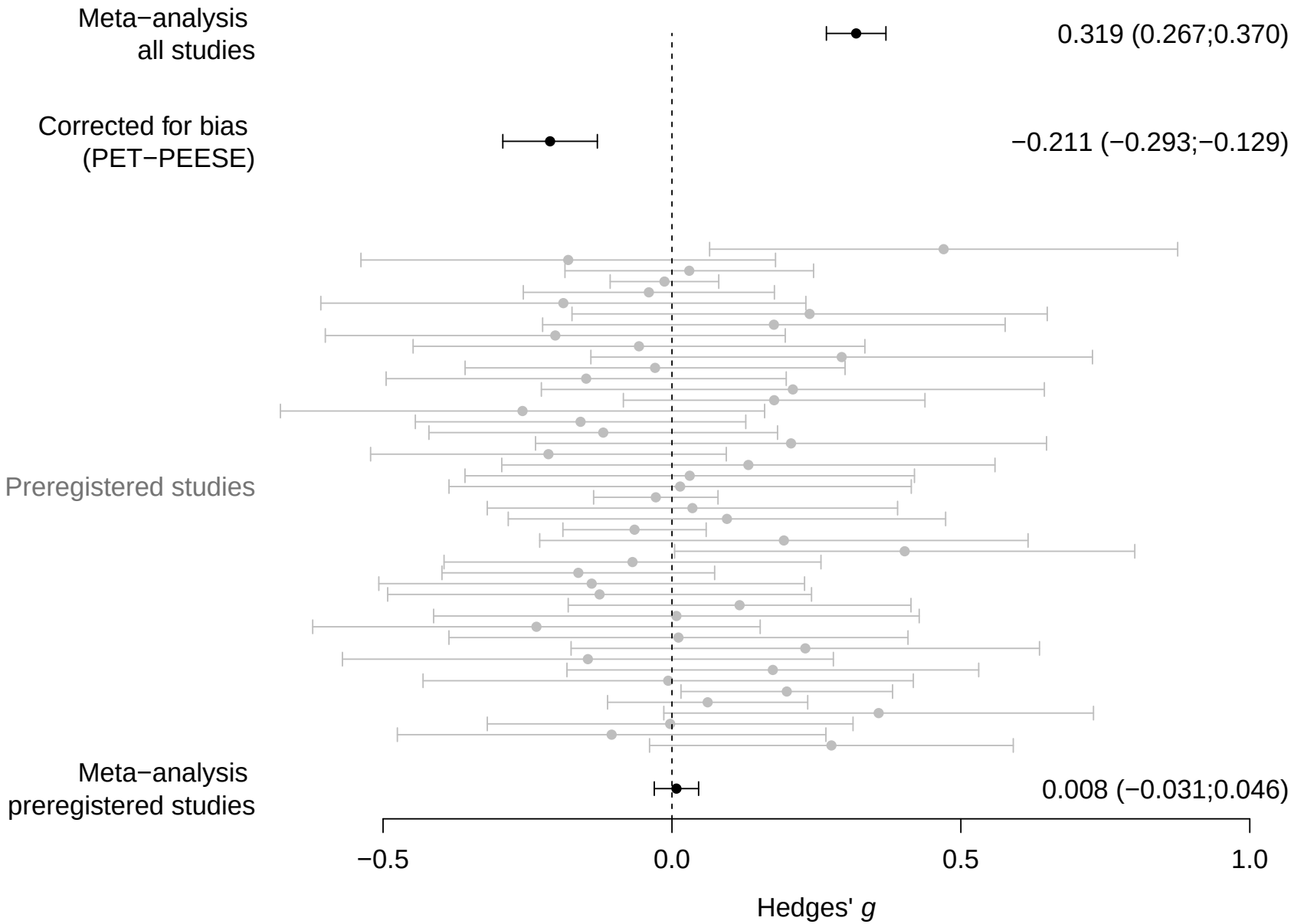
Working example: Introduction

- Money priming is the effect that people behave in a more self-sufficient way if they receive a money-related manipulation
- Lodder et al. (2019) meta-analyzed 236 studies on money priming
- Effect size measure of interest is Hedges' g
- Meta-analysis consists of 47 (19.9%) preregistered studies
- 57.7% of the non-preregistered and 6.4% of the preregistered studies are statistically significant

Working example: Funnel plots



Working example: Forest plot



HYEMA

- HYEMA treats non-preregistered and preregistered studies differently by using distinct likelihood functions

- Likelihood function of *non-preregistered* studies:
  - PDF of *truncated* normal distribution
  - Density of a study conditional on being (non)significant
  - Density is computed differently depending on significance

- Correction for publication bias in non-preregistered studies $\rightarrow$ significance is likely a criterion for publication

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- Likelihood function of *preregistered* studies:
  - PDF of normal distribution
  - Assumption of no bias in preregistered studies

HYEMA and its relation to other methods

- Ratio of preregistered studies determines the similarity between results of HYEMA and traditional meta-analysis:
  - Only preregistered studies $\rightarrow$ results coincide
  - Only non-preregistered studies $\rightarrow$ results differ the most if publication bias is present

- HYEMA is related to the hybrid method (van Aert et al., 2018) and selection models (Hedges, 1984; Iyengar et al., 1988; van Aert et al., 2024)

Working example: Results

- Average effect size:

	$\hat{\mu}$ (SE)	(95% CI)	H_0: μ=0
RE MA	0.319 (0.026)	(0.267;0.370)	z=12.133, p<.001
PET-PEESE	-0.211 (0.042)	(-0.293;-0.129)	$t(234)$=-5.080, p<.001
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- Between-study variance:

	$\hat{\tau}^2$ (SE)	(95% CI)	$\hat{\tau}$	H_0: τ^2=0
RE MA	0.118 (0.015)	(0.102;0.171)	0.344	$Q(235)$=1022.133, p<.001
HYEMA	0.080 (0.012)	(0.059;0.107)	0.283	LR=233.900, p<.001

Simulation study: Design

- Hedges' g effect sizes were simulated under the random-effects model
- Preregistered and significant non-preregistered studies were always published
- Nonsignificant non-preregistered studies were published with probability $1 - \textit{pub} \rightarrow \textit{pub} = 0; 0.5; 0.9; 1$
- Simulation study was tailored to the working example:
  - $\mu = 0.319$; $\tau^2 = 0.118 \rightarrow$ random-effects model
  - $\mu = 0.176$; $\tau^2 = 0.080 \rightarrow$ HYEMA
  - Number of preregistered and non-preregistered studies equal to observed in meta-analysis
- Outcomes were bias, RMSE, and Type-I error/power

Simulation study: Results

- Numbers in bold indicate the method with the least bias or lowest RMSE

			Bias μ			RMSE μ		
μ	τ^2	*pub*	RE MA	PET-PEESE	HYEMA	RE MA	PET-PEESE	HYEMA
0.319	0.118	0	**-0.000**	-0.004	0.000	**0.026**	0.083	0.037
		0.5	0.083	0.044	**0.000**	0.087	0.092	**0.037**
		0.9	0.229	0.083	**0.001**	0.230	0.112	**0.042**
		1	0.293	0.086	**0.002**	0.294	0.114	**0.048**
0.176	0.080	0	**-0.000**	-0.010	0.000	**0.023**	0.080	0.030
		0.5	0.068	0.041	**0.000**	0.072	0.088	**0.031**
		0.9	0.231	0.098	**0.001**	0.232	0.126	**0.036**
		1	0.335	0.087	**0.002**	0.335	0.132	**0.043**

- **Conclusion:** HYEMA has the lowest bias and least RMSE when publication bias is present

Simulation study: Results estimating τ^2

			Bias τ^2		RMSE τ^2	
μ	τ^2	*pub*	RE MA	HYEMA	RE MA	HYEMA
0.319	0.118	0	**-0.001**	-0.001	**0.015**	0.015
		0.5	-0.001	**-0.001**	0.015	**0.015**
		0.9	-0.026	**-0.001**	0.030	**0.017**
		1	-0.046	**-0.001**	0.048	**0.018**
0.176	0.080	0	-0.001	**-0.001**	**0.011**	0.012
		0.5	0.008	**-0.001**	0.014	**0.011**
		0.9	**-0.000**	-0.001	0.012	**0.011**
		1	-0.023	**-0.001**	0.025	**0.013**

- **Conclusion:** Performance is comparable except for conditions with extreme publication bias

Simulation study: Results testing $H_0 : \mu = 0$

- Numbers in bold indicate the method that has a Type-I error rate closest to $\alpha = 0.05$

μ	τ^2	*pub*	RE MA	PET-PEESE	HYEMA
0	0.118	0	**0.052**	0.366	0.052
		0.5	0.656	0.487	**0.051**
		0.9	1.000	0.649	**0.052**
		1.0	1.000	0.530	**0.056**
0	0.080	0	**0.049**	0.347	0.048
		0.5	0.554	0.464	**0.054**
		0.9	1.000	0.649	**0.051**
		1.0	1.000	0.458	**0.054**

Conclusion:

- Type-I error rate is adequately controlled by HYEMA
- Statistical power of HYEMA was close to 1 for all conditions

Discussion

- HYEMA seems to be a useful sensitivity analysis if preregistered studies are available
- Results can be considered not robust if, for example,
  - A significant effect is observed in the meta-analysis but not with HYEMA
  - There is a strong decrease in effect size estimate
- Also classifying replications as less likely to be biased than non-preregistered studies $\rightarrow$ extra sensitivity analysis?!
- Moderator variables can be included in HYEMA
- Software:
  - Web application: https://rcmvanaert.shinyapps.io/HYEMA/
  - `hybrid()` function in the `puniform` R package

Illustration hybrid() function

```r
install.packages("puniform") # Install puniform package
library(puniform) # Load puniform package

hybrid(yi = yi, vi = vi, conventional = conventional, side = "right")
```

```
##
## Results Hybrid method (k = 236; number conventional studies = 189)
##
## Model results Hybrid method:
##
##     est      se  ci.lb  ci.ub   zval  pval
##  0.1758 0.0323 0.1124 0.2392 5.4355 <.001
##
## ===
##
## Estimating between-study variance:
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##    tau2      se tau2.lb tau2.ub       LR  pval
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```

- Including moderators:

```r
hybrid(yi = yi, vi = vi, conventional = conventional, side = "right",
       mods = ~ x)
```

Limitations/future research

- Simulations tailored to example(s)
- Only PET-PEESE was included in the simulations
- *P*-hacking may affect the performance of HYEMA
- Preregistered studies may also be biased
  - Omit preregistered studies that are suspected to be biased
  - Risk-of-bias assessment
- Examining properties of PET-PEESE with interaction term (Stanley et al., 2012; Stanley et al., 2014) and extending selection model approaches

Thank you for your attention

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Likelihood function non-preregistered study

$$L_C(\mu, \tau^2; y_i, \sigma_i^2, y_i^{cv}) = \begin{cases} \dfrac{\frac{1}{\sqrt{\sigma_i^2 + \tau^2}} \phi\left(\frac{y_i - \mu}{\sqrt{\sigma_i^2 + \tau^2}}\right)}{1 - \Phi\left(\frac{y_i^{cv} - \mu}{\sqrt{\sigma_i^2 + \tau^2}}\right)} & \text{if } p_i \leq \alpha \\ \dfrac{\frac{1}{\sqrt{\sigma_i^2 + \tau^2}} \phi\left(\frac{y_i - \mu}{\sqrt{\sigma_i^2 + \tau^2}}\right)}{\Phi\left(\frac{y_i^{cv} - \mu}{\sqrt{\sigma_i^2 + \tau^2}}\right)} & \text{if } p_i > \alpha \end{cases}$$

- y_i: observed effect size estimate
- σ_i^2: within-study sampling variance
- y_i^{CV}: critical value
- ϕ: PDF of standard normal distribution
- Φ: CDF of standard normal distribution
- p_i: right-tailed p-value

Likelihood functions

- Likelihood function of preregistered study:

$$L_P(\mu, \tau^2; y_i, \sigma_i^2) = \frac{1}{\sqrt{\sigma_i^2 + \tau^2}} \phi\Big(\frac{y_i - \mu}{\sqrt{\sigma_i^2 + \tau^2}}\Big).$$

- Combined likelihood function:

$$\prod_{i=1}^{k} \Big(L_C(\mu, \tau^2; y_i, \sigma_i^2, y_i^{cv}) \times \mathbb{1}_i + L_P(\mu, \tau^2; y_i, \sigma_i^2) \times (1 - \mathbb{1}_i) \Big),$$

- $\mathbb{1}_i$: indicator function that is 1 for a non-preregistered study and 0 for a preregistered study