

# Introduction to Meta-Analysis

## Charles DiMaggio, PhD

“If only we knew what we know...”

Caria O’Dell and Jack Grayson

“Anything you can do, I can do  
meta...”

# Objectives

- Define Meta-Analysis
- Strengths and Limitations of Meta Analysis
- How to Conduct a Meta Analysis
  - Asking a Question
  - Searching, Evaluating and Coding Studies
  - Synthesizing with Statistical Methods

# What is meta-analysis?

“an exercise in mega-silliness...”

Eyesnack, 1978

“a new bete noire (which represents) the unacceptable face of staticism (and) should be stifled at birth”

Oakes, 1986

“Meta-Analysis, Shmeta-Analysis.”

Shapiro 1994

# What is meta-analysis?

“A statistical analysis that combines or integrates the results of several independent clinical trials considered by the analyst to be combinable”

ASA, 1988

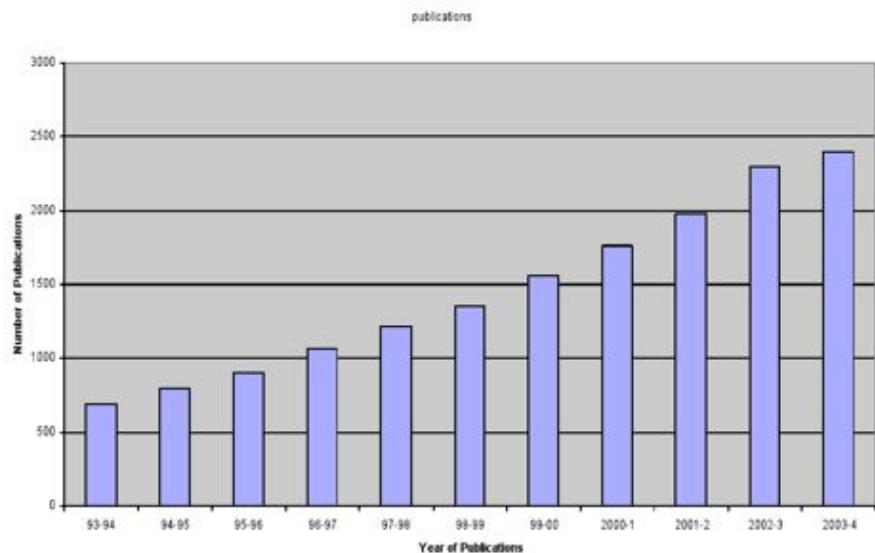
“Meta-analysis clearly has advantages over conventional narrative reviews and carries considerable promise as a tool in clinical research”

Eggers, Davey Smith, 1997

“...now widely accepted as a method of summarizing the results of empirical studies within the behavioral, social and health sciences”

Lipsey and Wilson, 2000

# The votes are in...



From: Basu, A. How to do meta-analysis,  
[www.pitt.edu/~super7/19011-20001/19431.ppt](http://www.pitt.edu/~super7/19011-20001/19431.ppt)



King of the hill...

# A working definition

- A set of methods to systematically and reproducibly search, sample and (statistically) synthesize evidence from studies.

# Strengths of Meta-Analysis

- Imposes Discipline
  - Makes process explicit and systematic
  - Organized way of combining a lot of information
  - More differentiated and sophisticated than traditional reviews
- Combining studies increases power
  - Find ‘significant’ results

# Weaknesses of Meta-Analysis

- Heterogeneity – “apples and oranges”
- Biases
  - Missing Studies
    - May differ from published studies (publication bias)
- Quality of Studies ( ‘GIGO’ )
  - What constitutes quality?
- Requires a lot of effort and substance-area expertise
- Mechanics of statistics may obscure theory
- Good for closed-ended questions only

# Meta-Analysis: A 12-Step Program

- I. Specify Problem
- II. Search for and Identify Studies
- III. Enter studies into database
- IV. Select Studies for Review
- V. Review Studies
- VI. Develop Coding Scheme
- VII. Abstract / Code Studies
- VIII. Select Effect Size Statistic
- IX. Transform and Weight Effect Sizes
- X. Assess heterogeneity
- XI. Assess Bias
- XII. Synthesize and Present Results

# I. Problem Specification

“What are the types and magnitudes of behavioral health disturbances such as depressive symptomatology, post traumatic stress, and somatization seen after terrorist incidents. Do responses vary by variables such as rural vs. urban, developed vs. developing, blast or explosive injuries vs. biological incidents, number injured, and level of publicity. Do terrorist incidents have quantifiable effects on local health care system utilization such as outpatient and emergency department visits, prescription seeking? Are effects sustained and for how long? What social behaviors result from terrorist incidents? Are they adaptive or maladaptive? What community (ecologic) level features are associated with adaptive behaviors?”

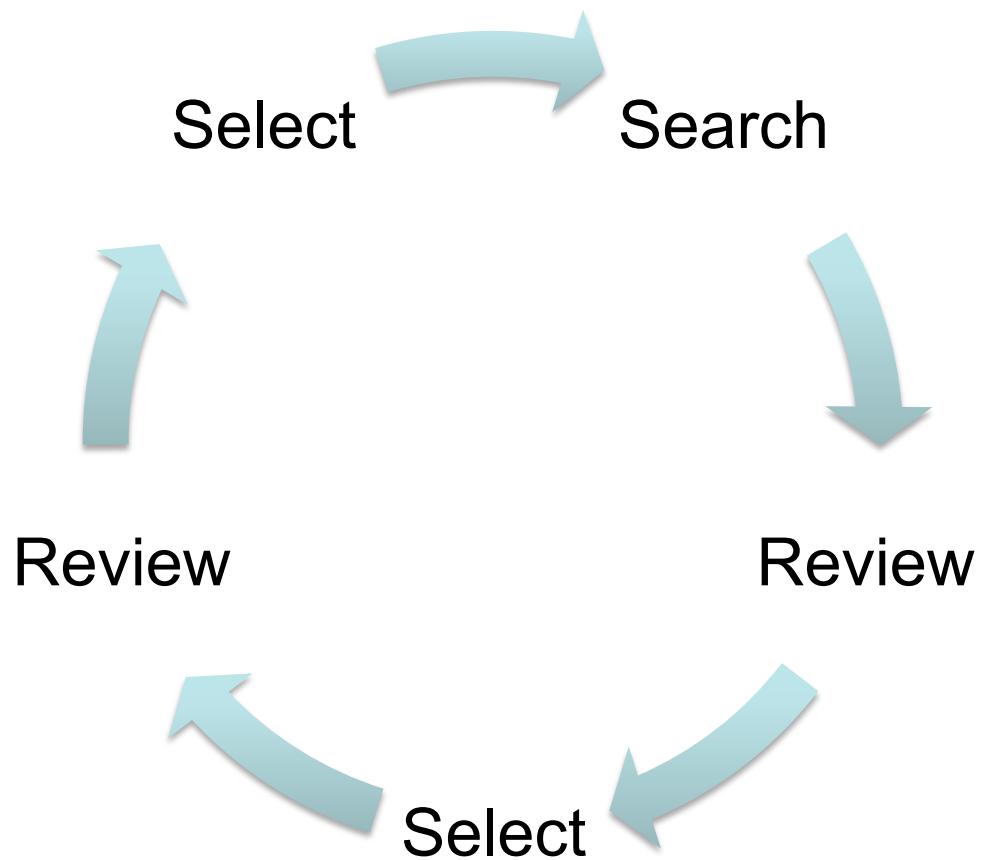
## II. Identify Studies

- Has a meta-analysis been done already?
  - PubMed Clinical Queries
- Electronic / Online Resources
  - PubMed, Medline, Cumulative Index of Nursing and Allied Health Literature (CINAHL), Allied and Complementary Medicine (AMED), PsychINFO, Health and Psychosocial Instruments, ProQuest Digital Dissertation Database, Papers First, Cochrane Reviews, ACP Journal Club, Database of Abstracts of Reviews of Effectiveness (DARE), the Cochrane Controlled Trials Register (CCTR), Sociologic Abstracts and Web of Science
  - Search Terms
    - ‘alcohol\*’, ‘epidem\*’, ‘risk’, ‘protect\*’, ‘cohort’, ‘case control’, ‘longitudinal’
- Hand Search
  - References of electronically identified articles
  - Contact investigators
    - *Ask a Librarian!*

# III. Enter Studies

- Endnote / Zotero / Bookends
  - Search and enter directly through program
  - Remove duplicates
  - Review titles and remove non-relevant studies
  - Review abstracts and remove non-relevant studies
- Retrieve pdf's
  - Attach to citation
  - Review full text
  - Divide into main categories

## IV. / V. Review and Select Studies



# VI. Develop Coding Scheme

- “Interviewing” a Study
- Conceptually
  - Effect Size (outcome) ← populations, methods, procedures, designs study methods, designs, procedures (explanatory)
- Examples of Data Elements
  - Identifying information (authors, journal, etc...)
  - Sample size
  - Type of population
  - Type of effect (e.g. odds ratio, prevalence)
  - Result

# VII. Abstract the Data

- Meta-analytic data is inherently hierarchical
  - Multiple outcomes per study
  - Multiple measurement points per outcome
  - Sub-samples per study population
- End up with multiple effect sizes per study
- Analyses almost always are of a subset of coded effect sizes. Data structure needs to allow for the selection and creation of those subsets
- *To maintain statistical independence, specific analyses can only include one effect size per study (or one effect size per sub-sample within a study)*

# Example of Relational Data Structure (Multiple Related Flat Files)

Study Level Data File

ID	PubYear	MeanAge	TxStyle
100	92	15.5	2
7049	82	14.5	1

Note that a single record in the file above is "related" to five records in the file to the right

Effect Size Level Data File

ID	ESNum	Outcome		TxN	CgN	ES
		Type				
100	1	1		24	24	-0.39
	2	1		24	24	0
	3	1		24	24	0.09
	4	1		24	24	-1.05
	5	1		24	24	-0.44
7049	1	2		30	30	0.34
	2	4		30	30	0.78
	3	1		30	30	0

Practical Meta-Analysis --  
Lipsey and Wilson

# VIII. The Effect Statistic (ES) – makes meta-analysis possible

- Comparable, standardized numeric scale for evidence across disparate studies
- Amenable to calculation of standard error
  - Allows weighting of study's contribution to evidence based on sample size
- Different ES's for different kind of outcomes
- Different statistical methods for same ES

# Kinds of Effect Statistics

- Proportion
  - Central tendencies
- Standardized mean difference ( $d$ )
  - Group contrasts of continuous measures
- Correlation coefficient ( $r$ )
  - Linear associations
- Odds-ratio
  - Group contrasts of dichotomous measures

## *IX. Transform and Weight the Effect Statistic*

- Transform
  - magnitude and direction of the effect
  - same scale for all studies
- Weight
  - inverse variance gives more ‘weight’ to larger studies
  - sample size is key ( $\uparrow n = \uparrow$ precision)
  - standard error
    - means, correlations, proportions, odds
      - not well-suited to complex procedures like multiple logistic regression

# Why Weight Effect Sizes?

- Studies vary in size.
- ES based on 100 subjects assumed more “precise” estimate of population ES than ES based on 10 subjects.
- Larger studies *should* carry more “weight”.
- Weighting by the *inverse variance* optimal approach

# An example of not weighting...

Day care and the risk of being left back a grade (“retained”)

Gray 1970	Retained	Total	Risk	<i>Risk difference</i>
Daycare	19	36	0.528	-0.16
Control	13	19	0.684	

less likely to be left back

+

Schweinhart	Retained	Total	Risk	<i>Risk difference</i>
Daycare	6	58	0.1034	-0.004
Control	7	65	0.1077	

less likely to be left back

=

Pooled results	Retained	Total	Risk	<i>Risk difference</i>
Daycare	25	94	0.266	+0.03
Control	20	84	0.238	WRONG!

more likely to be left back?

(Simpson's Paradox)

# Why weight by inverse variance?

- The standard error (SE) is a direct index of ES precision.
  - influenced by sample size
  - used to create confidence intervals.
- The smaller the SE, the more precise the ES.
- Optimal weights for meta-analysis (Hedges):

$$w = \frac{1}{SE^2}$$

# ***Transforming a Continuous Measure: The Standardized Mean Difference ( $d$ or $g$ )***

$$\overline{ES} = \frac{\overline{X}_{G1} - \overline{X}_{G2}}{s_{pooled}}$$

$$s_{pooled} = \sqrt{\frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}}$$

- standardized group contrast on an continuous measure
- uses a pooled standard deviation

# *Weighting a Continuous Measure*

- SE for a standardized mean difference:

$$se = \sqrt{\frac{n_1 + n_2}{n_1 n_2} + \frac{\overline{ES}_{sm}}{2(n_1 + n_2)}}$$

- Weight for standardized mean difference:

$$w = \frac{1}{se^2}$$

# Methods for Dichotomous Effect Sizes

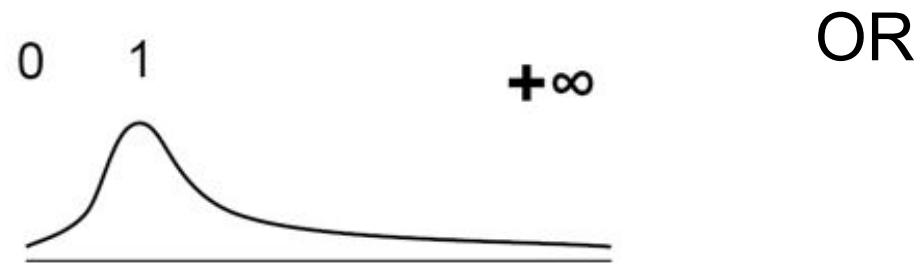
- Variance-Based Method – transform and work on log scale
  - Lipsey and Wilson, CMA
  - AKA “Inverse Variance Methods”
  - Can be applied to OR's, RR's, RD's
  - Can be applied when don't have complete 2x2 table info
- Mantel-Haenszel – work on original scale
  - Cochrane, Petitti, R packages
  - Long history of experience
  - Statistically optimal
  - “Fixed Effects”
  - vs. Peto Method
- DerSimonian and Laird
  - Cochrane, R packages
  - “Random Effects”

# Variance Method for Dichotomous Outcomes

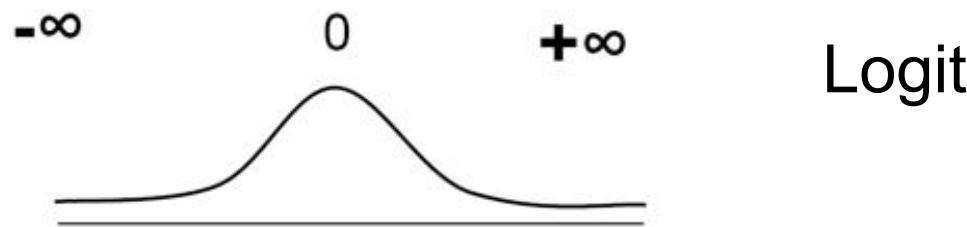
1. Transform the result to the log scale
2. Weight the result by inverse variance
3. Calculate the weighted mean effect size
4. Calculate the standard error of the weighted mean effect size
5. Calculate a confidence interval for the weighted mean effect size

# Variance Method for Odds Ratios

1. Transform the Odds Ratio to Log Scale



OR



Logit

## 2. Weight the Logit

- s.e. for a Logit

$$se = \sqrt{\frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \frac{1}{d}}$$

- Weight for a Logit

$$w = \frac{1}{se^2}$$

### 3. Calculate the Weighted (Mean) Odds Ratio

Study	ES	w	w*ES
1	-0.33	11.91	-3.93
2	0.32	28.57	9.14
3	0.39	58.82	22.94
4	0.31	29.41	9.12
5	0.17	13.89	2.36
6	0.64	8.55	5.47
7	-0.33	9.80	-3.24
8	0.15	10.75	1.61
9	-0.02	83.33	-1.67
10	0.00	14.93	0.00
		269.96	41.82

$$\bar{ES} = \frac{\sum(w \times ES)}{\sum w} = \frac{41.82}{269.96} = 0.15$$

- Enter log of OR (ES) and its inverse variance weight (w)
- Multiply w by ES.
- Sum the columns, w and w\*ES.
- Divide the sum of (w\*ES) by the sum of (w)
- Convert back by exponentiation

## 4. Calculate the Standard Error of the (Mean) Odds Ratio

- The standard error of the mean is the square root of 1 divided by the sum of the weights.

Study	ES	w	w*ES
1	-0.33	11.91	-3.93
2	0.32	28.57	9.14
3	0.39	58.82	22.94
4	0.31	29.41	9.12
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8	0.15	10.75	1.61
9	-0.02	83.33	-1.67
10	0.00	14.93	0.00
		269.96	41.82

$$se_{\bar{ES}} = \sqrt{\frac{1}{\sum w}} = \sqrt{\frac{1}{269.96}} = 0.061$$

# Variance Method: Mean, Standard Error, Z-test and Confidence Intervals for an Odds Ratio

Mean ES

$$\bar{ES} = \frac{\sum (w \times ES)}{\sum w} = \frac{41.82}{269.96} = 0.15$$

SE of the Mean ES

$$se_{\bar{ES}} = \sqrt{\frac{1}{\sum w}} = \sqrt{\frac{1}{269.96}} = 0.061$$

Z-test for the Mean ES

$$Z = \frac{\bar{ES}}{se_{\bar{ES}}} = \frac{0.15}{0.061} = 2.46$$

95% Confidence Interval

$$Lower = \bar{ES} - 1.96(se_{\bar{ES}}) = 0.15 - 1.96(.061) = 0.03$$

$$Upper = \bar{ES} + 1.96(se_{\bar{ES}}) = 0.15 + 1.96(.061) = 0.27$$

# Mantel-Haenszel Method

- For Fixed Effects Models
- Better than variance methods when rare events and small trials (otherwise similar results)

$$OR_{mh} = \sum (w_i * OR_i) / \sum w_i$$

$$OR_i = (a_i * d_i) / (b_i * c_i)$$

$$weight_i = 1 / var_i$$

$$OR.var_i = n_i / (b_i * c_i)$$

$$RR.var_i = n_i / ((a_i + b_i) * c_i)$$

$$RD.var_i = n_i / n_{1i} * n_{2i}$$

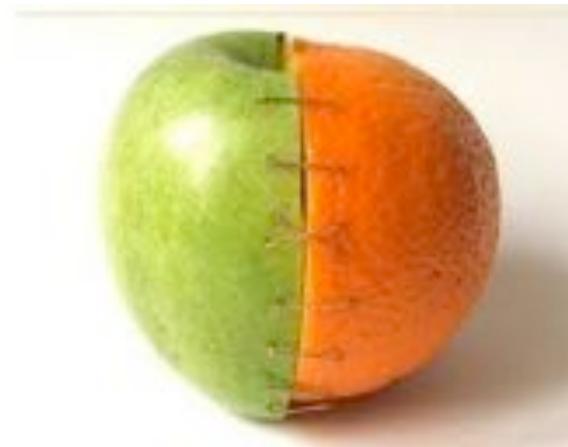
# Mantel-Haenszel 95 % CI

$$\exp(\ln(\text{OR}_{\text{mh}}) \pm 1.96 * \sqrt{\text{Var}[\ln(\text{OR}_{\text{mh}})]})$$

$$\text{Var}[\ln(\hat{\text{OR}}_{\text{MH}})] \cong \frac{\sum_{j=1}^k \frac{a_j d_j}{n_j} \cdot \frac{a_j + d_j}{n_j}}{2 \left( \sum_{j=1}^k \frac{a_j d_j}{n_j} \right)^2} + \frac{\sum_{j=1}^k \left( \frac{b_j c_j}{n_j} \cdot \frac{a_j + d_j}{n_j} + \frac{b_j + c_j}{n_j} \cdot \frac{a_j d_j}{n_j} \right)}{2 \left( \sum_{j=1}^k \frac{a_j d_j}{n_j} \right) \left( \sum_{j=1}^k \frac{b_j c_j}{n_j} \right)} + \frac{\sum_{j=1}^k \frac{b_j c_j}{n_j} \cdot \frac{b_j + c_j}{n_j}}{2 \left( \sum_{j=1}^k \frac{b_j c_j}{n_j} \right)^2}$$

Source: Robins J, Breslow N, Greenland S. A general estimator for the variance of the Mantel-Haenszel odds ratio. Am J Epidemiol. 1986 Nov;124(5):719-23.

# Heterogeneity



# Heterogeneity vs. Bias and Confounding

- Studies differ due to recruitment, bias, confounding, etc... (Observational studies more so than experimental studies.)
- There are no statistical methods to account or control for bias and confounding in the original studies
- Some epidemiologists believe *any* summary measure of effect is likely to be misleading. Goal of M-A should be to explore and explain differences, rather than smooth over them.

# Fixed Effects vs. Random Effects

- Two statistical approaches to calculating the variance for the weighted mean effect statistic.
- Fixed Effects
  - Variance of synthesized effect statistic based only on studies included in the analysis
- Random Effects
  - Variance of synthesized effect statistic based on idea that studies included in the analysis are a random *sample* of all possible studies that could have been included
    - “conservative” vs. “abstruse and uninformative”

# Fixed Effects Model

- “What is the effect size based solely on the evidence of the studies included in the meta-analysis?”
- Total variance measured only on basis of within-study variance
- Studies weighted on basis of their inverse variance (sample size)
- Approach recommended by Sir Richard Peto and others.

# Random Effects Model

- “What is the average effect size based on the studies included in the meta-analysis as a *sample* of all possible studies?”
- Total variance includes between-study as well as within-study variance
- As between-study variance becomes larger (heterogeneity) dominates, swamps within-study variance and all *studies weighted equally*
  - *collection of separate studies vs. sample from underlying population of studies...*

# Fixed Effects vs. Random Effects

- When there is little or no heterogeneity, essentially return the same results
- Random effects models do not ‘control’ for heterogeneity, rather they are assuming a different underlying model.
- Some researchers believe that when there is evidence of heterogeneity, shouldn’t combine studies at all.
- **Caution** if random effects return meaningfully different results from fixed effects

# X. Assessing Heterogeneity

- Test the assumption that all effect sizes are measuring a single, underlying mean.
- Look at effect size CI's. If don't overlap, likely heterogeneity.
- Chi square statistic ("Q test")
  - $Q = \sum w_i (ES_i - \text{meanES})^2$ ,  $df = \#ES - 1$
  - small p → heterogeneity
    - few studies → low power (set p=0.10)
    - many studies → statistical significance vs. meaningful heterogeneity ("too much power")

# Q - The Homogeneity Statistic

Study	ES	w	w*ES	w*ES^2
1	-0.33	11.91	-3.93	1.30
2	0.32	28.57	9.14	2.93
3	0.39	58.82	22.94	8.95
4	0.31	29.41	9.12	2.83
5	0.17	13.89	2.36	0.40
6	0.64	8.55	5.47	3.50
7	-0.33	9.80	-3.24	1.07
8	0.15	10.75	1.61	0.24
9	-0.02	83.33	-1.67	0.03
10	0.00	14.93	0.00	0.00
		269.96	41.82	21.24

- Calculate a new variable that is the ES squared multiplied by the weight.
- Sum new variable.

# Calculating Q

$$\begin{aligned}\sum w &= 269.96 \\ \sum(w \times ES) &= 41.82 \\ \sum(w \times ES^2) &= 21.24\end{aligned} \quad Q = \sum(w \times ES^2) - \frac{[\sum(w \times ES)]^2}{\sum w} = 21.24 - \frac{41.82^2}{269.96} = 21.24 - 6.48 = 14.76$$

- Calculated Q (14.76) is less than chi square critical value of 16.92
- **fail to reject** the null hypothesis of homogeneity
- Thus, the variability across effect sizes does not exceed what would be expected based on sampling error.

$I^2$

- percentage of variation due to heterogeneity (vs. chance)
- $(Q-df)/Q * 100$
- e.g.  $(14.76-9)/14.76 * 100 = 39\%$
- methods available for 95% CI for  $I^2$

# So your studies are heterogeneous...

- a) There are ‘real’ differences between studies, i.e. more than one underlying population mean.
  - Single mean ES not a good measure of the distribution.
  - Model between study differences (ANOVA)
- b) Assume heterogeneity is random → Random Effects Model

# Random Effect Model

- Additional variance component, based on Q, added to weight

$$w_i = \frac{1}{se_i^2 + \hat{v}_\theta}$$

$$\hat{v}_\theta = \frac{Q_T - k - 1}{\sum w - \left( \frac{\sum w^2}{\sum w} \right)}$$

- Run analysis with new weights

# Calculating the Random Effects Variance Component

- The total Q for example data was 14.76
- k is the number of effect sizes (10)
- The sum of w = 269.96
- The sum of w<sup>2</sup> = 12,928.21

$$\hat{\nu}_\theta = \frac{Q_T - k - 1}{\sum w - \left( \frac{\sum w^2}{\sum w} \right)} = \frac{14.76 - 10 - 1}{269.96 - \frac{12,928.21}{269.96}} = \frac{5.76}{269.96 - 47.89} = \underline{\underline{0.026}}$$

Practical Meta-Analysis --  
Lipsey and Wilson

# DerSimonian and Laird Method

$$\ln \text{OR}_{\text{dt}} = \frac{\sum(w_i^* \times \ln \text{OR}_i)}{\sum w_i^*}$$

**DerSimonian and Laird  
Summary OR**

$$w_i^* = \frac{1}{[D + (1 \div w_i)]}$$

**Additional component  
to weight**

$$D = \frac{[Q - (S - 1)] \times \sum w_i}{[(\sum w_i)^2 - \sum (w_i^2)]} \text{ and } D=0 \text{ if } Q < S-1.$$

**(S is number  
of studies)**

$$Q = \sum w_i (\ln \text{OR}_i - \ln \text{OR}_{\text{mth}})^2$$

$$\text{CI} = e^{\ln \text{OR}_{\text{dt}} \pm 1.96 \times \sqrt{\text{variance}}}$$

# DerSimonian-Laird Random Effects Model (for M-H approach)

$$\ln \text{OR}_{dl} = \frac{\text{sum}(w_i^* \times \ln \text{OR}_i)}{\text{sum } w_i^*} \quad \text{Dersimonian and Laird Summary OR}$$

$$w_i^* = \frac{1}{[D + (1 \div w_i)]} \quad \text{Additional Component "D" to weight}$$

$$D = \frac{[Q - (S - 1)] \times \text{sum } w_i}{[(\text{sum } w_i)^2 - \text{sum } (w_i^2)]} \text{ and } D=0 \text{ if } Q < S-1, \quad (S = \# \text{ studies})$$

$$Q = \text{sum } w_i (\ln \text{OR}_i - \ln \text{OR}_{mh})^2$$

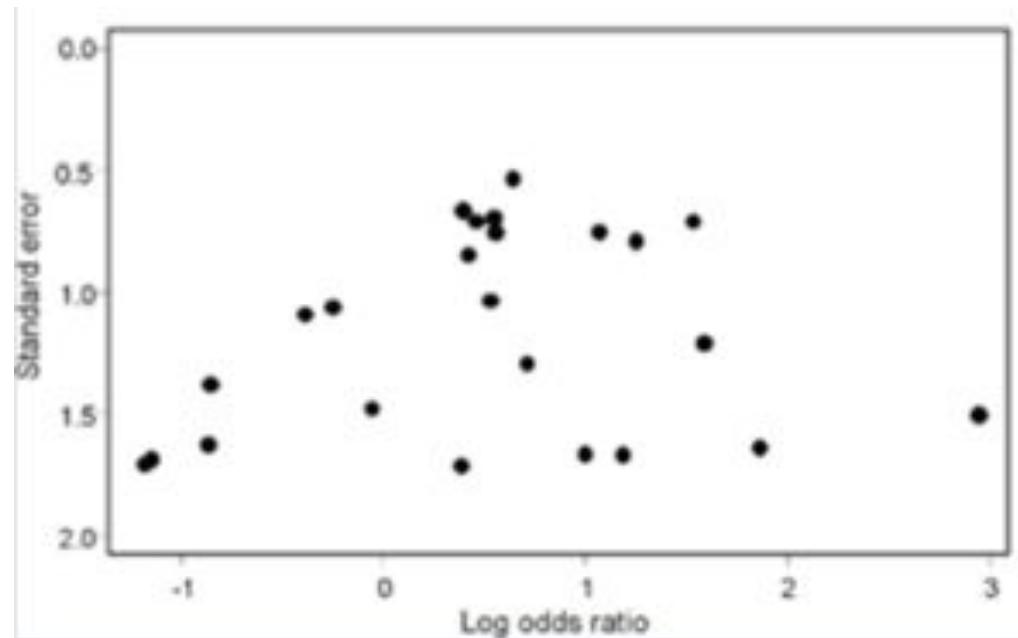
$$\text{CI} = e^{\ln \text{OR}_{dl} \pm 1.96 \times \sqrt{\text{variance}_s}}$$

# XI. Assessing Bias

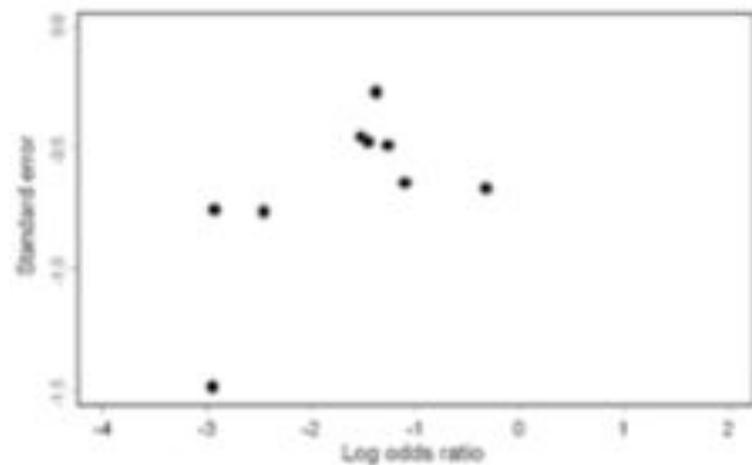
- Some biases are peculiar to meta-analysis.
- Positive results are more likely to be...
  - Published (publication bias)
  - Published quickly (time lag bias)
  - Published in English (language bias)
  - Published more than once
  - Be cited by others (citation bias)
- Will be present to some extent in all meta analyses. Need to assess *how much* of a problem it is.

# Funnel Plots

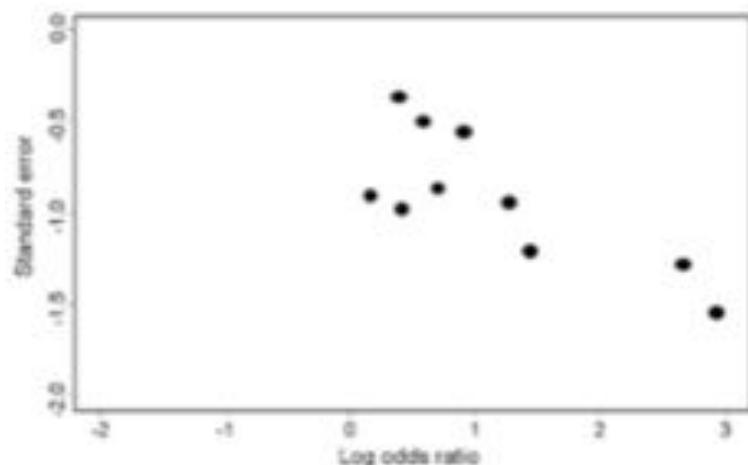
- Vertical Axis is measure of ES precision
- Horizontal Axis is measure of ES magnitude
- Expect more-precise estimates to cluster together near top of plot and less-precise estimates to fan out near bottom of plot



# Possible Publication Bias



Outlier from less precise study?



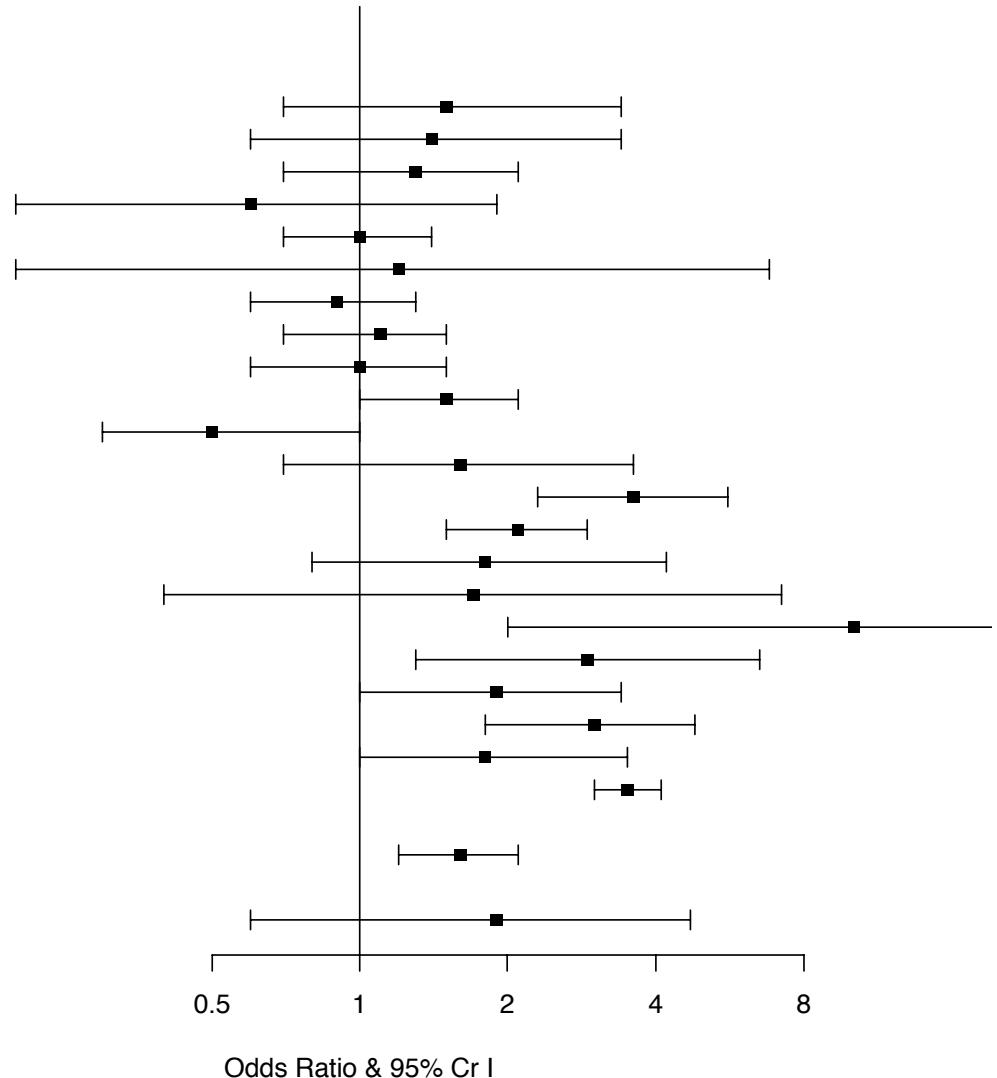
Pattern of less precise studies showing more positive effect.

# XII. Presenting Results

- QUOROM statement (Moher D et al (1999) Lancet 354: 1896-1900)
- Abstract
  - Background (include statement of the main research question)
  - Methodology/Principal Findings
  - Conclusions/Significance
- Introduction
- Methods
  - Searching - describe information sources, restrictions
  - Selection - inclusion and exclusion criteria
  - Data abstraction
  - Validity Assessment
  - Study characteristics e.g. type of study designs, participants' characteristics
  - Quantitative data synthesis - measures of effect, method of combining results, missing data; how statistical heterogeneity was assessed
- Results
  - Flow of included studies
  - Study characteristics
  - Quantitative data synthesis- agreement on the selection and validity assessment, simple summary results, Funnel plots, **Forest plots**
- Discussion
- Limitations

## Forest Plot

STUDY	ESTIMATE
Agran, 1996	1.5 (0.7, 3.4)
Bunn, 2003(b)	1.4 (0.6, 3.4)
Bunn, 2003(c)	1.3 (0.7, 2.1)
Bunn, 2003(d)	0.6 (0.2, 1.9)
Bunn, 2003(e)	1.0 (0.7, 1.4)
Bunn, 2003(f)	1.2 (0.2, 6.8)
Bunn, 2003(g)	0.9 (0.6, 1.3)
Bunn, 2003(i)	1.1 (0.7, 1.5)
Bunn, 2003(j)	1.0 (0.6, 1.5)
Bunn, 2003(k)	1.5 (1.0, 2.1)
Damsere, 2010	0.5 (0.3, 1.0)
Donroe, 2008	1.6 (0.7, 3.6)
Johansson, 2007	3.6 (2.3, 5.6)
Jones, 2005	2.1 (1.5, 2.9)
Leden2, 2006	1.8 (0.8, 4.2)
Mueller, 1990	1.7 (0.4, 7.2)
Mutto, 2002	10.1 (2.0, 50.5)
Roberts2, 1995	2.9 (1.3, 6.5)
Shephard, 2010	1.9 (1.0, 3.4)
Stevenson, 1996	3.0 (1.8, 4.8)
Testerm, 2004	1.8 (1.0, 3.5)
Wazana, 2000	3.5 (3.0, 4.1)
Synthesis	1.6 (1.2, 2.1)
Predictive	1.9, (0.6, 4.7)



# Software Considerations

- **Comprehensive Meta-Analysis**
  - does all calculations for you; user-friendly interface; convenient
  - Little control over approaches, calculations, figures
  - Still need some kind of DBMS
  - \$\$
- **MS Access → MS Excel**
  - “easy” interface, wide availability for collaboration
  - Either write all formulas or use (“free”) add-on apps, e.g.
    - MIX (<http://www.mix-for-meta-analysis.info/>)
    - Lipsey (<http://mason.gmu.edu/~dwilsonb/ma.html>)
    - MetaEasy(<http://www.jstatsoft.org/v30/i07>)
- **R – rmeta, meta, metafor**
  - really, and truly free
  - Explicit programming and reproducibility
  - Learning curve
- **SAS, SPSS, Stata, etc...**
  - \$\$\$\$\$

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# FOREST PLOT FULL META

# Table Text

study<-c(" ", "Agran, 1996", "Bunn, 2003(b)", "Bunn, 2003(c)", "Bunn, 2003(d)", "Bunn, 2003(e)", "Bunn, 2003(f)", "Bunn, 2003(g)", "Bunn, 2003(h)", "Bunn, 2003(i)", "Bunn, 2003(j)", "Bunn, 2003(k)", "Damsere, 2010", "Donroe, 2008", "Johansson, 2007", "Jones, 2005", "Leden2, 2006", "Mueller, 1990", "Mutto, 2002", "Roberts2, 1995", "Shephard, 2010", "Stevenson, 1996", "Testerm, 2004", "Wazana, 2000", " ", "Synthesis", " ", "Predictive")

estimate<-c(
  " ",
  "1.5 (0.7, 3.4)",
  "1.4 (0.6, 3.4)",
  "1.3 (0.7, 2.1)",
  <snip>
  "1.9 (1.0, 3.4)",
  "3.0 (1.8, 4.8)",
  "1.8 (1.0, 3.5)",
  "3.5 (3.0, 4.1)",
  " ",
  "1.6 (1.2, 2.1)",
  " ",
  "1.9, (0.6, 4.7)")
<snip>

ln.OR<-log(OR)
ln.lo<-log(lcl.OR)
ln.ucl<-log(ucl.OR)

plot(1:27,seq(1,28),len=27), type="n",axes=F,
xlab="Odds Ratio & 95% Cr I",
ylab=" ", xlim=c(-4.2,2.7))
axis(1, at=c(-.69,0,.69,1.386,2.079),labels=c(0.5, 1, 2, 4, 8), cex=0.3)
abline(v=0)

# column labels
text (-4.2,28,"STUDY", adj=c(0,0), cex=0.6)
text (-2.8,28,"ESTIMATE", adj=c(0,0), cex=0.6)

#loop text
for(i in 1:28) {
  text (-4.2,i,study[28-i], adj=c(0,0), cex=0.6)
  text (-2.8,i,estimate[28-i], adj=c(0,0), cex=0.6)
}

#loop point estimate ORs for graph
for(i in 1:28) {
  points(ln.OR[i],28-i,pch=15,cex=1)
  # loop 95% CI lines
  lines(c(ln.lo[i],ln.ucl[i]),c(28-i,28-i),lty=1)
  # Ends of 95% CI
  lines(c(ln.lo[i],ln.lo[i]),c((28-i+.3),(28-i-.3)),lty=1)
  lines(c(ln.ucl[i],ln.ucl[i]),c((28-i+.3),(28-i-.3)),lty=1)
}

```

R Code for  
Forest Plot

vs.

meta  
package:

*forest(x)*

# Sources and Resources

- **Lipsey and Wilson. Practical Meta-Analysis. (Sage, 2001)**
- **Petitti. Meta-Analysis, Decision Analysis and Cost-Effectiveness Analysis. (Oxford, 2000)**
- **Cochrane Collaboration Open Learning Material (<http://www.cochrane-net.org/openlearning/HTML/mod0.htm>)**