

Methods for Meta-Analysis

PRESENTATION AT GSU CIBER

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Outline

Overview of meta-analysis and its purpose

Examples of meta-analyses applied to issues in business and management

Outline the steps included in meta-analysis

Introduction to innovative meta-analysis methods applicable to business and management

What is meta-analysis?

Meta-analysis refers to statistical methods used to synthesize quantitative results from a set of studies

Meta-analysis is used in the context of a systematic review to make generalizations about the effects in the literature

My assumptions in this presentation

For the purpose of this presentation, I will assume that we are conducting a meta-analysis in the context of a systematic review

I define systematic review as a method that comprehensively and transparently identifies studies on a given issue in order to synthesize the findings in these studies

How does meta-analysis contribute to our knowledge?

In management and business (and in education, crime and justice, and medicine), there is a movement for evidence-based decision-making

Meta-analysis and systematic review provide comprehensive and replicable methods for synthesizing what we know and what we don't know

We can base decisions on what we know, and we can plan new studies to gather evidence about gaps in our understanding

What questions can meta-analysis address?

Effectiveness of interventions – Is a particular intervention or treatment effective? Does effectiveness vary across studies?

- **Group differences:** How do two groups differ on a characteristic (e.g., sex/gender differences in leadership)?

Associations among constructs – How do two constructs or measures relate to one another? Does this relationship vary across studies?

Examples from my own work

EFFECTIVENESS STUDIES

School-Based Interventions to Reduce Dating and Sexual Violence: A Systematic Review

Lisa De La Rue, Joshua R. Polanin, Dorothy L. Espelage, Terri D. Pigott

Accommodation-based programmes for individuals experiencing, or at risk of experiencing, homelessness: A systematic review and Network Meta-Analysis

Clara Keenan¹, Sarah Miller¹, Jennifer Hanratty¹, Terri Pigott², Jayne Hamilton¹, Christopher Coughlan¹, Peter Mackie¹, Suzanne Fitzpatrick¹, John Cowman³

Under review: Systematic review and meta-analysis of interventions to improve the word-problem solving skills of students with math difficulties. With GSU faculty member Jonté Myers

Examples from my work

ASSOCIATION STUDIES

Linking Big Five Personality Domains and Facets to Alcohol (Mis)Use: A Systematic Review and Meta-Analysis

With SMU faculty member Priscilla Liu

Examining the links between spatial skills and math skills

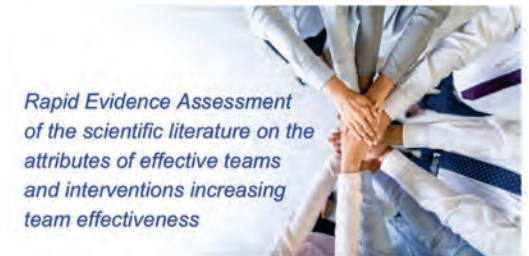
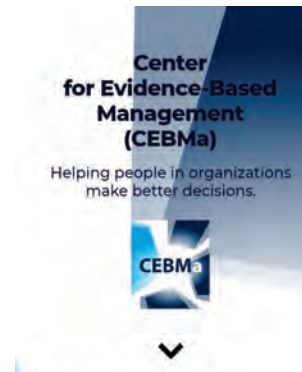
With UCI faculty member Kinnari Atit and University of Limerick faculty member Jason Power

Other meta-analysis research questions

Prevalence: What is the estimated prevalence of some condition or phenomenon as measured in the literature? Example: incidence rate of domestic violence in low- and middle-income countries

Screening and diagnostic tests: How effective are screening and diagnostic tests for identifying a condition? Example: Effectiveness of antibody tests for identification of current and past infection with SARS-CoV-2

Examples from the business and management literature



Effectiveness question

Is an intervention effective?

How does the effectiveness of the intervention vary across studies?

Example: Delise et al. (2010)

The Effects of Team Training on Team Outcomes: A Meta-Analysis

Lisa A. Delise, C. Allen Gorman, PhD, Abby M. Brooks, PhD, Joan R. Rentsch, PhD, and Debra Steele-Johnson, PhD

A meta-analysis was conducted to determine relationships between team training and team effectiveness. Results from the 21 studies provided evidence that training is positively related to team effectiveness and effectiveness in five outcome categories: affective, cognitive, subjective task-based skill, objective task-based skill, and teamwork skill.

Group differences

Are there differences between two groups on some characteristic?

Do studies vary in their estimates of this difference?

Eagly et al. (2003)

Transformational, Transactional, and Laissez-Faire Leadership Styles: A Meta-Analysis Comparing Women and Men

Alice H. Eagly and Mary C. Johannesen-Schmidt
Northwestern University

Marloes L. van Engen
Tilburg University

A meta-analysis of 45 studies of transformational, transactional, and laissez-faire leadership styles found that female leaders were more transformational than male leaders and also engaged in more of the contingent reward behaviors that are a component of transactional leadership. Male leaders were generally more likely to manifest the other aspects of transactional leadership (active and passive management by exception) and laissez-faire leadership. Although these differences between male and female leaders were small, the implications of these findings are encouraging for female leadership because other research has established that all of the aspects of leadership style on which women exceeded men relate positively to leaders' effectiveness whereas all of the aspects on which men exceeded women have negative or null relations to effectiveness.

Associations among constructs

How do two constructs relate to one another?

Is the strength of the association between these two constructs related to characteristics of the studies?

TIES, LEADERS, AND TIME IN TEAMS: STRONG INFERENCE ABOUT NETWORK STRUCTURE'S EFFECTS ON TEAM VIABILITY AND PERFORMANCE

PRASAD BALKUNDI
State University of New York at Buffalo

DAVID A. HARRISON
The Pennsylvania State University

How do members' and leaders' social network structures help or hinder team effectiveness? A meta-analysis of 37 studies of teams in natural contexts suggests that teams with densely configured interpersonal ties attain their goals better and are more committed to staying together; that is, team task performance and viability are both higher. Further, teams with leaders who are central in the teams' intragroup networks and teams that are central in their intergroup network tend to perform better. Time sequencing, member familiarity, and tie content moderate structure-performance connections. Results suggest stronger incorporation of social network concepts into theories about team effectiveness.

Steps for conducting a meta-analysis

First: conduct a systematic review

Systematic reviews include a **comprehensive and replicable search** of the literature

Systematic reviews also use replicable and transparent methods for **screening the studies that are eligible for the review**

Systematic reviews include **extracting and coding** information from studies to use in the analysis of study results

Data extraction and coding

A critical part of a systematic review and meta-analysis is **data extraction**

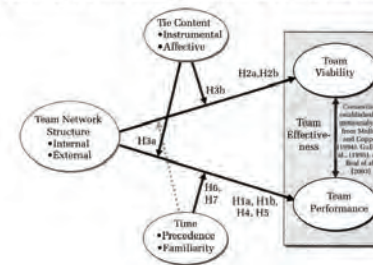
From each study, a reviewer records information about:

- **Study Characteristics** such as Participants, Interventions (if applicable), Study Design (if applicable), Outcomes, Settings
- **The effect of the study** such as a measure of the effectiveness of the intervention or the association between two constructs

We want to extract information both to describe the studies included but more importantly to help us understand why study effects might vary across studies

Example from Balkundi et al. (2006)

FIGURE 1
Theoretical Framework Linking Team Network Structure to Team Outcomes



Does the familiarity among team members moderate the relationship between team network structure and team performance?

Example from Delise et al. (2010)

Hypothesis 3. Sample type will moderate the relationship between team training and team effectiveness, including each of the five aspects of team effectiveness.

Is the effectiveness of team training different for studies that use military samples versus civilian samples?

Data extraction and coding

Note: Data extraction and coding is arguably the most resource-intensive part of a systematic review and meta-analysis

The study characteristics coded should reflect important issues in the field and relate directly to hypotheses about why study results might vary

Data Extraction: Effect sizes

We also extract an **effect size** from each study – a measure of the study's results that will be the outcome for the meta-analysis

Effect sizes are standardized measures that allow us to compare across studies even when studies do not use the same measures

In the social and behavioral sciences, there are few universally-agreed upon measures like blood pressure

Two common effect sizes

Standardized mean difference – used in effectiveness and group difference questions for the mean difference between two groups

Correlation – used in association questions for the measure of the relationship between two constructs

Standardized mean difference (SMD)

The SMD provides the difference between two groups in standard deviation units

$$ES_{SMD} = \frac{\bar{Y}_1 - \bar{Y}_2}{s_p} \quad SE_{SMD} = \sqrt{\frac{n_1 + n_2}{n_1 n_2} + \frac{ES_{SMD}^2}{2(n_1 + n_2)}}$$

Effect size for association studies

For a meta-analysis focused on association, we extract the correlation, r , from each study

But, since the correlation is not normally distributed, we use a transformation of the correlation in the analysis called Fisher's Z

$$ES_z = 0.5 \ln \left[\frac{1+r}{1-r} \right] \quad SE_z = \frac{1}{n-3}$$

Meta-Analysis

The effect size is the outcome in meta-analysis models

In meta-analysis, we conduct analyses similarly to other applications of statistical analysis

Two main questions:

- What is the **average** effect size across all studies and how much does the effect size vary across studies?
- What characteristics of studies are associated with variation in effect size across studies?

Meta-Analysis uses weighted techniques

Recall that I showed you the SEs for the effect sizes a few slides ago

We noted that the SEs depend on the sample size of the study

Thus, the precision of the effect size depends on sample size

Meta-analysis uses weights in the analysis – weighting by the SE of the effect size

Examples about the average effect size

The first question we usually ask is: what is the average effect size across studies?

From Balkundi et al. (2006):

Hypothesis 4: Centrality of team's formal leader in a team's informal social network is positively associated with team task performance

From Delice et al. (2010):

Hypothesis 1: Team training will have a positive effect on overall team effectiveness

Balkundi et al. (2006) results

TABLE 1
Meta-Analytic Relationship of Social Network Properties with Team Performance and Team Viability

Variable	k Studies	Total n	Mean r	Variable r	95% Confidence Interval	Estimated ρ	Failsafe k
Team performance							
Hypothesis 1a: Density of instrumental ties	17	2,442	.13	.02	(.09, .17)	.15	285
Hypothesis 1b: Density of expressive ties	9	515	.20	.02	(.12, .28)	.22	56
Hypothesis 4: Team leader centrality	13	505	.27	.27	(.19, .35)	.29	130
Hypothesis 5: Team centrality in intergroup network	10	440	.13	.05	(.04, .22)	.13	12
Team viability							
Hypothesis 2a: Density of instrumental ties	10	1730	.14	.02	(.09, .18)	.14	116
Hypothesis 2b: Density of expressive ties	4	178	.45	.01	(.33, .57)	.55	48

Delise et al. (2010)

TEAM TRAINING OUTCOME	k	N	d	CORRECTED SD	% VARIANCE SAMPLING ERROR	95% CI
Affective	7	195	.80	.24	74.27	.33, 1.28
Cognitive	6	229	1.37	.48	36.42	.41, 2.33
Subjective task-based skill	6	152	.88	.35	59.01	.17, 1.59
Objective task-based skill	13	504	.76	.40	41.50	-.03, 1.56
Teamwork skill	9	333	.64	.33	51.91	-.01, 1.30
Overall ^a	41	1,413	.85	.44	39.77	-.03, 1.74

Note: k = number of effect sizes; N = total number of teams for studies combined; d = mean sample-weighted effect size; corrected SD = standard deviation of effect sizes corrected for sampling error; % variance sampling error = percentage of variance due to sampling error; CI = confidence interval.

How much do studies vary in their effect size across studies?

We are also interested in how much the effect size varies across studies

Do studies agree about the effectiveness of an intervention or a strength of an association among two constructs?

Formally, we call this examining the **heterogeneity** of the effect sizes across studies

Eagly et al. (2003)

Table 3
Study-Level Effect Sizes for Transformational, Transactional, and Laissez-Faire Leadership Styles

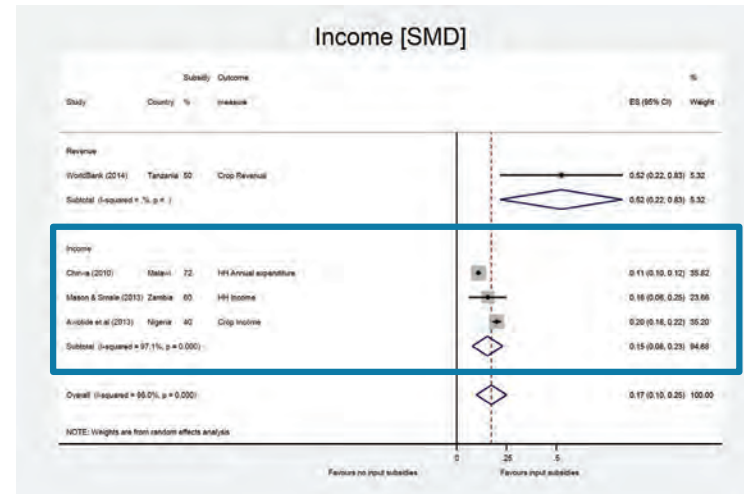
Leadership measure	All studies				Excluding outliers	
	k	d _s	95% CI	Q ^a	Mean unweighted d	d _s
Transformational	44	-0.10	-0.13, -0.08	152.94**	-0.19	40
Charisma	25	-0.09	-0.12, -0.06	51.61**	-0.13	24
Idealized Influence (attribute)	10	-0.12	-0.16, -0.08	18.56	-0.06	
Idealized Influence (behavior)	15	-0.02	-0.06, 0.01	29.79**	-0.07	14
Inspirational Motivation	29	-0.05	-0.08, -0.03	88.40**	-0.10	24
Intellectual Stimulation	35	-0.05	-0.07, -0.02	150.74**	-0.12	30
Individualized Consideration	28	-0.19	-0.22, -0.16	37.31	-0.20	
Transactional						
Contingent Reward	21	-0.13	-0.17, -0.10	29.83	-0.13	
Management by Exception (active)	12	0.12	0.08, 0.16	21.24*	0.11	11
Management by Exception (passive)	18	0.27	0.23, 0.30	19.18	0.23	
Laissez-Faire	16	0.16	0.14, 0.19	18.74	0.06	

Note. Positive effect sizes (d_s) on a given leadership style indicate that men had higher scores than women, and negative d_s indicate that women had higher scores than men. k = number of studies; d_s = mean weighted d; CI = confidence interval; Q = homogeneity of d_s.
* Significance indicates rejection of the hypothesis of homogeneity.
** p < .05; *** p < .01.

What characteristics of studies are associated with effect size heterogeneity?

Often the most interesting aspect of a meta-analysis is the exploration of effect size heterogeneity

What are potential aspects of studies (participants, intervention components, settings, study designs) that are associated with effect size variation?



Forest plot from Hemming et al. (2018) – Agricultural input subsidies for improving productivity, farm income, consumer welfare and wider growth in LMIC: a systematic review

TABLE 2. META-ANALYSIS OF THE EFFECTS OF TEAM TRAINING ON TEAM TRAINING OUTCOMES: MILITARY VERSUS CIVILIAN SAMPLES

TEAM TRAINING OUTCOME	k	N	d	CORRECTED SD	% VARIANCE SAMPLING ERROR	95% CI
Military						
Affective	2	31	1.12	0	100	1.12, 1.12
Subjective task-based skill	2	28	1.15	0	100	1.15, 1.15
Objective task-based skill	2	88	.85	.19	73.60	.47, 1.23
Teamwork skill	3	83	.66	0	100	.66, .66
Overall^b	10	270	1.05	1.02	57.23	.32, 1.77
Civilian						
Affective	4	144	.84	.24	69.05	.37, 1.31
Subjective task-based skill	4	124	.81	.44	42.57	-.07, 1.69
Objective task-based skill	11	416	.74	.43	38.67	-.11, 1.60
Teamwork skill	6	250	.64	.43	35.78	-.22, 1.49
Overall^b	31	1,143	.80	.45	37.44	-.09, 1.70

Note. k = number of effect sizes; N = total number of teams for studies combined; d = mean sample-weighted effect size; corrected SD = standard deviation of effect sizes corrected for sampling error; % variance sampling error = percentage of variance due to sampling error; CI = confidence interval.

Delise et al. (2010) subgroup analysis

Balkundi et al. (2006) meta-regression

TABLE 2
Time-Based Moderators Predicting Relationship
between Integrative Network Structures and
Team Performance

Variable	Model 1	Model 2
Precedence	.41*	
Familiarity		-.40*
R^2	.17*	.16*
k	34	35

* $p < .05$

For newly acquainted or inexperienced team members, informal ties were more critical to performance. As team members gained experience with one another and their work, effects of those ties declined ($\beta = -0.40$, $k = 35$, $p < .05$).

Summary of meta-analysis

We use meta-analysis models to:

- Examine the mean effect size and its variance across studies
- Explore how characteristics of studies relate to variance in effect size across studies – examining study heterogeneity

Meta-analysis models use weighted methods to estimate model parameters

Conducting meta-analyses

Dedicated meta-analysis software: [Comprehensive Meta-Analysis](#)

R packages: [metafor](#)

The **most updated meta-analysis methods** are available in R packages

Innovations in meta-analysis methods

Dependent effect sizes – New methods to analyze multiple effect sizes per study

metaSEM – Methods for estimating path models using meta-analysis

Publication bias and selection modeling – Methods for exploring the potential bias in meta-analysis results due to publication bias

Evidence and gap maps – Using systematic review methods to create maps of the evidence that exists in the literature.

Performance Measurement and Management in Primary Care Delivery Systems



Thank you!

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Books about systematic review and meta-analysis

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Meta-analysis and power in meta-analysis

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