# Thesis Seminar
# Meta-analysis

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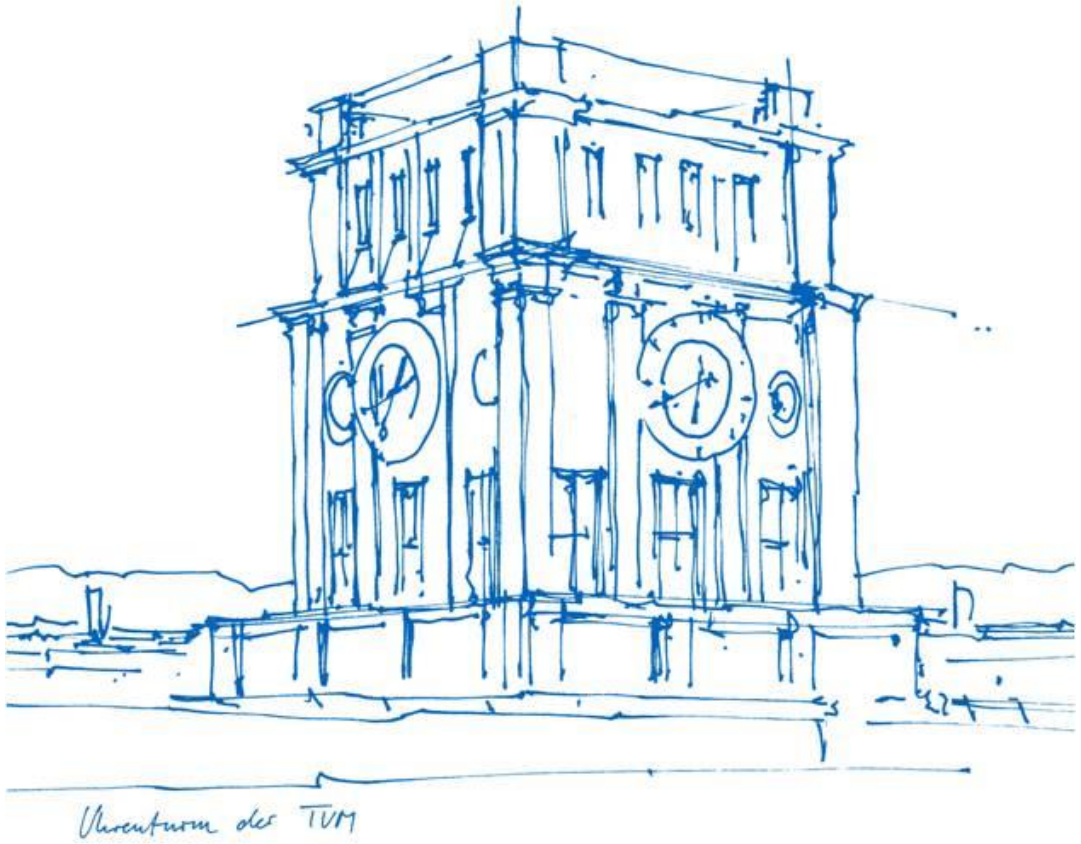
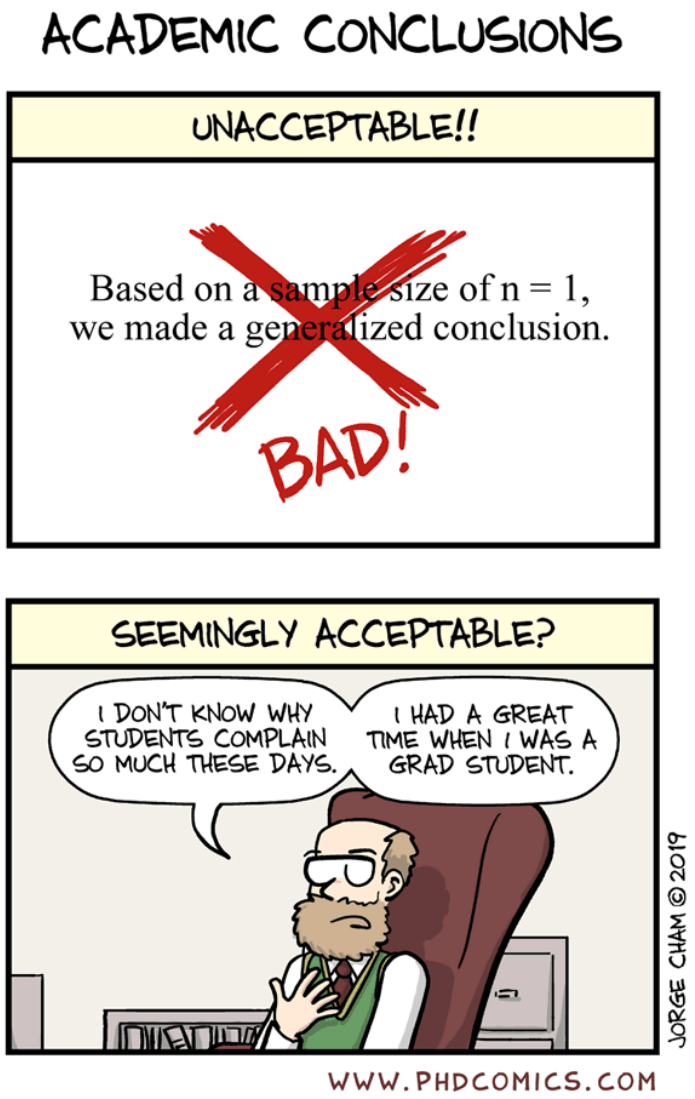


# Why do we need meta-analyses?



# Why do we need meta-analyses?

- Nowadays an enormous stream of academic publications!
- A single study does not provide a precise, definite answer
- Science is cumulative: many studies are (partial) replications and extensions

**But** do more and more empirical findings lead to **more certainty**

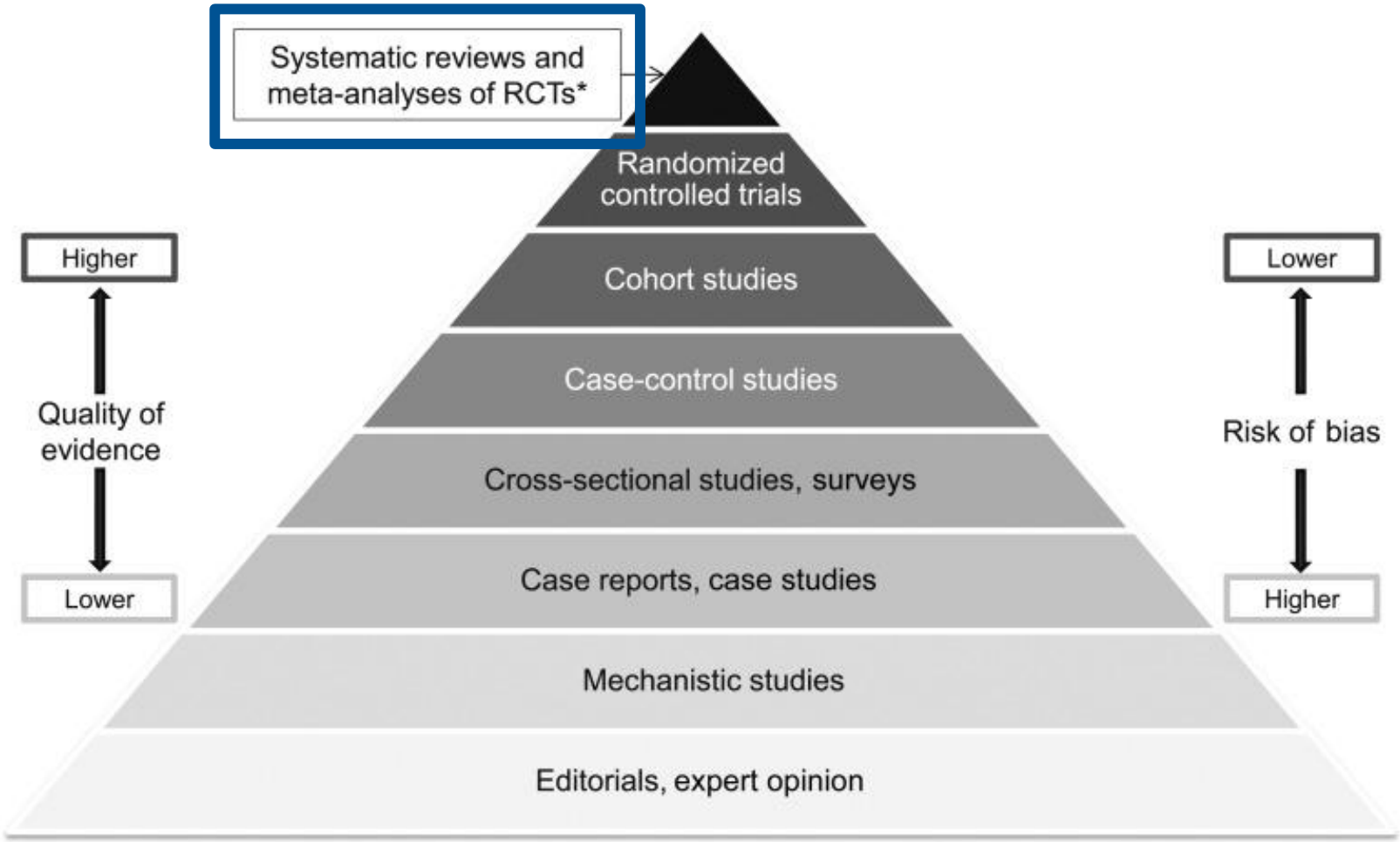
or to **more variety and inconsistency** in results…?

**Required:**

- Insightful **summary or overview**
- Combine a (large) set of studies to determine the **limits & conditions of findings**

Eden, D. (2002). From the editors: Replication, meta-analysis, scientific progress, and AMJ's publication policy. *Academy of Management Journal*, 841-846.

# Meta-analysis on experiments: highest level of evidence




Yetley, E. A., MacFarlane, A. J., Greene-Finestone, L. S., Garza, C., Ard, J. D., Atkinson, S. A., Bier, D. M., Carriquiry, A. L., Harlan, W. R., Hattis, D., King, J. C., Krewski, D., O'Connor, D. L., Prentice, R. L., Rodricks, J. V., & Wells, G. A. (2017). Options for basing Dietary Reference Intakes (DRIs) on chronic disease endpoints: Report from a joint US-/Canadian-sponsored working group. *American Journal of Clinical Nutrition*, *105*(1), 249S-285S. https://doi.org/10.3945/ajcn.116.139097

# Agenda

1. **What** are meta-analyses?

2. **How** are meta-analyses conducted?

3. How to **read** & **critically examine** meta-analytical findings?

4. **Best practices** & further readings

# What are meta-analyses?

# What are meta-analyses?

**“The analysis of analyses.”**

- Gene V. Glass in “Primary, secondary and meta-analysis of research”, 1976.

**Definition:**

= statistical integration of all “published” (better: existing) empirical research results through quantitative comparison & combining of these findings

Meta-analyses **overcome typical problems & validity issues of primary studies**

- For meta-analysis, effect sizes are summarized **independently of significance**
- Weighted, mean effect size over all studies is **closer to true effect** in the whole population

Schewe, A. F., Hülsheger, U. R., & Maier, G. W. (2014). Metaanalyse–praktische Schritte und Entscheidungen im Umsetzungsprozess. Zeitschrift für Arbeits-und Organisationspsychologie A&O.

# How to conduct meta-analyses?

# Process of conducting a meta-analysis

1. Definition of the research proposition
2. Data collection
   a) Collection of studies
   b) Selection / Exclusion of studies
   c) Development of coding questionnaire
   d) Coding of studies
3. Data analysis
   a) Computation of effect sizes
   b) Dealing with publication bias
   c) Examination of heterogeneity
   d) Moderator analysis, meta-regression, …
4. Report findings
5. Formulation of conclusions and directions for further research

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# Example: Contradictory findings

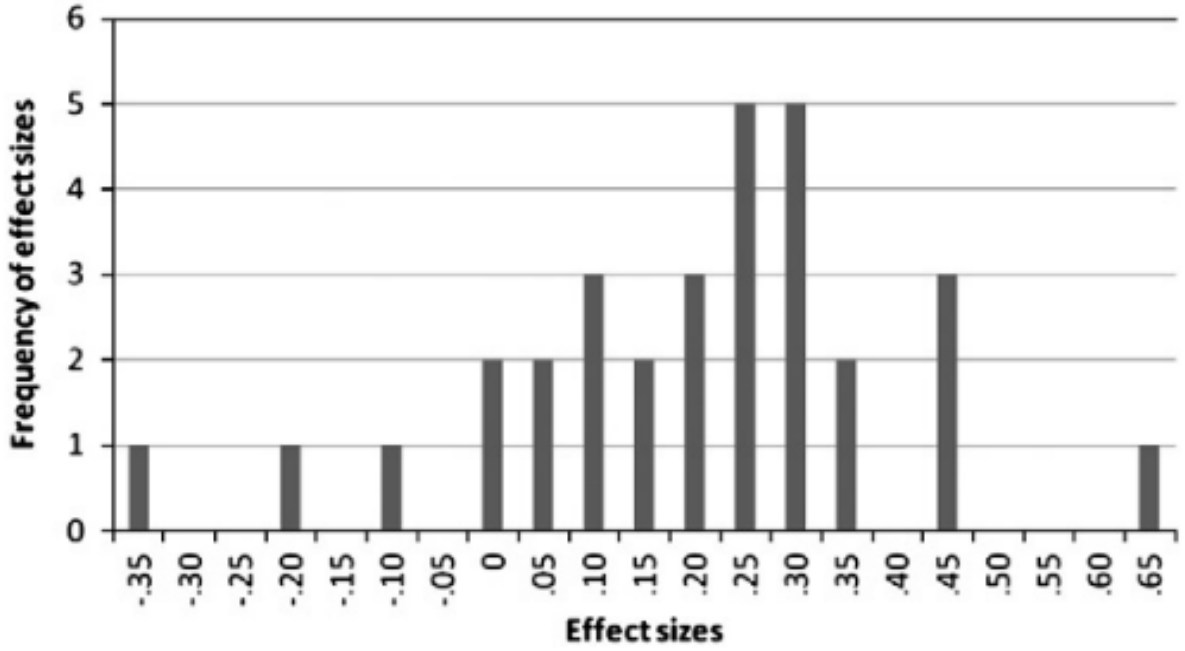


**Fig. 1.** Range of effect sizes (r) for the relationship between transformational leadership and innovation (aggregated correlations).

Rosing, K., Frese, M., & Bausch, A. (2011). Explaining the heterogeneity of the leadership-innovation relationship: Ambidextrous leadership. *The Leadership Quarterly*, *22*(5), 956–974.

# But …


https://www.instagram.com/thedissertationcoach/

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# Collection of studies

- Recommendation: **systematic literature review**
- But meta-analyses do **not necessarily** require a comprehensive set of studies

→ example: single-study meta-analysis

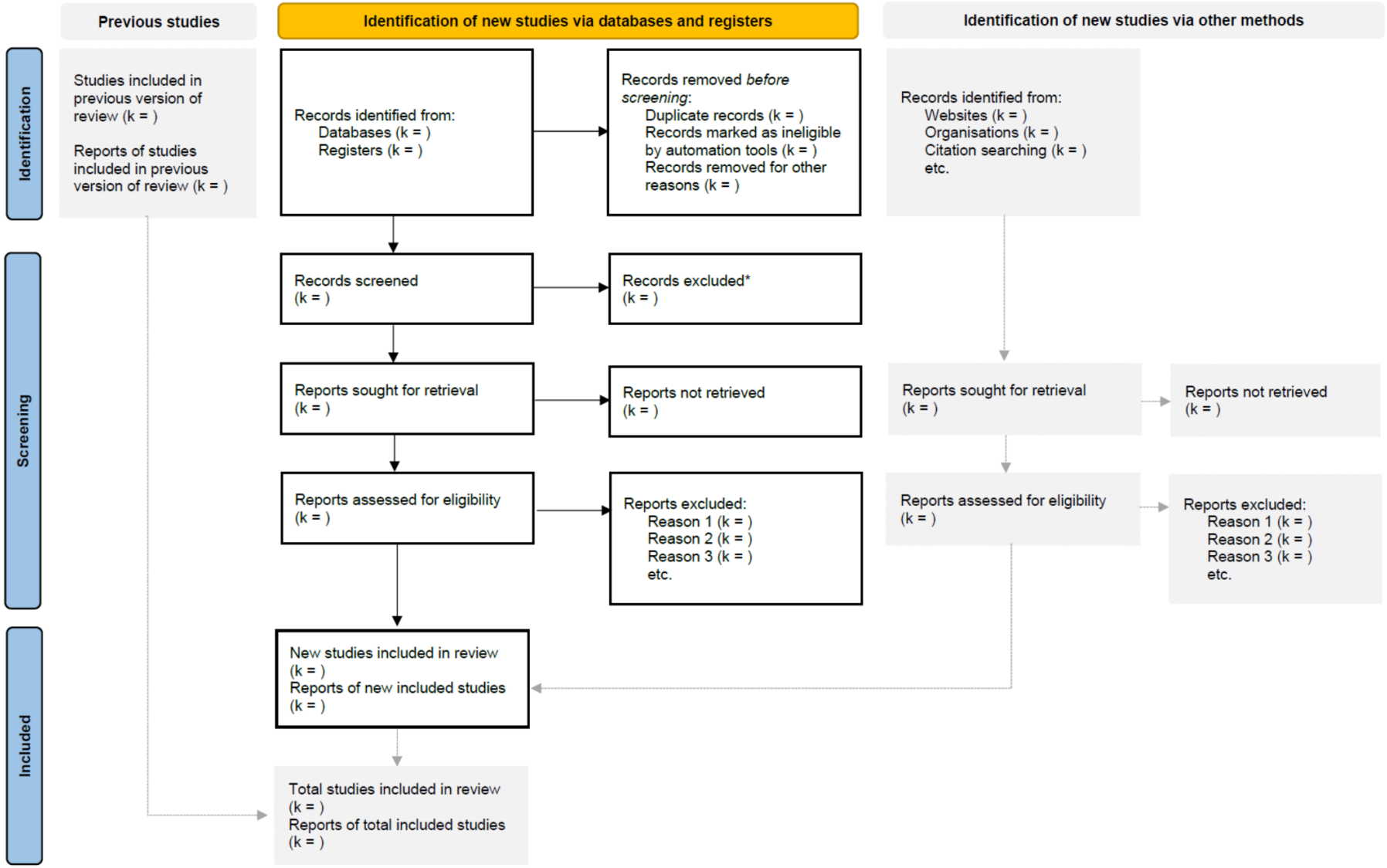
**TABLE 3** Meta-analysis of main effect sizes

| | Integral | | | | | | | Incidental | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Anger** | ***k*** | ***d*** | **95% CI** | ***p*** | ***Q*** | $I^2$ | $T^2$ | ***k*** | ***d*** | **95% CI** | ***p*** | ***Q*** | $I^2$ | $T^2$ |
| Deliberative RPs | 14 | 0.17 | 0.06, 0.29 | .003 | 20.07 | 35.23 | 0.03 | 14 | −0.17 | −0.28, −0.06 | .003 | 34.46 | 68.28 | 0.07 |
| Affective RPs | 14 | 0.14 | 0.02, 0.25 | .018 | 18.21 | 28.59 | 0.02 | 14 | −0.07 | −0.18, 0.04 | .217 | 17.54 | 25.90 | 0.02 |
| Experiential RPs | 14 | 0.15 | 0.03, 0.26 | .011 | 19.42 | 33.07 | 0.02 | 14 | −0.10 | −0.22, 0.01 | .067 | 18.66 | 30.23 | 0.02 |
| Intentions | 10 | −0.15 | −0.27, −0.03 | .014 | 31.11 | 71.07 | 0.10 | 10 | −0.06 | −0.18, 0.06 | .324 | 4.69 | | |
| | **Integral** | | | | | | | **Incidental** | | | | | | |
| **Fear** | ***k*** | ***d*** | **95% CI** | ***p*** | ***Q*** | $I^2$ | $T^2$ | ***k*** | ***d*** | **95% CI** | ***p*** | ***Q*** | $I^2$ | $T^2$ |
| Deliberative RPs | 16 | 0.26 | 0.17, 0.36 | <.001 | 21.22 | 29.30 | 0.02 | 16 | −0.01 | −0.10,0.09 | .910 | 9.17 | | |
| Affective RPs | 16 | 0.31 | 0.22, 0.41 | <.001 | 43.75 | 65.72 | 0.07 | 16 | −0.01 | −0.10,0.08 | .854 | 1.76 | | |
| Experiential RPs | 16 | 0.28 | 0.18, 0.37 | <.001 | 33.84 | 55.67 | 0.05 | 16 | 0.01 | −0.08, 0.10 | .820 | 9.81 | | |
| Intentions | 12 | −0.10 | −0.20, −0.01 | .036 | 35.67 | 69.16 | 0.07 | 12 | −0.01 | −0.10, 0.09 | .957 | 22.54 | 33.45 | 0.02 |

*Note.* $I^2$ and $T^2$ reported only with significant Q. Bolded values are significant at p < .05.
Abbreviations: CI, confidence interval; RP, risk perception.

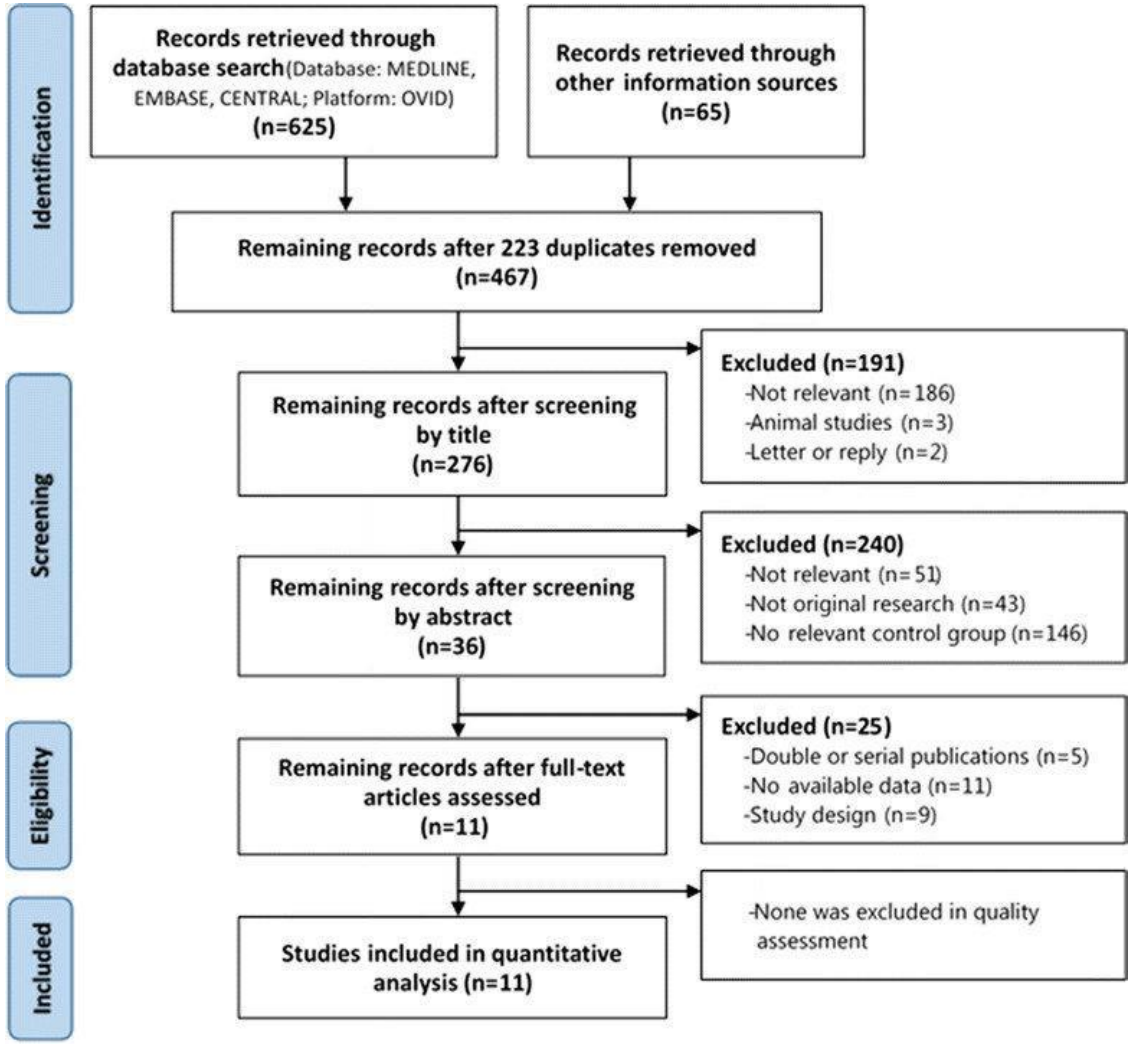
Ferrer, R. A., & Ellis, E. M. (2020). Preliminary evidence for differential effects of integral and incidental emotions on risk perception and behavioral intentions: A meta-analysis of eight experiments. *Journal of Behavioral Decision Making,,1–15*. https://doi.org/10.1002/bdm.2209

# PRISMA Flow Chart




Page, M. (2020). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Preprint*, *59*(Supplement), S59–S61. https://doi.org/10.7248/jjrhi.59.s59

# PRISMA Flow Chart - Example




Zheng, Y., Wang, M., He, S., & Ji, G. (2015). Short-term effects of intragastric balloon in association with conservative therapy on weight loss: a meta-analysis. *Journal of Translational Medicine*, *13*(1), 246.

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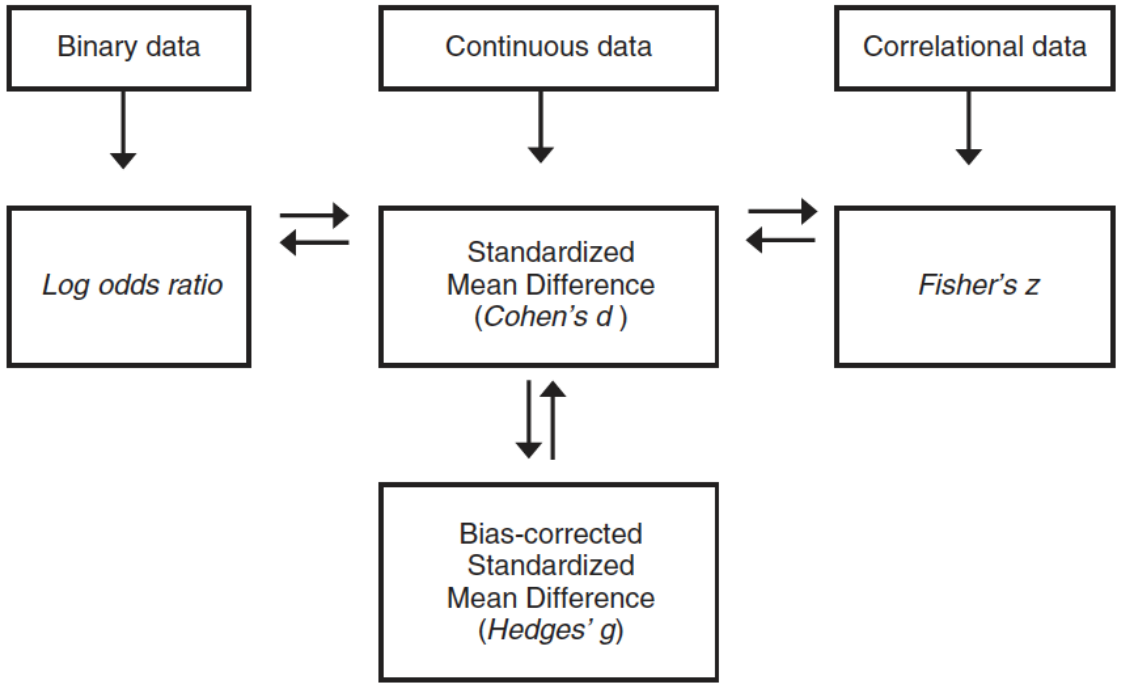
# Coding table

| A | B | | D | E | | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|
| Stud_ID | Jahr | ... | Samp_ID | N | ... | ES_ID | aV | aV_Name | ES_r |
| 01 | 1998 | ... | 01 | 245 | ... | 01 | 6 | Job satisfaction | .26 |
| 01 | 1998 | ... | 02 | 316 | ... | 02 | 7_1 | Emotional attachment | .34 |
| 01 | 1998 | ... | 02 | 316 | ... | 03 | 7_2 | Turnover thoughts (rev.) | .32 |
| 01 | 1998 | ... | 02 | 316 | ... | 04 | 7 | Comb: Org. attachment | .33 |
| 02 | 2005 | ... | 03 | 81 | ... | 05 | 7 | Org. attachment | .4 |

Schewe, A. F., Hülsheger, U. R., & Maier, G. W. (2014). Metaanalyse–praktische Schritte und Entscheidungen im Umsetzungsprozess. Zeitschrift für Arbeits-und Organisationspsychologie A&O.

# Choosing and calculating effect sizes

- Choice **based on reported studies**
- Effect sizes can be **converted** into others
- Most studies do not report effect sizes, hence **calculation is necessary**




Often **more than one effect size from one study** (different treatment groups, multiple comparisons etc.)
→ Before calculation of summary effect: combining or correcting dependent effect sizes & standard errors

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). *Introduction to meta-analysis*. John Wiley & Sons.

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# Computation of the summary effect: Fixed effect model vs. random effects model

## Fixed effect model:

- All studies included in analyses are **functionally identical**
- Goal: estimate **one true effect**
- **No generalization** to other populations

## Random effects model:

- Studies **not functionally identical**
- Goal: estimate **mean of effects' distribution**
- **Generalize** to other populations

⚠ Only applicable if enough studies available!

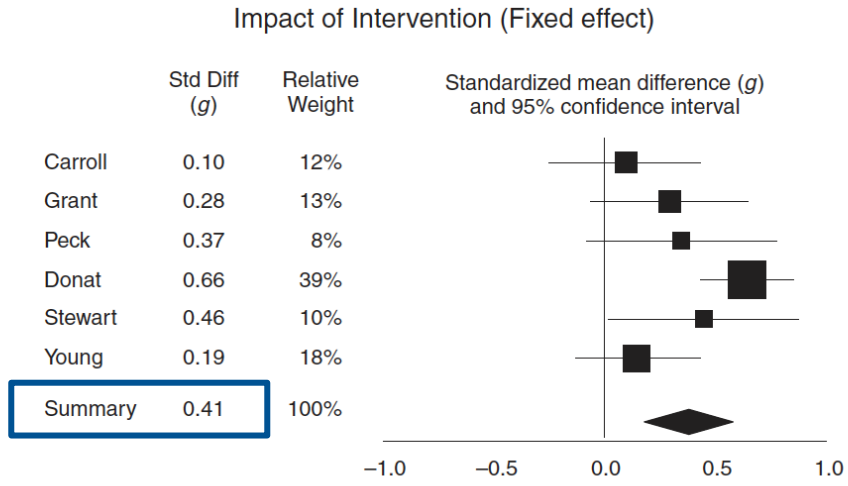


**Figure 13.1** Fixed-effect model – forest plot showing relative weights.

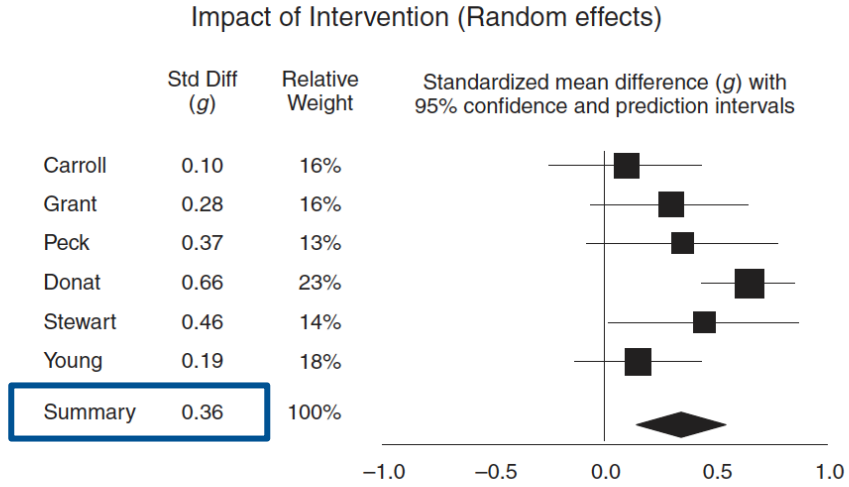


**Figure 13.2** Random-effects model – forest plot showing relative weights.

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). *Introduction to meta-analysis*. John Wiley & Sons.

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# The file drawer problem

⚠ Studies with significant intervention effect tend to be **published more often** than studies with null results

**Tests:** (exemplary)
- Funnel plot
- Orwin's Fail-Safe-N-Test

**Solutions:** (exemplary)
- Search for grey literature
- Trim-and-Fill
- Cumulative meta-analysis

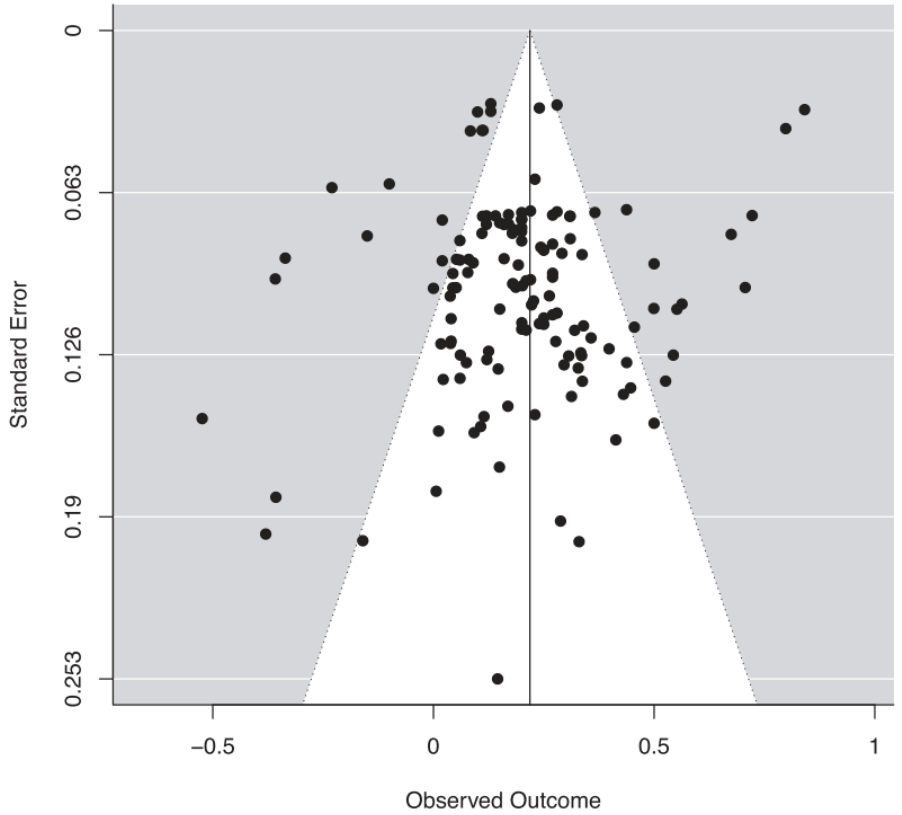


Figure: Wake, S., Wormwood, J., & Satpute, A. B. (2020). The influence of fear on risk taking: a meta-analysis. *Cognition and Emotion, 34(6),* 1143–1159. https://doi.org/10.1080/02699931.2020.1731428

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# Assessing heterogeneity

**Heterogeneity** = variation in true effect sizes

Important because heterogeneity could suggest
a. The existence of **outliers**
b. The existence of **subgroups**
c. That we **compare apples with oranges**

**Important estimators:** Q test, $I^2$, $T^2$

**Investigation via**
1. Outlier detection with Confidence Intervals
2. Influence Analysis
3. Gosh Plot Analysis

(4. Subgroup analyses)

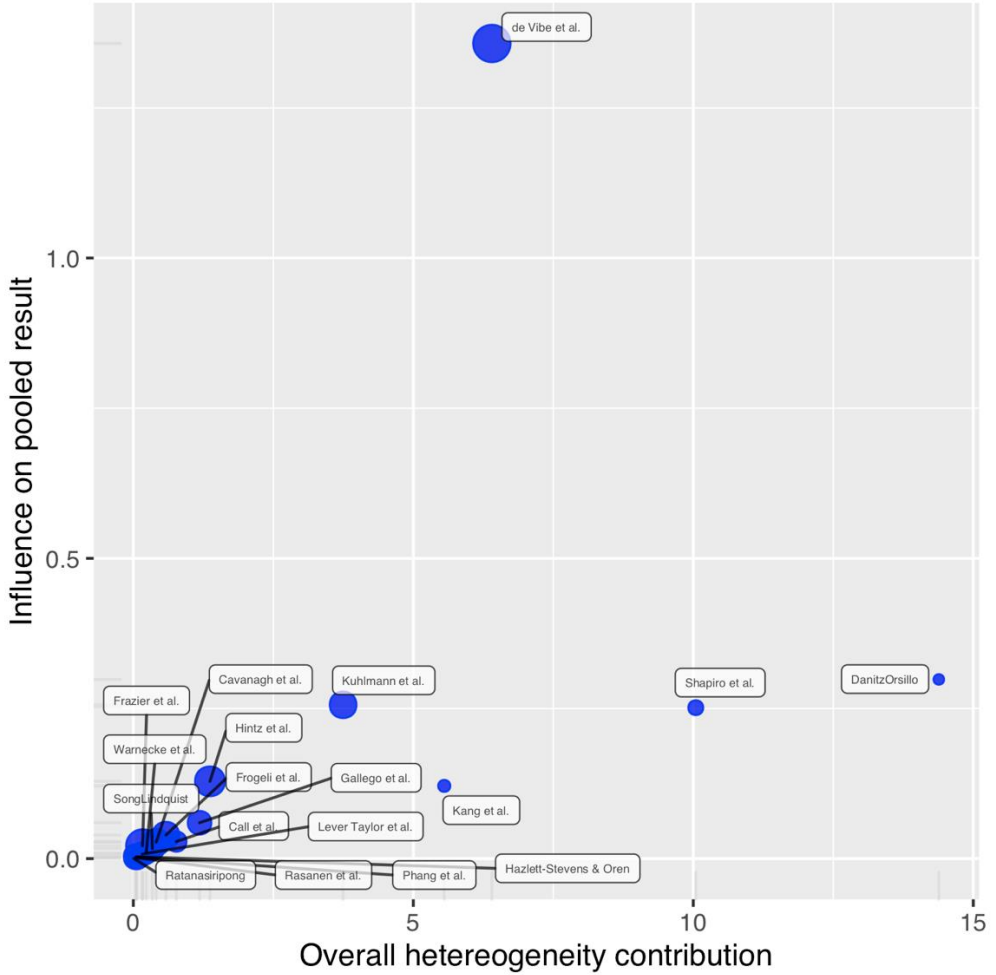


Figure 6.2: Baujat Plot


Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). *Introduction to meta-analysis*. John Wiley & Sons

Viechtbauer, W., & Cheung, M. W.-L. (2010). Outlier and influence diagnostics for meta-analysis. *Research Synthesis Methods*, *1*(2), 112–125. https://doi.org/10.1002/jrsm.11

Figure: Harrer, M., Cuijpers, P., Furukawa, T.A, & Ebert, D. D. (2019). Doing Meta-Analysis in R: A Hands-on Guide. DOI: 0.5281/zenodo.2551803.https://bookdown.org/MathiasHarrer/Doing_Meta_Analysis_in_R/

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# Moderator analyses

**Options**

1. **Subgroup analyses**
2. **Correlations** between moderator & common effect size
3. **Meta-regression**

**Because of**

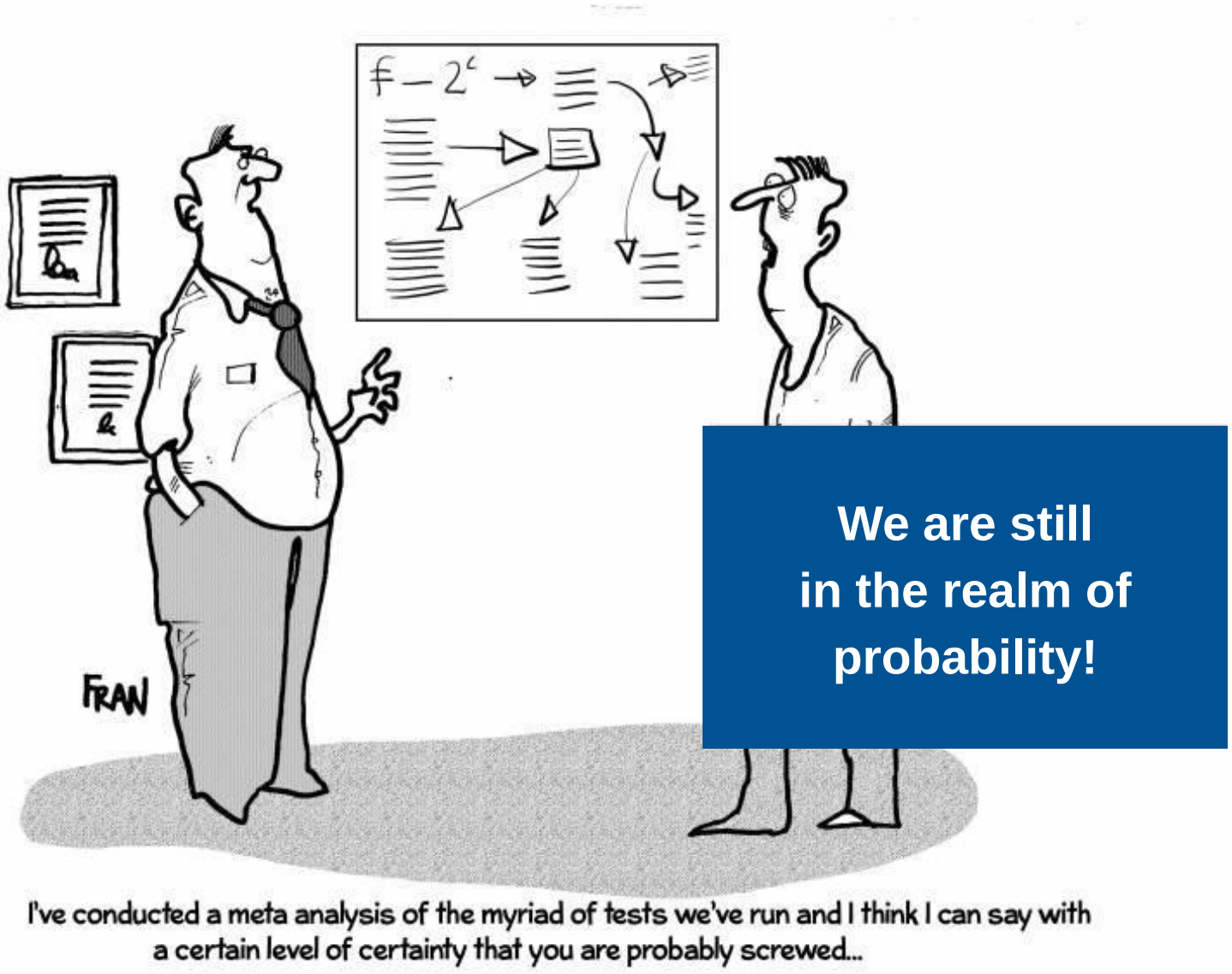
a. A priori hypotheses
b. High heterogeneity

→ **Better:** specific set of moderators based on theoretical assumptions because of capitalization of chance
→ In subgroup analyses: watch out for **interdependence/correlation** of moderators
→ Meta-regression not advised as it is error-prone & requires high *k*

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). *Introduction to meta-analysis*. John Wiley & Sons
Schmidt, F. L., & Hunter, J. E. (2003). Meta-analysis. *Handbook of psychology*, 533-554.

# How to read & critically examine meta-analytical findings?

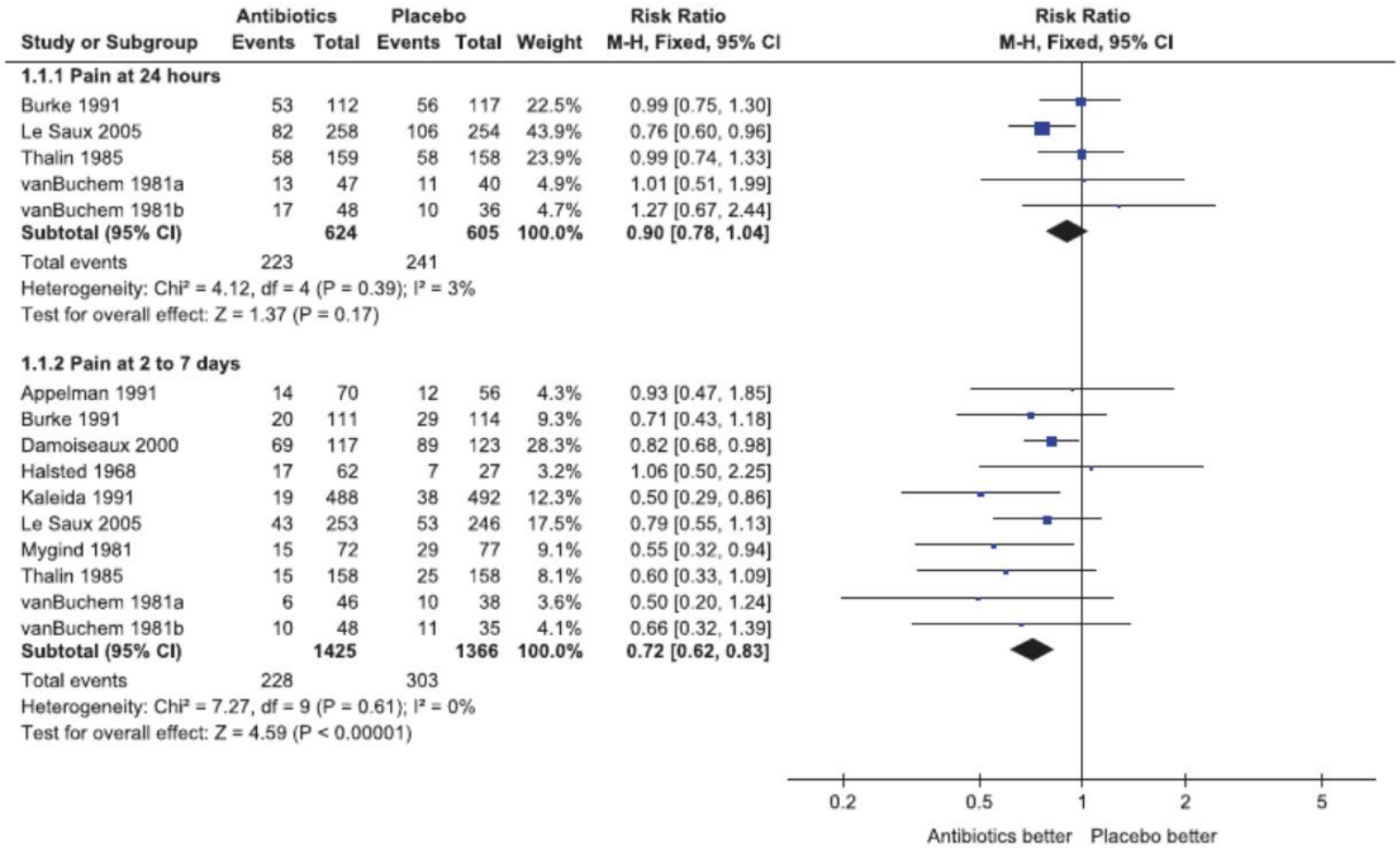
# What is important when reading meta-analyses?




**We are still in the realm of probability!**

https://www.cartoonstock.com/directory/m/medical_analysis.asp

# How to read a meta-analysis? - Forest Plot



| Study or Subgroup | Antibiotics Events | Total | Placebo Events | Total | Weight | Risk Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| **1.1.1 Pain at 24 hours** | | | | | | |
| Burke 1991 | 53 | 112 | 56 | 117 | 22.5% | 0.99 [0.75, 1.30] |
| Le Saux 2005 | 82 | 258 | 106 | 254 | 43.9% | 0.76 [0.60, 0.96] |
| Thalin 1985 | 58 | 159 | 58 | 158 | 23.9% | 0.99 [0.74, 1.33] |
| vanBuchem 1981a | 13 | 47 | 11 | 40 | 4.9% | 1.01 [0.51, 1.99] |
| vanBuchem 1981b | 17 | 48 | 10 | 36 | 4.7% | 1.27 [0.67, 2.44] |
| **Subtotal (95% CI)** | | **624** | | **605** | **100.0%** | **0.90 [0.78, 1.04]** |
| Total events | 223 | | 241 | | | |
| Heterogeneity: Chi² = 4.12, df = 4 (P = 0.39); I² = 3% | | | | | | |
| Test for overall effect: Z = 1.37 (P = 0.17) | | | | | | |
| **1.1.2 Pain at 2 to 7 days** | | | | | | |
| Appelman 1991 | 14 | 70 | 12 | 56 | 4.3% | 0.93 [0.47, 1.85] |
| Burke 1991 | 20 | 111 | 29 | 114 | 9.3% | 0.71 [0.43, 1.18] |
| Damoiseaux 2000 | 69 | 117 | 89 | 123 | 28.3% | 0.82 [0.68, 0.98] |
| Halsted 1968 | 17 | 62 | 7 | 27 | 3.2% | 1.06 [0.50, 2.25] |
| Kaleida 1991 | 19 | 488 | 38 | 492 | 12.3% | 0.50 [0.29, 0.86] |
| Le Saux 2005 | 43 | 253 | 53 | 246 | 17.5% | 0.79 [0.55, 1.13] |
| Mygind 1981 | 15 | 72 | 29 | 77 | 9.1% | 0.55 [0.32, 0.94] |
| Thalin 1985 | 15 | 158 | 25 | 158 | 8.1% | 0.60 [0.33, 1.09] |
| vanBuchem 1981a | 6 | 46 | 10 | 38 | 3.6% | 0.50 [0.20, 1.24] |
| vanBuchem 1981b | 10 | 48 | 11 | 35 | 4.1% | 0.66 [0.32, 1.39] |
| **Subtotal (95% CI)** | | **1425** | | **1366** | **100.0%** | **0.72 [0.62, 0.83]** |
| Total events | 228 | | 303 | | | |
| Heterogeneity: Chi² = 7.27, df = 9 (P = 0.61); I² = 0% | | | | | | |
| Test for overall effect: Z = 4.59 (P < 0.00001) | | | | | | |



**Figure 1**. Forest plot. Antibiotics for acute otitis media in children: Effect on recovery from pain [16]. Copyright Cochrane Collaboration, reproduced with permission.

Anzures-Cabrera, J., & Higgins, J. P. (2010). Graphical displays for meta-analysis: an overview with suggestions for practice. *Research synthesis methods*, *1*(1), 66-80.

# How to read a meta-analysis? - Table

**Table 3.** *Overall results for treatment–control sample on judgement and decision-making outcomes by emotion group comparison*

| | | | | | | | 95% CI | | |
|---|---|---|---|---|---|---|---|---|---|
| | *k* | *N* | *d* | *SD* | *SE* | *PVA* | *L* | *U* | *Q* |
| $TC^{j}$ | | | | | | | | | |
| Anger | 6 | 535 | 0.06 | 0.09 | 0.05 | 100.00 | −0.04 | 0.16 | 1.16 |
| Fear | 6 | 542 | 0.11* | 0.11 | 0.05 | 100.00 | 0.01 | 0.21 | 1.54 |
| Sadness | 9 | 553 | 0.18* | 0.22 | 0.07 | 100.00 | 0.04 | 0.32 | 6.66 |
| Happiness | 5 | 304 | 0.17* | 0.26 | 0.07 | 100.00 | 0.03 | 0.31 | 4.83 |
| $TC^{dm}$ | | | | | | | | | |
| Anger | 10 | 862 | 0.26*** | 0.29 | 0.05 | 58.69 | 0.16 | 0.36 | 17.04* |
| Fear | 6 | 484 | 0.18*** | 0.19 | 0.05 | 100.00 | 0.08 | 0.28 | 4.44 |
| Sadness | 13 | 975 | 0.33*** | 0.28 | 0.06 | 71.02 | 0.21 | 0.45 | 18.31 |
| Disgust | 2 | 192 | 0.36*** | 0.27 | 0.04 | 59.06 | 0.28 | 0.44 | 3.39 |
| Guilt | 3 | 333 | 0.98*** | 0.34 | 0.04 | 34.85 | 0.90 | 1.06 | 8.61* |

*Notes:* $TC^{j}$ = treatment–control judgement sample; $TC^{dm}$ = treatment–control decision-making sample; *k* = number of effect-size estimates; *N* = sum of participants; *d* = average sample-weighted effect-size estimate using Cohen's *d*; *SD* = standard deviation of effect-size estimates; *SE* = standard error of effect-size estimates; *PVA* = percent of variance accounted for by sampling error; 95% CI = 95% confidence interval; *Q* = *Q* statistic (Hunter & Schmidt, 1990). $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Angie, A. D., Connelly, S., Waples, E. P., & Kligyte, V. (2011). The influence of discrete emotions on judgement and decision-making: A meta-analytic review. Cognition and *Emotion, 25*(8), 1393–1422. https://doi.org/10.1080/02699931.2010.550751

# Example: Business Case for Women Leaders

**Table 2**

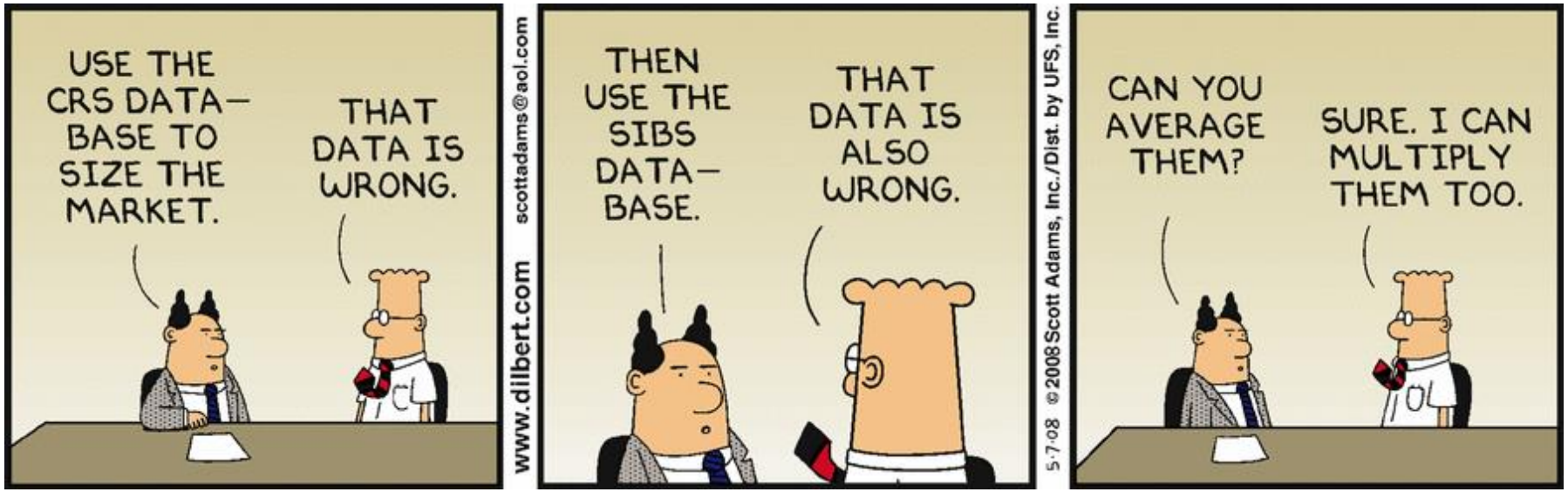
**Meta-Analytic Results for Women's Representation in Leadership and Firm Financial Performance**

| | *k* | *n* | $\bar{p}$ | 95% Confidence Interval | 80% Credibility Interval | *Qw* |
|---|---|---|---|---|---|---|
| Women's leadership and firm performance | 78 | 117,639 | +.02 | +.01 to +.04 | *–.07 to +.12* | 345.51* |
| Female representation on board of directors | 62 | 75,978 | +.04 | +.05 to +.09 | *–.04 to +.18* | 561.95* |
| Female CEO | 12 | 45,165 | –.02 | *–.04 to +.15* | *–.08 to +.05* | –64.72 |
| Female representation on top management team | 13 | 27,431 | +.01 | *–.00 to +.04* | –.03 to +.07 | 165.66* |
| Accounting performance measures | 75 | 111,905 | +.02 | +.01 to +.05 | *–.09 to +.15* | 246.03* |
| Return on assets | 46 | 90,368 | +.03 | *–.00 to +.05* | *–.09 to +.13* | 150.16* |
| Return on equity | 20 | 37,026 | +.05 | *–.03 to +.03* | *–.09 to +.09* | –9.58 |
| Leverage | 18 | 56,119 | +.06 | *–.00 to +.05* | *–.11 to +.13* | 119.56* |
| Sales | 10 | 18,077 | +.04 | +.03 to +.37 | *–.16 to +.56* | 25.84* |
| Profitability | 9 | 4,329 | +.00 | *–.01 to +.14* | *–.08 to +.20* | 46.10* |
| Composite measure | 5 | 1,041 | –.05 | *–.09 to +.04* | *–.12 to +.09* | –22.90 |
| Return on capital | 3 | 205 | –.03 | *–.20 to +.24* | *–.33 to +.35* | –1.33 |
| Return on investment | 2 | 850 | +.01 | *–.05 to +.06* | –.04 to +.07 | 8.67* |
| Market performance measures | 30 | 67,627 | +.05 | +.01 to +.05 | *–.05 to +.10* | 228.93* |
| Tobin's *Q* | 17 | 56,348 | +.01 | *–.00 to +.06* | *–.06 to +.12* | 115.93* |
| Stock performance | 14 | 21,011 | +.06 | *–.06 to +.04* | *–.14 to +.12* | –14.65 |
| Market capitalization | 4 | 3,879 | +.14 | *–.08 to +.16* | *–.12 to +.20* | 10.61* |

*Note:* Confidence intervals in italics include 0; credibility intervals in italics range in excess of .11. *k* = number of effect sizes; $\bar{p}$ = mean estimate of the Fisher's *z*–transformed corrected population correlation of the cumulated effect sizes.
*$p < .05$.

Hoobler, J. M., Masterson, C. R., Nkomo, S. M., & Michel, E. J. (2018). The business case for women leaders: Meta-analysis, research critique, and path forward. *Journal of Management, 44*(6), 2473-2499.

# Always keep in mind …




**… garbage in, garbage out!**

www.dilbert.com

# Best practices & further readings

# 5 Things to Know About Meta-Analysis

1. A meta-analysis is a **safer starting point than a single study**
   – but it won't *necessarily* be more reliable

2. A meta-analysis is a **snapshot in time**
   – it can even be out-of-date the day it's published

3. **Look carefully** before you take an outcome literally
   – it may not be what it appears to be

4. **Data choices and statistical technique** can change a result

5. **Absence of evidence** is not evidence of absence
   …most of the time


*Photo by Mike Gogulski (Wikimedia Commons)*

Bastian (2015). Another 5 Things to Know About Meta-Analysis. Retrievable via https://blogs.plos.org/absolutely-maybe/2015/06/30/another-5-things-to-know-about-meta-analysis/

# Additional materials:
# Tutorial videos on meta analysis

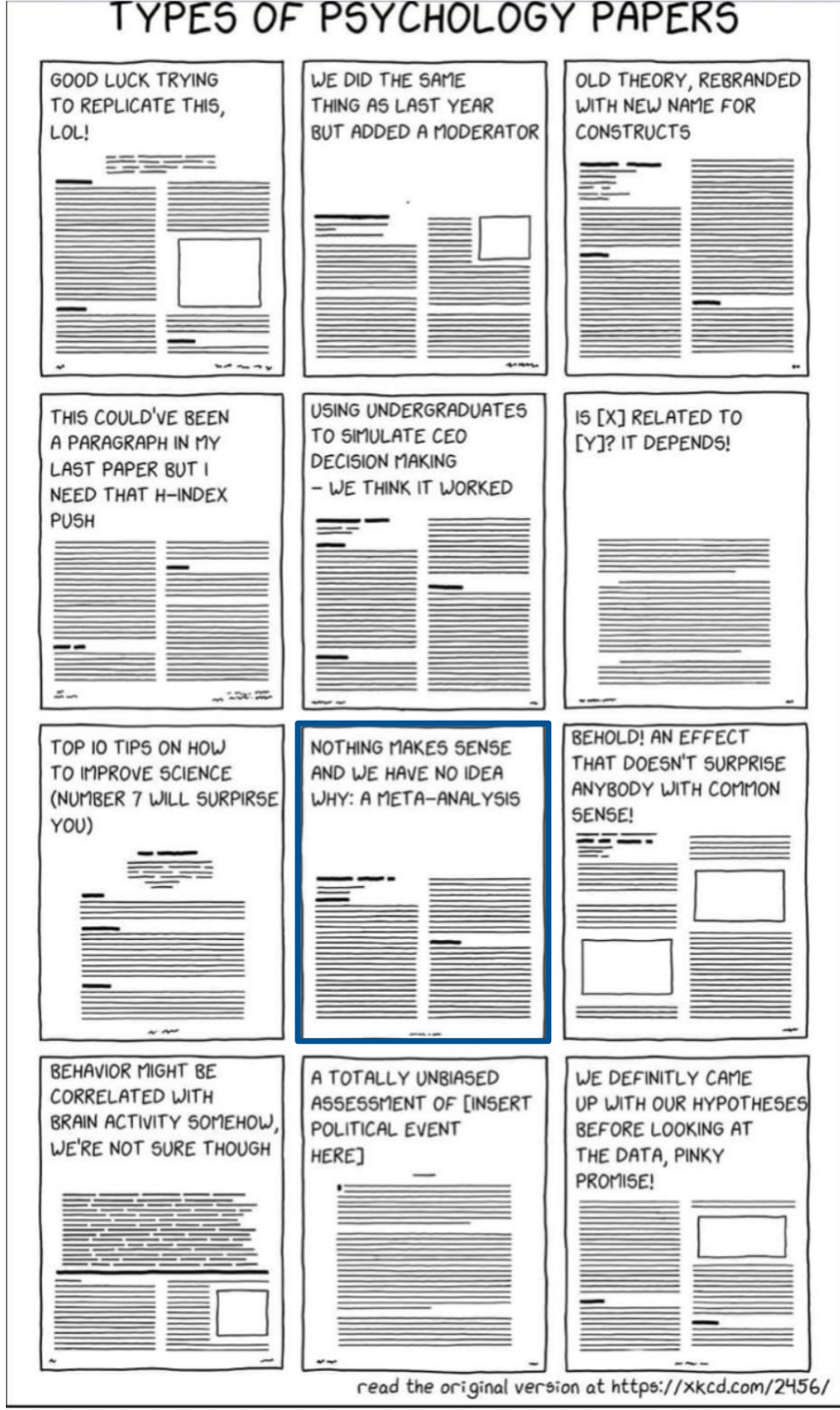
## http://metalab.stanford.edu/tutorials.html

The website offers several video tutorials on the following questions:

- Why meta-analysis (MA)?
- What are effect sizes?
- How do I define my MA question?
- Why should I bother keeping track of the MA creation process?
- Now that I have my list of related studies, how do I set my inclusion criteria?
- How do I select the studies to include?
- How exactly can I go about looking through my initial list and making decisions?
- What are the relevant variables for a MA, and how many input rows/columns should I make?
- How do I enter and code relevant studies?
- How do I calculate Effect Sizes?
- What if I don’t have all the required information?
- How to run a meta-analytic regression ?
- Are there some MA specific plots that I should make?

# Own experiences/Best practices

- Published meta-analyses often do not stick to guidelines
- Learning by doing
- Document each step
- Report for replicability
- Be critical about own results
- Use R packages or other software for calculations



# Resources

**Recommended books**

- Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). *Introduction to meta-analysis*. John Wiley & Sons → My favorite!
- Schmidt, F. L., & Hunter, J. E. (2003). Meta-analysis. *Handbook of psychology*, 533-554.
- Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis*. SAGE publications, Inc. → especially for how to calculate effect sizes from missing data

**Useful guides for conducting meta-analyses with R**

- Harrer, M., Cuijpers, P., Furukawa, T.A, & Ebert, D. D. (2019). *Doing Meta-Analysis in R: A Hands-on Guide*. DOI: 10.5281/zenodo.2551803.https://bookdown.org/MathiasHarrer/Doing_Meta_Analysis_in_R/
- Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36*(3), 1–48. http://www.metafor-project.org/doku.php/

# Questions?


https://fixingtheeconomists.wordpress.com/2014/08/12/on-meta-analysis-in-economics/