A Primer for Conducting a Meta-Analysis

USING ROBUMETA, METAFOR, META-VIZ, and FORESTER

Jay Jeffries & Jonah Garbin | Seminar | 22 Oct 2021

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Agenda

- Introduction
- General Steps in Conducting
- Jonah's Meta-Analysis
- Thoughts and Questions

Differentiating Methodology

- Literature Review: Qualitatively summarizes a collection of literature within a field of study through use of subjective, interpretive, less formal techniques.
    - Provides context and background information for a line of research.
- Systematic Review: Synthesizes screened works from pre-specified eligibility criteria to appraise quality and validity of studies to answer a research question.
    - “Systematic” defines the method of transparency and reproducibility to minimize bias (i.e. cherry-picking) when selecting studies.
- **Meta-Analysis: Statistically describes study outcomes derived from a screened sample of articles or unpublished works via a common metric (e.g. d, g, r, OR, Cramer’s V).**
    - **Results in the *robust* calculation and interpretation of an overall estimated effect size for a relationship or intervention of interest.**

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Rationale: *Why Meta-Analysis*?

You want to estimate the average effect (or variance) from a set of studies

Example: When all scores are included in the analysis, children classified with speech language impairement scored lower on writing measures than their typically developing peers (*g* = −0.97).

Do Children Classified With Specific Language Impairment Have a Learning Disability in Writing? A Meta-Analysis

Journal of Learning Disabilities
2020, Vol. 53(4) 292–310

DOI: 10.1177/0022219420917338
journaloflearningdisabilities.sagepub.com
SAGE

Steve Graham, EdD[1], Michael Hebert, PhD[2], Evan Fishman, PhD[3], Amber B. Ray, PhD[4], and Amy Gillespie Rouse, PhD[5]

Rationale: *Why Meta-Analysis*?

You want to explore variations or probe moderators across study results

Example: The studies indicated that visual art therapy significantly reduced depressive symptoms (g = −0.380 [−0.693, −0.067], p = .017) anxiety symptoms (g = −0.263, [−0.482, −0.044], p = .019).

Review > J Adv Nurs. 2020 Mar 23. doi: 10.1111/jan.14362. Online ahead of print.

Visual art therapy as a treatment option for cognitive decline among older adults. A systematic review and meta-analysis

Golden M Masika [1] [2], Doris S F Yu [3], Polly W C Li [3]

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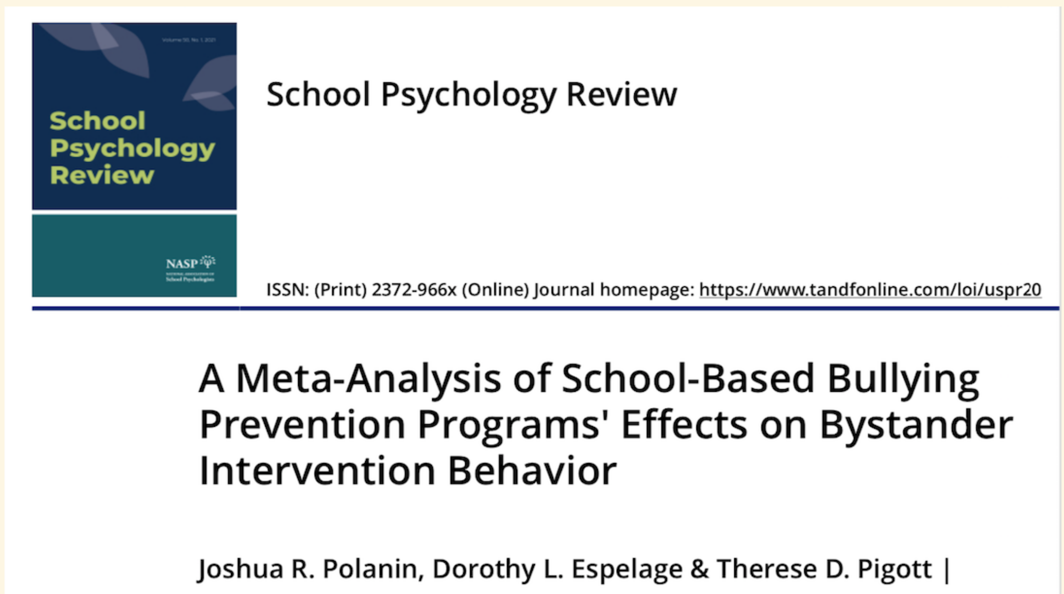
Rationale: *Why Meta-Analysis*?

You want to identify bias in the existing reported literature

Example: Egger's regression test produced nonsignificant results ($\beta = .57$, $p = .26$). The trim and fill procedure to address publication bias revealed that 1 negative result was missing from the bystander intervention outcomes, but the imputed missing value did not change the overall statistical significance. These results show publication bias did not significantly impact outcomes.


School Psychology Review

ISSN: (Print) 2372-966x (Online) Journal homepage: https://www.tandfonline.com/loi/uspr20

A Meta-Analysis of School-Based Bullying Prevention Programs' Effects on Bystander Intervention Behavior

Joshua R. Polanin, Dorothy L. Espelage & Therese D. Pigott |

Steps To Conducting a Meta-Analysis

1. Formulate Research Questions
2. Literature Search
3. Screen the Literature
4. Code the Studies
5. Visualize Data
6. Statistically Describe Effect Sizes
7. Data and Bias Diagnostics
8. Interpreting Outcomes
9. Presenting Results

Cooper, Hedges, & Valentine (2019) *The Handbook Of Research Synthesis and Meta-Analysis*

Pigott, Polanin, Williams (2021) *AERA-ICPSR Workshop*

1. Formulate Research Question

Routes to consider...

- *Intervention Effectiveness*: how effective is an intervention or group of interventions?
  - E.g. What is the impact of a specific simulation-based learning intervention on new graduate nurse self-efficacy?
- *Relationships*: how are these constructs related to one another?
  - E.g. How is student civic engagement associated with school pride?
- *Prevalence*: how likely is the occurrence of a condition?
  - E.g. What is the difference in likelihood of ACL tear across sex for basketball athletes?

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1. Formulate Research Question

Routes to consider...

- *Instrument Diagnostics*: how well does an instrument or test predict a condition across conditions or groups?
    - How well does the WISC-V intelligence scale evaluate students of ELL status?
    - May be worthwhile before conducting a replication study
- *Comparative Effectiveness*: how do interventions or instruments compare or relate to one another?
    - How does the Marlowe-Crowne Social Desirability Scale compare to the Brief Social Desirability Scale when assessing those applying for management positions?
    - Great for evaluating feasibility of a cheaper program when compared to a more expensive program

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1. Formulate Research Questions

Defining Research Criteria

Helpful for Literature Searching!

P - Population, Participants

I - Independent Variables (or predictors)

C - Conditions (settings, contexts, time frame)

O - Outcomes (measures, dependent variables, criterion)

S - Study design

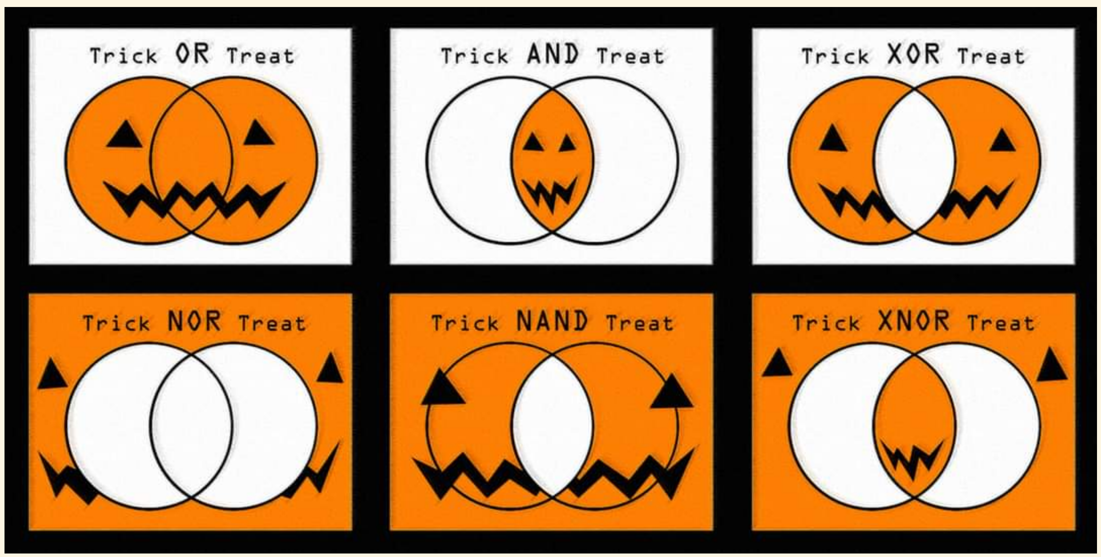
An adaptation of Cronbach's *UTOS* framework

2. Literature Search

Database Searching

Use your **PICOS** information to create Boolean operators to commune with the literature, improve the yield, and make this process as easy as possible.

- Update search term list as you become more familiar with the literature



Your aim is to capture all plausible content relevant to your research question!

2. Literature Search

Database Searching

Select databases, journals that are prevalent to your field of research.

- Unsure about this? Contact our library liason, Erica DeFrain.

Ensure that you are including a search for *unpublished* research

- ProQuest Dissertation & Theses, EBSCO Open Dissertations, Open Access Dissertation and Theses (OATD)
- Document delivery systems -- Interlibrary Loan/ILLiad
- Contact author(s)

Locating unpublished research is, inevitably, be difficult

- Feeds the phenomenon of Publication Bias

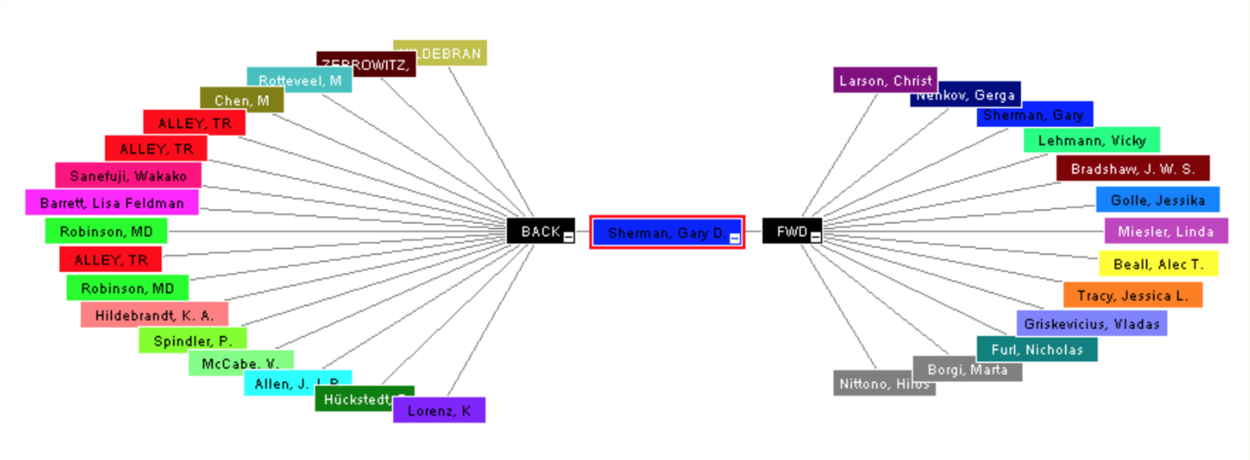
2. Literature Search

Citation Searching and Footnote Chasing

1. Backward citation search: looking at the works cited by an author

1. Forward citation search: following where a work has been cited after its publication

Create boundaries. Know when to stop searching. This *could* go on forever.



Sherman et al. (2009)

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Database Search Example

Databases: ERIC, APA PsycInfo, ProQuest Dissertations & Theses

Search terms:

Independent variable:

“technostress” OR “tech* stress*” OR “tech* strain*” OR “tech* related stress*” OR “tech* induced stress*” OR “digital* stress*” OR “digital* tech* stress*” OR “digital* related stress*” OR “digital* induced stress*” OR “tech* overload” OR “tech* complex*” OR “tech* uncertain*” OR “tech* invasion” OR “tech* unreliability” OR “connection overload” OR “communication overload” OR “availability stress” OR “online vigilance” OR “online stress*” OR “internet stress*” OR “approval anxiety” OR “FoMo” OR “fear of missing out”

Dependent variable (AND):

“anxiety” OR “anxiety disorder” OR “anxiety health” OR “anxious” OR “social anxiety” OR “social anxiety disorder” OR “social phobia” OR “general* anxiety disorder” OR “general* anxiety” OR “phobia” OR “math* anxiety” OR “panic disorder” OR “panic anxiety”

Population (AND):

“education” OR “primary ed*” OR “secondary ed*” OR “high-school” OR “highschool*” OR “students” OR “learning” OR “adolescent*” OR “adolescence” OR “K-12” OR “higher ed*”

Exclusion terms (NOT):

“employee” OR “workforce” OR “job* train*” OR “career train*” OR “job* ed*” OR “career ed*” OR “work* ed*” OR “industry ed*”

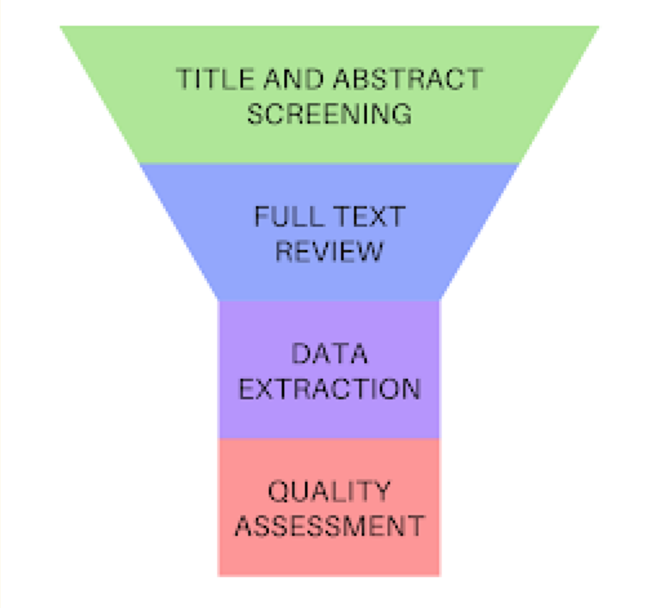
2. Literature Search

Managing Search Results

To record your selection process pull all journal, database, and citation search results into an reference manager.

- Zotero
- Mendelay
- EndNotes
- RefWorks

Export content into Excel (or some equivalent) to assess criteria in the screening step



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3. Screen the Literature

To identify articles eligible for review, you will go through a process of screening

1. Your first phase of screening: filter though abstract or titles
2. Your second phase of screening: filter whole-document

Things you are looking for:

- Evidence of your **PICOS** list; i.e. inclusion and exclusion criteria
- The I.V.(s) and D.V.(s) that you are interested in
- Areas to update your search term list
- Potential moderators of interest
  - What other common factors impact your RQ's? Write these down!
- An *effect size*

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Defining Form of Effect Size

This decision should be informed by:

- your research question
- your field of research and audience (education, psychology, medicine?)
- how you wish to interpret your findings

You typically select from one of three families:

1. Mean difference
2. Proportion
3. Association

Types of Effect Sizes (ES)

Effects Based on Means (Standardized)

- Cohen's *d*: difference between groups in terms of standard deviations
- Hedge's *g*: small sample correction (when $n \leq 20$) version of *d*
- Glass's Δ: uses untainted SD of control group (use when SDs are sig. different)

Types of Effect Sizes (ES)

Effects Based on Binary Proportion Data

- Odds Ratio *OR*: ratio of events (e.g. lung cancer in smoker) to non-events (e.g. lung cancer in non-smokers)
- Risk Ratio *RR*: ratio of two proportions to show relative risk
- Risk Differences *RD*: attributable risk difference between two groups

Types of Effect Sizes (ES)

Effects Based on Association

- Pearson product-moment correlation coefficient *r*: measure of association between two continuous variables
- Point-biserial correlation r_{pb}: measure of association when one variable is dichotomous
- Phi coefficient Φ : measure of association when both variables are dichotomous

These are accompanied by a Fishers z-transformation to an approximately normal distribution so that values can be accurately compared across samples

- Also provides sampling variance used to compute average weighted effect
- Are eventually transformed back into a correlation coefficient

3. Screen the Literature

Effect Size Calculators and Converters

When you run into:

- an F-statistic that you need translated into a Cohen's *d*
- a β that you must identify as an *r*
- a Risk Ratio that you wish were a Hedge's *g*
- a χ^2 value that needs to be an *OR*

Use these resources or create your own Excel/R calculators

Campbell's Collaboration

Psychometrica

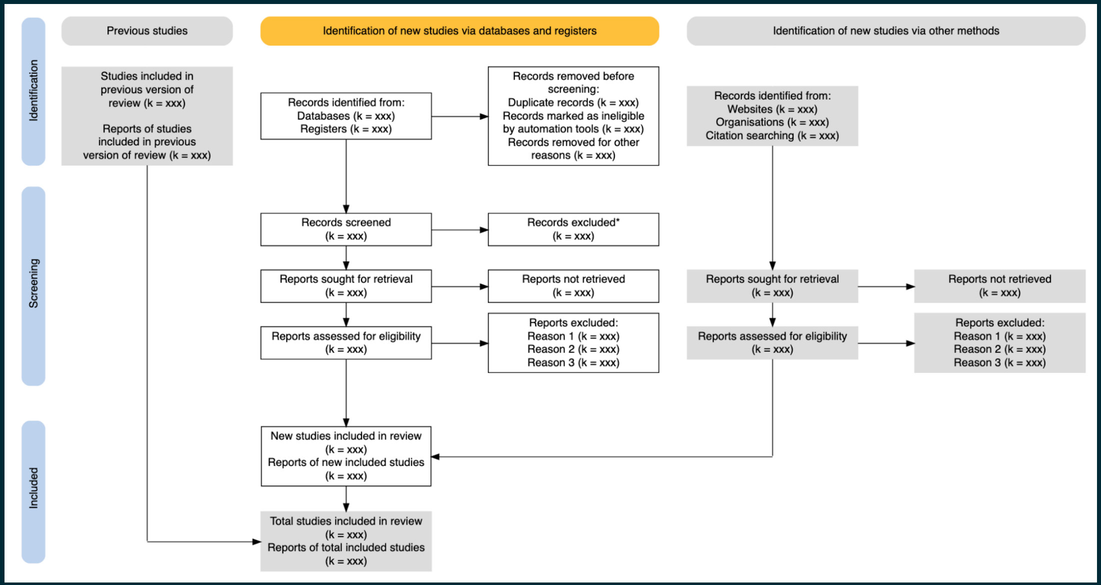
escal

Standard Reporting

Transparent reporting is inherent in meta-analyses, and requires you to track your literature search.

- Allows others to audit your search, replicate, and confirm your findings
  - Validity and honesty of your research practice (you have "*the receipts*"!)
- Concurrent with your search, screening, and quality appraisal process

Recommended PRISMA Guidelines



Shiny app to automate the creation of your flow diagram.

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4. Code the Studies

Codebook and Moderators

General information

- article title, author, study number, effect size ID, publication type

Participant information

- sample size, % female, race/ethnicity indicators, average age, % diagnosed, etc.

Measure information

- name of instrument, scale, metric

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4. Code the Studies

Codebook and Moderators

Effect size information

- effect size statistic, variance, upper/lower CI, Fisher's z score

Study Quality information

- measurement reliability (sample/manual), article quality tool, study power

5. Visualize the Data

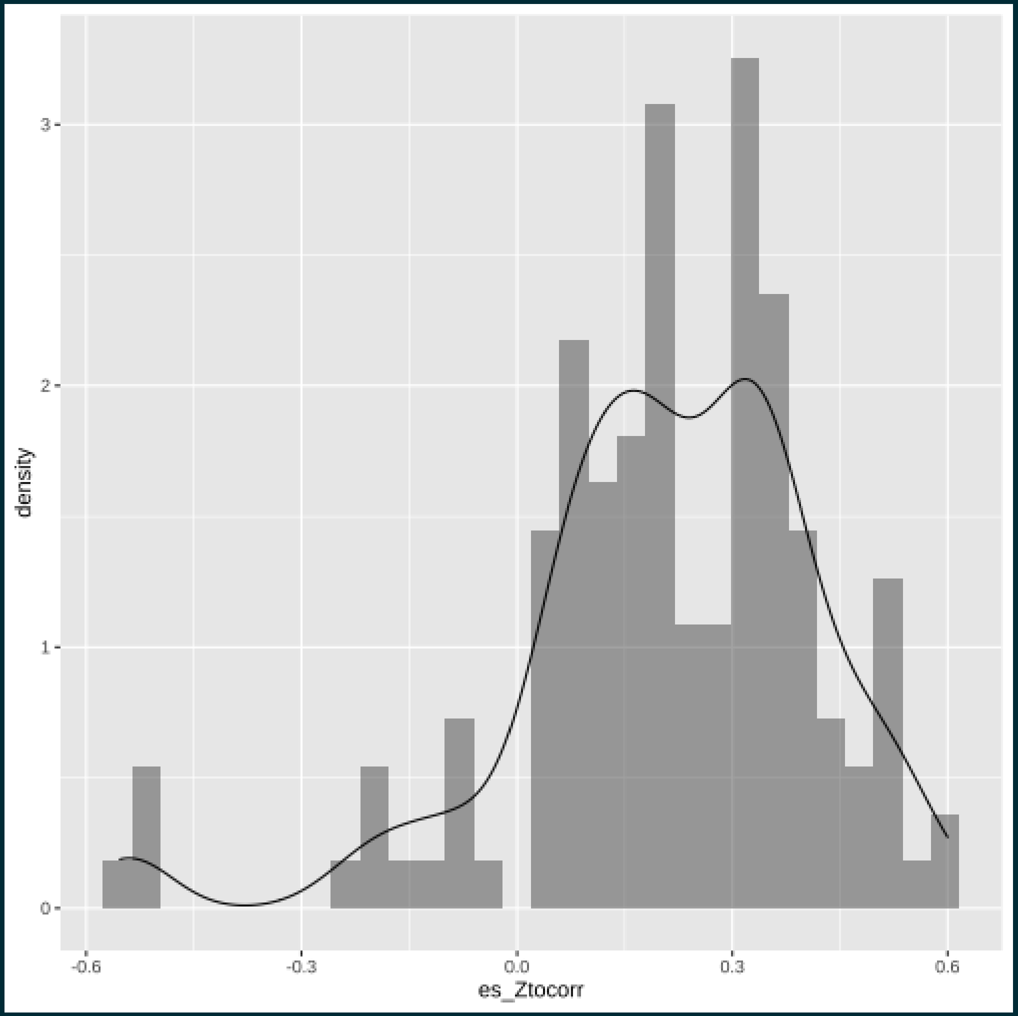
Figure 2. Technostress Publications Descriptive Statistics

	Mean Statistic		
n	Published	Year	Effect_Sizes_per_Article
139	129	2017.741	3.57

Figure 1. Technostress Meta-Analysis Descriptive Statistics

	Mean Statistic								
n	N	Age	Female	Black	Hispanic	Asian	Native	Multiple_RaceEthnicity	Unweighted_Effect_Size
139	4505.81	17.1	74.58	10	11.41	6.29	2.44	5.16	0.2

5. Visualize the Data



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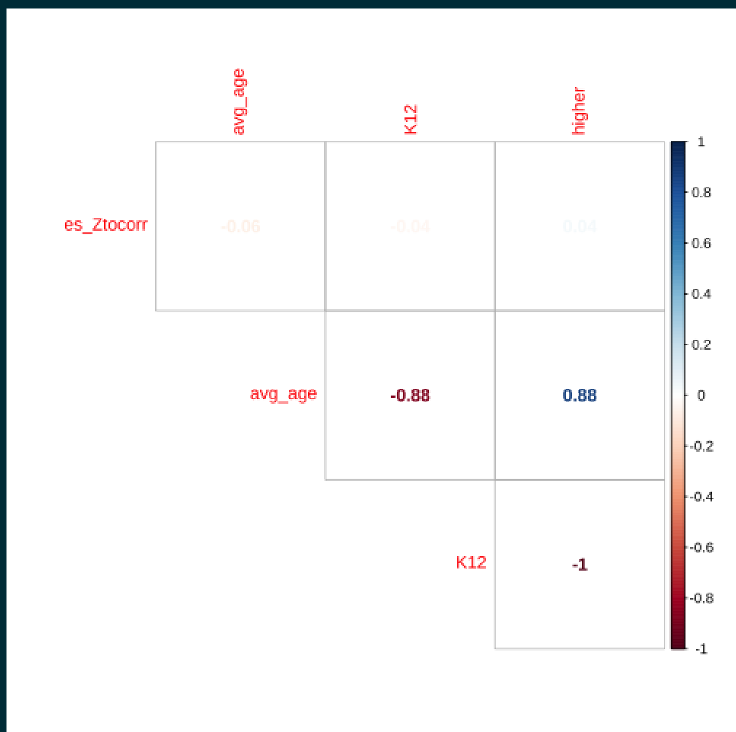

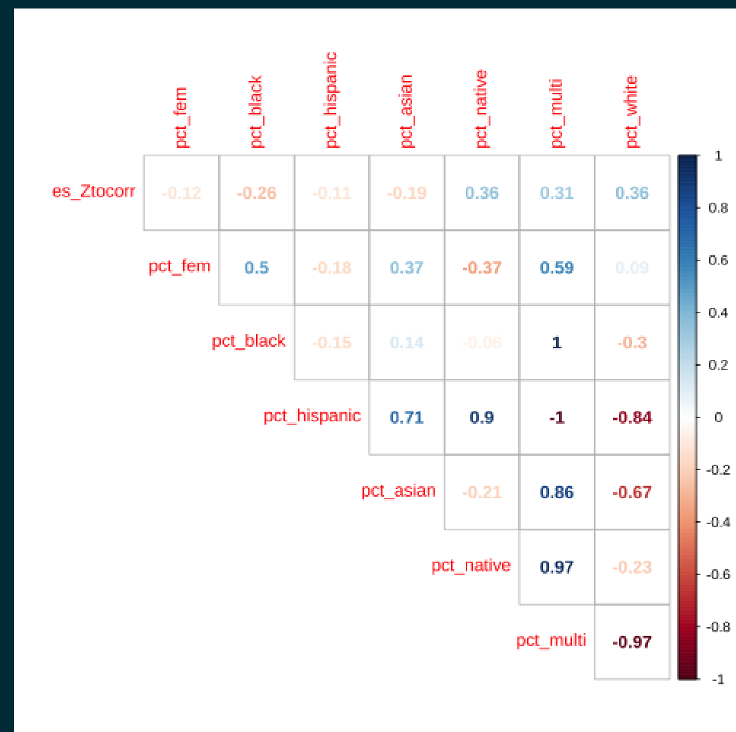

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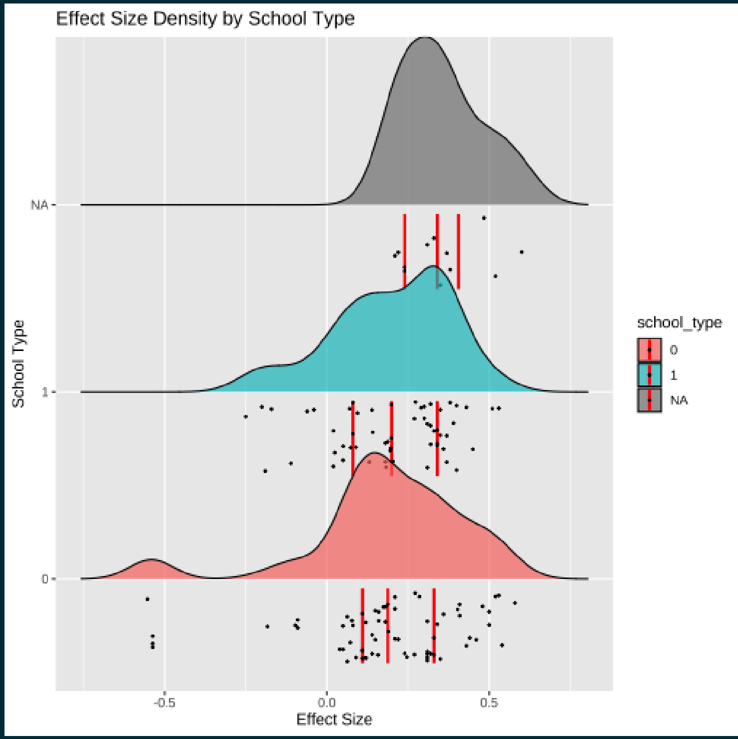
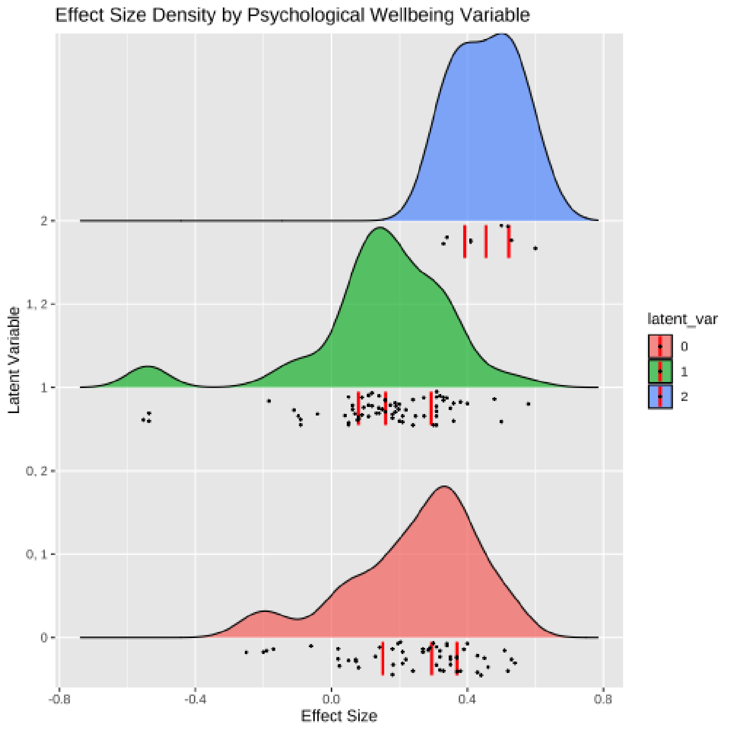
5. Visualize the Moderators





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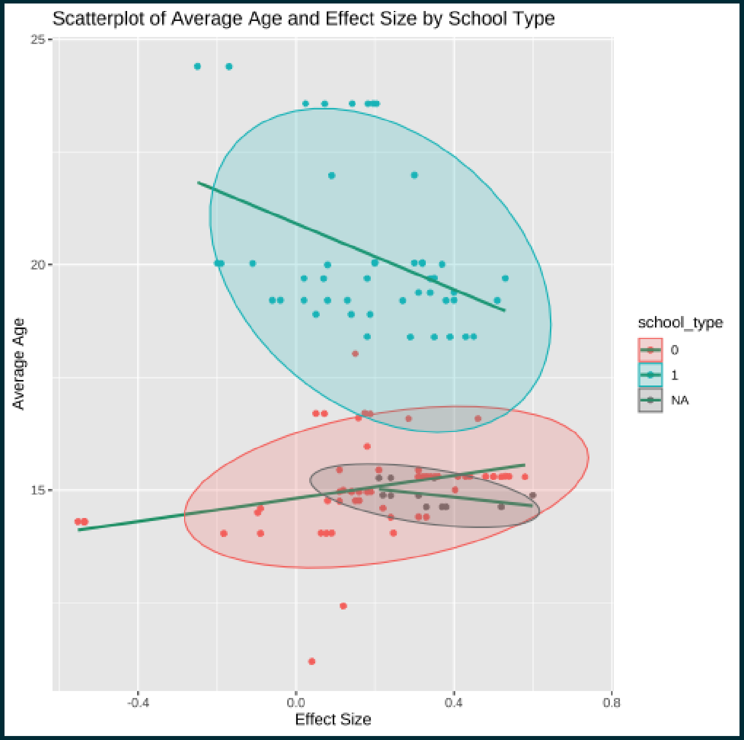
5. Visualize the Moderators



5. Visualize Study Power

Using {meta-viz}

6. Statistically Describe Effect Sizes

Robust Variance Estimation (RVE)

Effect sizes advantage: comparable across all screened studies

- Requires a SE for each ES, as they are vital to the calculation of an average weighted effect size

Inverse variance weights for clustered effect sizes

- Allocates more weight to studies that are more precise
  - Efficiency!
  - Generally, which studies result in more precise prediction?

`{robumeta}` function implements RVE in a meta-regression

- Outcomes are read the same as a typical regression
  - Criterion (dependent) outcome is your effect size of choice
  - Predictors (moderators) are provided beta weights

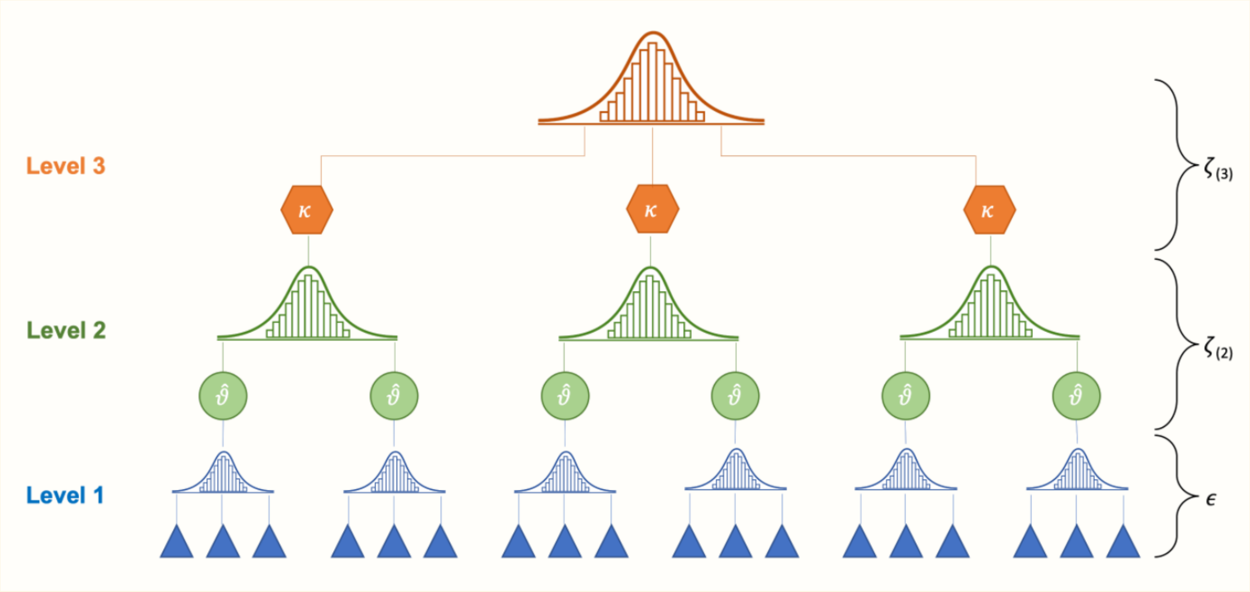
Fisher & Tipton (2015)

6. Statistically Describe Effect Sizes

Model Types

Effect size dependencies create an implied multilevel structure

- Treatment of heterogeneity (variance) depends on the type of model you choose to conduct a meta-analysis with

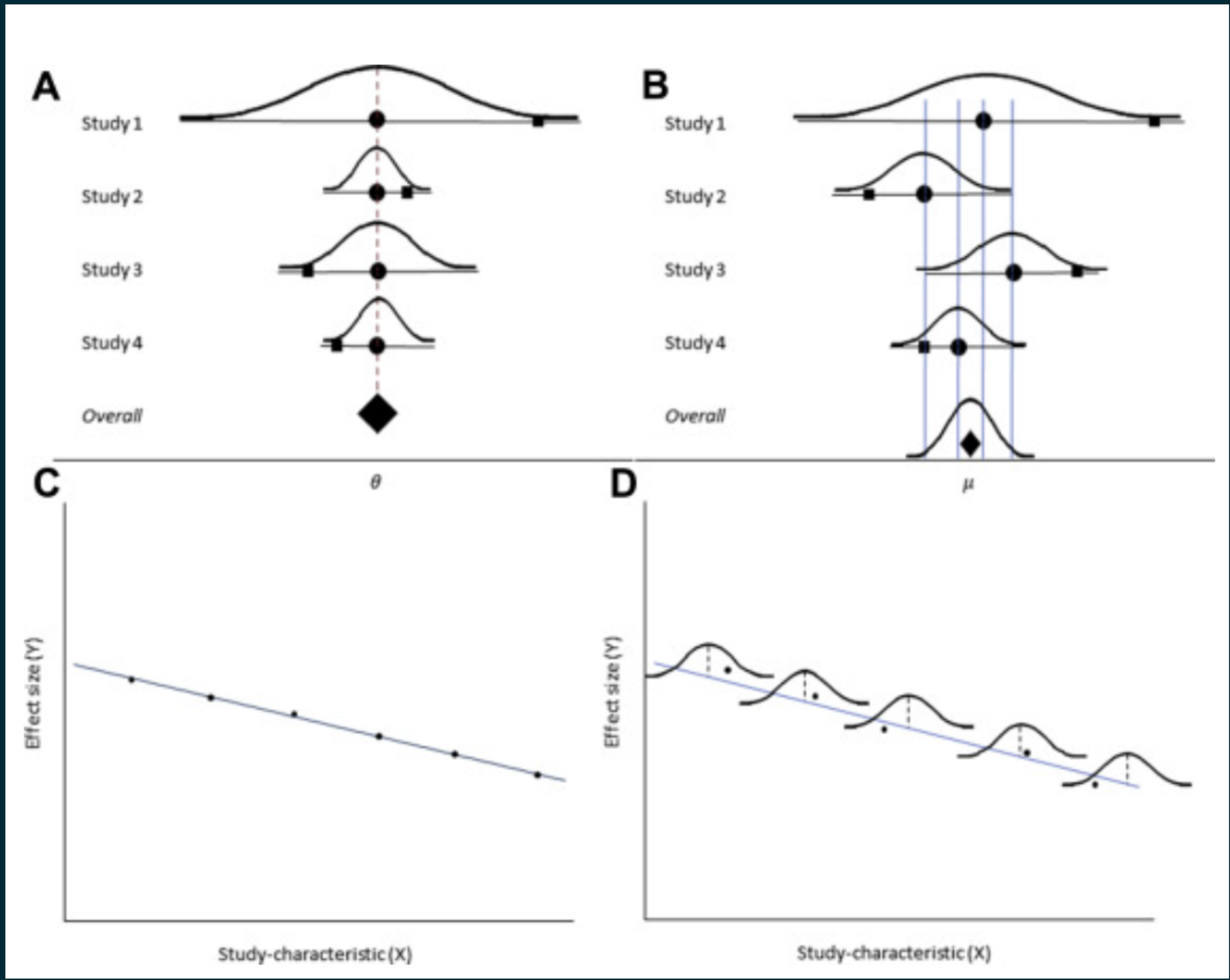


Type of Model

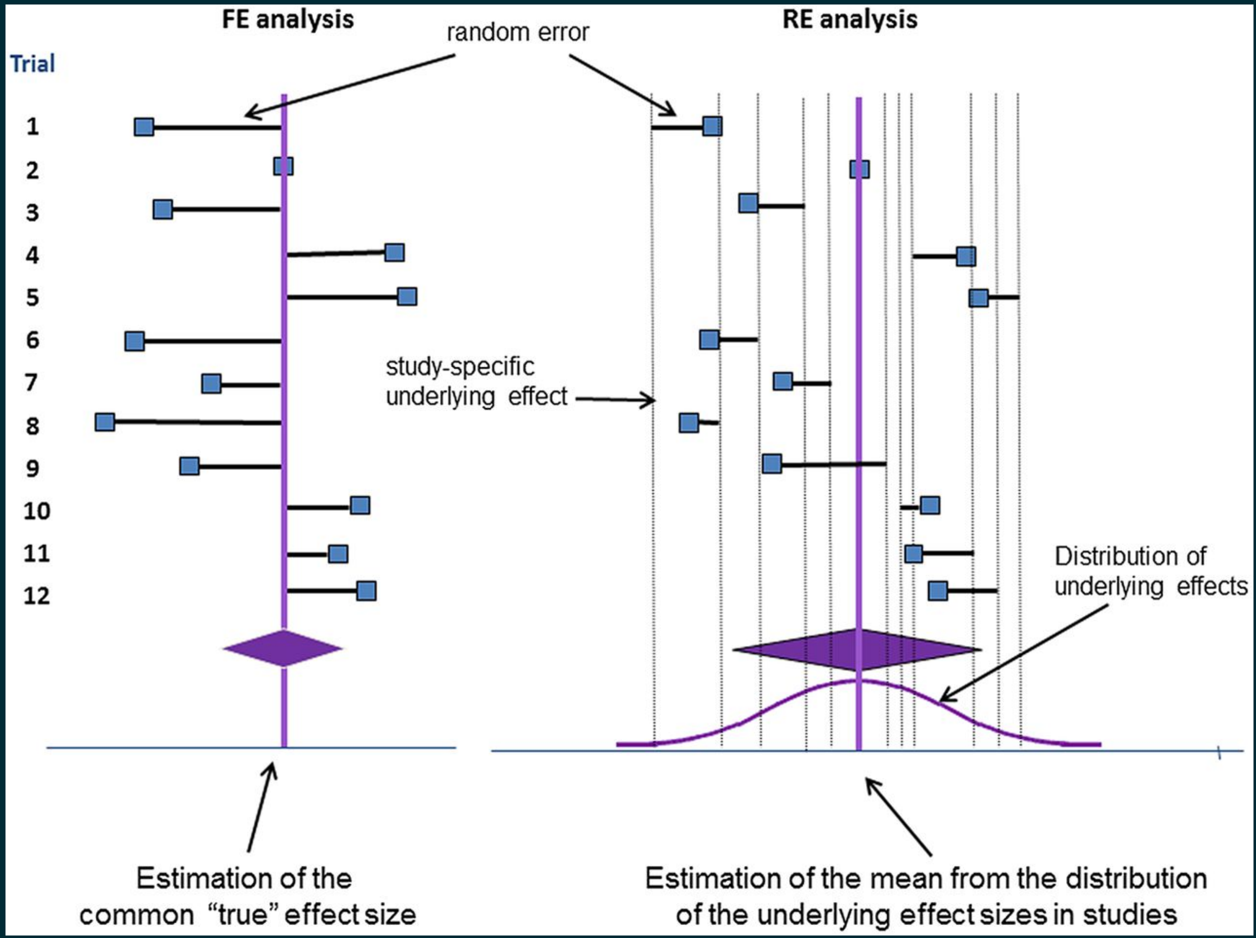
Fixed Effect	Random Effect
One true effect	True effect varies
Effects from a single, homogeneous population	Effects from a distribution of effect sizes
Differences between studies are due only to sampling error	Differences between studies are due to many factors
Larger studies are more influential	Studies weighted in a balanced way
Only account for within-study heterogeneity & error	Accounts for within-study and between-study heterogeneity & error
Goal is to find the one true effect size that all studies share	Goal is to find the average effect from the distribution of effect sizes
Often used for smaller sample of articles	Difficult to understand heterogeneity in small sample of articles

Borenstein et al. (2010)

Type of Model



Type of Model



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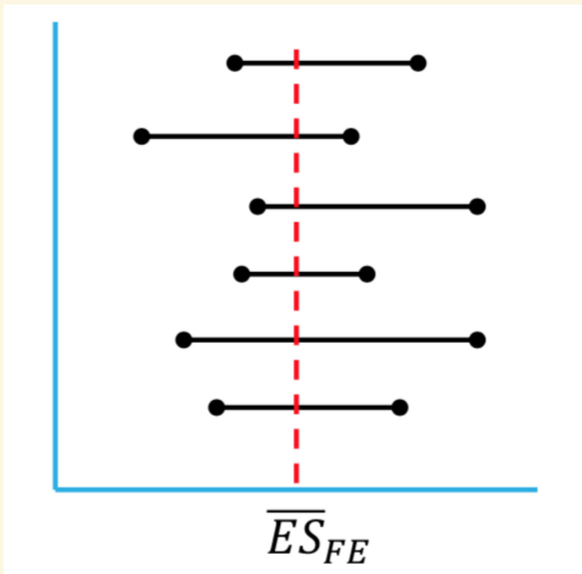
Fixed Effects Model



Strong assumption: effect sizes are homogeneous

- Reserve for instances where studies are *close* replications of one another

One source of variability:

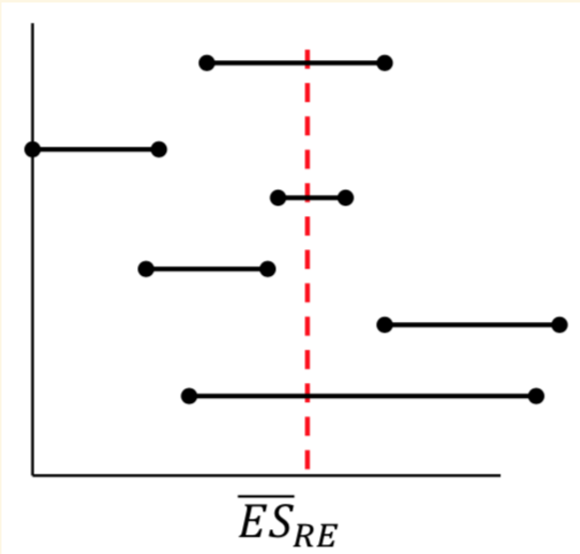
- sampling error (SE_i)
- while w_i indicates ES weight

$$\overline{ES}_{RE} = \frac{\Sigma_{i=1}^{j}(w_i ES_i)}{\Sigma_{i=1}^{j}(w_i)}$$

$$w_i = \frac{1}{SE_i^2}$$

Pigott, Polanin, Williams (2021) *AERA-ICPSR Workshop*

Random Effects Model



Harder to rule out a random effects model unless sterile conditions, carefully scripted, and precise replications

Two sources of variability:

- sampling error (SE_i)
- between-study variance (τ^2)
- w_i still indicates ES weight

$$\overline{ES}_{RE} = \frac{\Sigma_{i=1}^{j}(w_i ES_i)}{\Sigma_{i=1}^{j}(w_i)}$$

$$w_i = \frac{1}{SE_i^2 + \hat{\tau}^2}$$

Pigott, Polanin, Williams (2021) *AERA-ICPSR Workshop*

6. Statistically Describe Effect Sizes

{robumeta} Input

```
base1 <- robu(formula = fishers_z ~ 1, data = TechnostressData,
            modelweights = "CORR", studynum = studyID,
            var.eff.size = var,
            small = FALSE)
```

6. Statistically Describe Effect Sizes

{robumeta} Output

```
## RVE: Correlated Effects Model
##
## Model: fishers_z ~ 1
##
## Number of studies = 37
## Number of outcomes = 139 (min = 1 , mean = 3.76 , median = 3 , max = 18 )
## Rho = 0.8
## I.sq = 99.43528
## Tau.sq = 0.02709812
##
##                  Estimate StdErr t-value dfs    P(|t|>) 95% CI.L 95% CI.U Sig
## 1 X.Intercept.    0.173 0.0331    5.21  36 0.00000781    0.106     0.24 ***
## ---
## Signif. codes: < .01 *** < .05 ** < .10 *
## ---
```

6. Statistically Describe Effect Sizes

T^2 = .027

- Quantifies the variance of the true effect size
  - SD of true effect = .16
- Insensitive to sample size

$$Q = \left(\Sigma_{i=1}^{k} w_i ES_i^2\right) - \frac{\left(\Sigma_{i=1}^{k} w_i ES_i\right)^2}{\Sigma_{i=1}^{k} w_i}$$

$$\tau^2 = \frac{Q - df}{\Sigma_i^k w_i - \frac{\Sigma_{i=1}^{k} w_i^2}{\Sigma_{i=1}^{k} w_i}}$$

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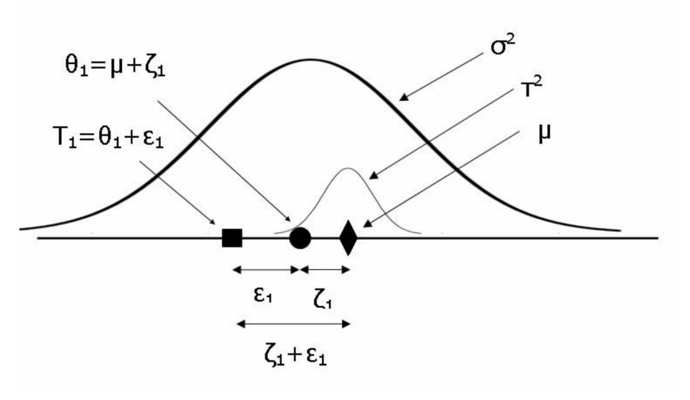
6. Statistically Describe Effect Sizes

I^2 = 99.43%

- Percentage of variability *not* caused by sampling error
  - i.e. the % between-study heterogeneity
- Impacted by sample size



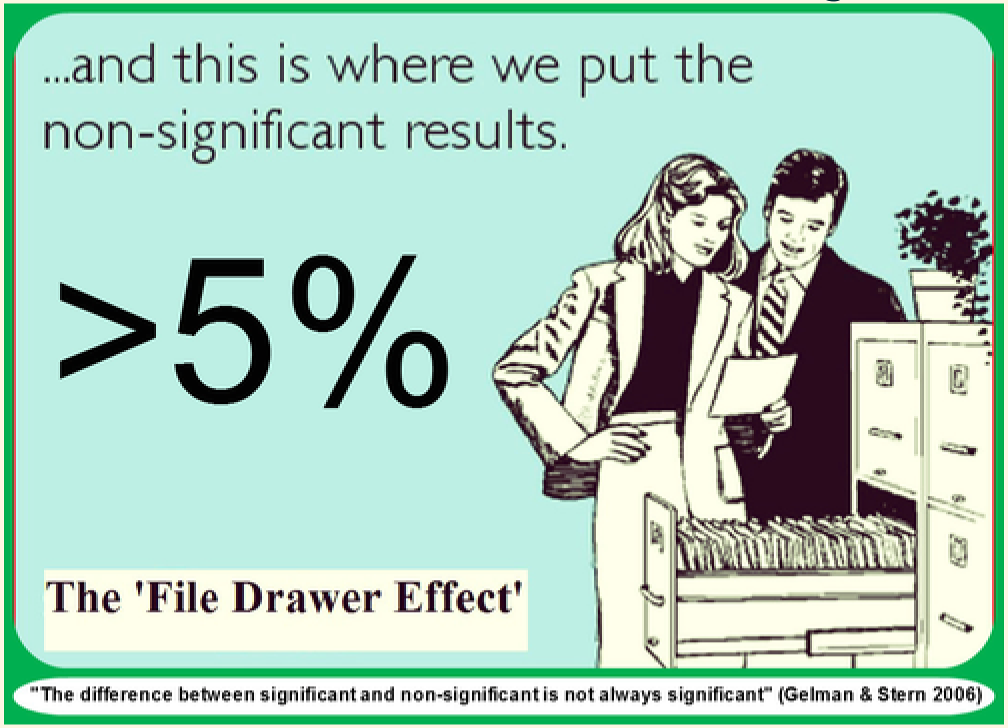
Random effects model. The observed effect T_1 (box) is sampled from a distribution with true effect θ_1, and variance σ^2. This true effect θ_1, in turn, is sampled from a distribution with mean μ and variance τ^2.

Borenstein et al. (2007)

7. Data and Bias Diagnostics

Publication Bias

- Phenomenon where published research is dependent on the direction or strength of results
  - Non-significance typically underpublished = inflation of ES
- Consequences: Distorts literature, wastes resources, misguides research, harm



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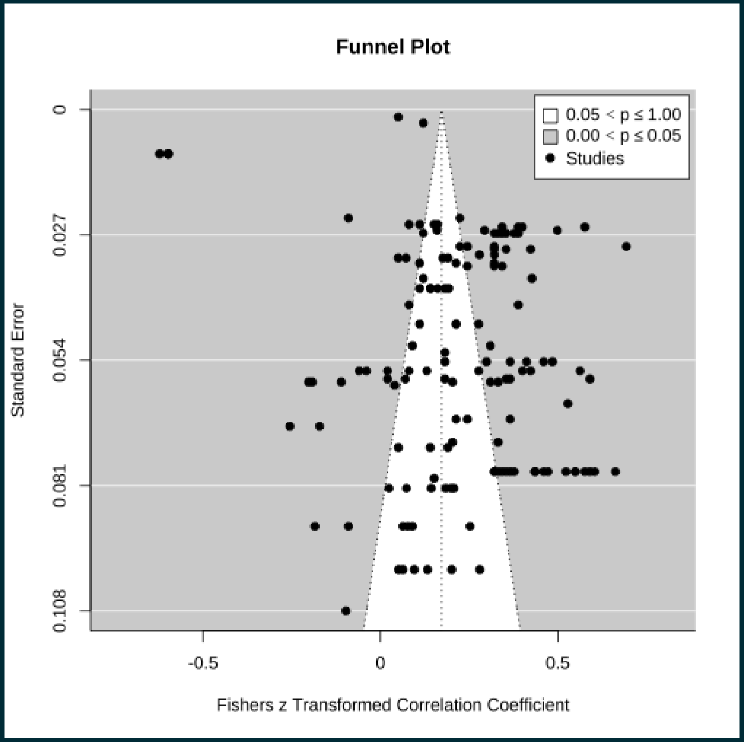
7. Data and Bias Diagnostics

{metafor} Funnel Plots using



Funnel Plot Asymmetry

- Plot fixed on the average weighted ES = .173
- Comes from heterogeneity, publication bias, chance

Where are we missing studies?

Note: SE's increase from top to bottom

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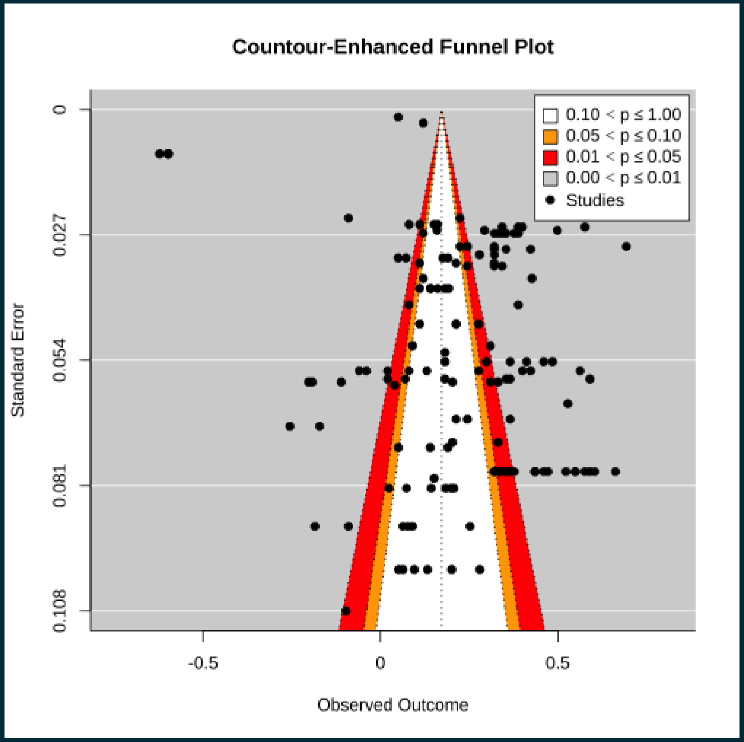
6. Data and Bias Diagnostics

{metafor} Funnel Plots



Egger's Regression Test

- Statistical est for asymmetry
- Regresses effect size on its standard error (weighted by inverse variance)
- Significance indicates asymmetry

Note: SE's increase from top to bottom

7. Data and Bias Diagnostics

{robumeta} Egger's Test

```
robu(formula = fishers_z ~ SE, data = TechnostressData,
                    modelweights = "CORR", studynum = studyID,
                    var.eff.size = var, small = TRUE) %>% print()
```

```
## RVE: Correlated Effects Model with Small-Sample Corrections
##
## Model: fishers_z ~ SE
##
## Number of studies = 37
## Number of outcomes = 139 (min = 1 , mean = 3.76 , median = 3 , max = 18 )
## Rho = 0.8
## I.sq = 99.43605
## Tau.sq = 0.02863188
##
##                Estimate StdErr t-value  dfs P(|t|>) 95% CI.L 95% CI.U Sig
## 1 X.Intercept.    0.145 0.0984   1.477 15.2   0.160  -0.0641    0.355
## 2           SE    0.591 1.7344   0.341 14.6   0.738  -3.1134    4.296
## ---
## Signif. codes: < .01 *** < .05 ** < .10 *
## ---
```

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7. Data and Bias Diagnostics

{robumeta} Trim and Fill Test Summary

```
##
## Estimated number of missing studies on the left side: 33 (SE = 7.7028)
##
## Random-Effects Model (k = 172; tau^2 estimator: REML)
##
##   logLik  deviance       AIC       BIC      AICc
## -20.9763   41.9526   45.9526   52.2360   46.0241
##
## tau^2 (estimated amount of total heterogeneity): 0.0717 (SE = 0.0081)
## tau (square root of estimated tau^2 value):      0.2678
## I^2 (total heterogeneity / total variability):   99.39%
## H^2 (total variability / sampling variability):  162.98
##
## Test for Heterogeneity:
## Q(df = 171) = 25717.4792, p-val < .0001
##
## Model Results:
##
## estimate      se    zval    pval   ci.lb   ci.ub
##   0.1326  0.0209  6.3438  <.0001  0.0916  0.1736  ***
```

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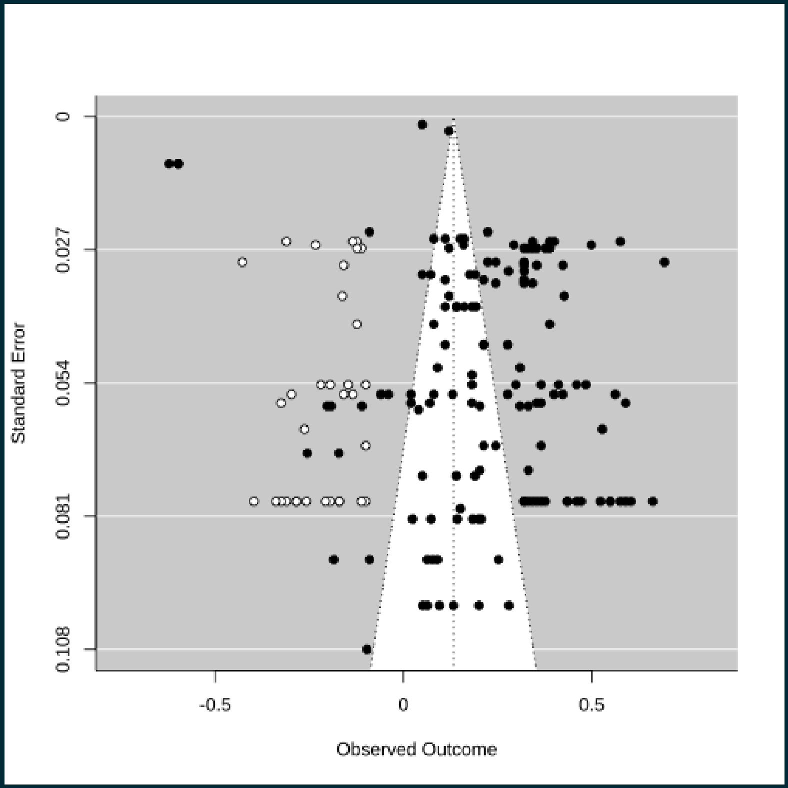
6. Data and Bias Diagnostics

{metafor} Trim and Fill Simulated Funnel Plot



7. Data and Bias Diagnostics

PET-PEESE Publication Bias Correction

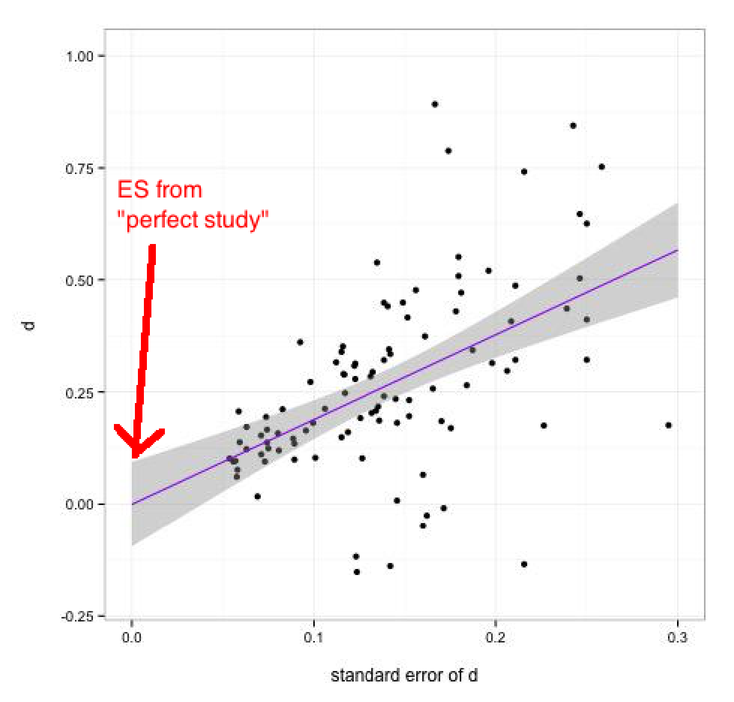
PET - Precision-Effect Testing

- provides ES that corrects for publication bias
  - the ES of a hypothetically "perfect" meta-analysis
- looks for positive correlation between standard error and ES
- biased as it assumes a homogeneous underlying true effect

PEESE - Precision-Effect Estimate with Standard Error

- typically a follow-up test when PET is significant

Both have *large* limitations but are seen in current literature.



7. Data and Bias Diagnostics

{robumeta} PET Correction

```
## RVE: Correlated Effects Model with Small-Sample Corrections
##
## Model: fishers_z ~ fishers_SE
##
## Number of studies = 37
## Number of outcomes = 139 (min = 1 , mean = 3.76 , median = 3 , max = 18 )
## Rho = 0.8
## I.sq = 99.43605
## Tau.sq = 0.02863188
##
##                Estimate StdErr t-value  dfs P(|t|>) 95% CI.L 95% CI.U Sig
## 1 X.Intercept.    0.145 0.0984   1.477 15.2   0.160  -0.0641    0.355
## 2   fishers_SE    0.591 1.7344   0.341 14.6   0.738  -3.1134    4.296
## ---
## Signif. codes: < .01 *** < .05 ** < .10 *
## ---
## Note: If df < 4, do not trust the results
```

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7. Data and Bias Diagnostics

p-Uniform* Publication Bias Correction

p-uniform* Corrector (RE)

- Assumes that *p*-values uniformly distributed at the true ES (as is true in normal NHST)
- ES estimate of *p*-uniform *represents the ES for which the* p*-values are uniformly distributed

van Aert et al. (2016)

7. Data and Bias Diagnostics

{puniform} Output

```
##
## Method: ML (k = 139; ksig = 103)
##
## Estimating effect size p-uniform*
##
##        est     ci.lb     ci.ub       L.0    pval
##     0.1305    0.0609    0.1983   13.2266   <.001
##
## ===
##
## Estimating between-study variance p-uniform*
##
##       tau2   tau2.lb   tau2.ub     L.het    pval
##     0.0626    0.0492    0.0811       Inf   <.001
```

8. Interpreting Outcomes

Meta-Regression with Moderators

```
## RVE: Correlated Effects Model with Small-Sample Corrections
##
## Model: fishers_z ~ avg_age + higher + dep
##
## Number of studies = 28
## Number of outcomes = 107 (min = 1 , mean = 3.82 , median = 3 , max = 18 )
## Rho = 0.8
## I.sq = 99.28004
## Tau.sq = 0.168822
##
##                Estimate StdErr t-value   dfs P(|t|>) 95% CI.L 95% CI.U Sig
## 1 X.Intercept.   0.4689 0.3772   1.243  8.75  0.2461  -0.3880   1.3259
## 2      avg_age  -0.0163 0.0251  -0.650  7.70  0.5345  -0.0746   0.0420
## 3       higher   0.0943 0.1223   0.771 12.75  0.4547  -0.1704   0.3591
## 4          dep  -0.1308 0.0547  -2.390 11.58  0.0348  -0.2506  -0.0111  **
## ---
## Signif. codes: < .01 *** < .05 ** < .10 *
## ---
## Note: If df < 4, do not trust the results
```

8. Interpreting Outcomes

Plug and Chug 1

If you are interested in the average age of students in your sample (average age = 17.1), who are participanting in K-12, and you measured anxiety, your Fishers z would be equal to:

```
z <- (.4689 + (-.0163 * (17.1) ) + (.0943 * (0) ) + (-.1308 * (0) ))
z
```

```
## [1] 0.19017
```

FISHERINV(.19017); z to *r* transformation, *r* = .1879

8. Interpreting Outcomes

Plug and Chug 2

If your sample involves 19 year olds, higher education, and you measured depression, your Fishers z would be equal to:

```
z1 <- (.4689 + (-.0163 * (19) ) + (.0943 * (1) ) + (-.1308 * (1) ))
z1
```

```
## [1] 0.1227
```

FISHERINV(.1227); z to *r* transformation, *r* = .1220

9. Presenting Results

Forest Plot

- x-axis = ES of interest, centered at 0
- y-axis = study name/author name/effect size ID
- bars around points = 95% confidence interval
- largers points = larger N

```
forester(left_side_data = TechnostressData[,c(1, 3, 5, 6, 64)],
         estimate = TechnostressData$es_Ztocorr,
         ci_low = TechnostressData$es_Ztocorr_CI_lower,
         ci_high = TechnostressData$es_Ztocorr_CI_upper,
         display = FALSE,
         xlim = c(-1, 1),
         null_line_at = c(0,.165),
         file_path = "/Users/jayjeffries/Desktop/Meta-Analysis/Data File
         font_family = "sans")
```

Resources

Doing Meta-Analysis in R Online Text

- Advanced sections: MLM M-A, SEM M-A, Network M-A, Bayesian M-A

{robumute} Vignette - RVE Meta-Regression, Egger's Test

{metafor} Vignette - Funnel Plots, Trim and Fill

{metaviz} Vignette - Power Sunset Plot

{puniform} Vignette - Publication Correction

{forester} GitHub Page - Publication-Ready Forest Plot

Interactive Meta-Analysis Site

- Explore heterogeneity of math intervention outcome effect sizes sponsored by *IES*

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Thoughts and Questions