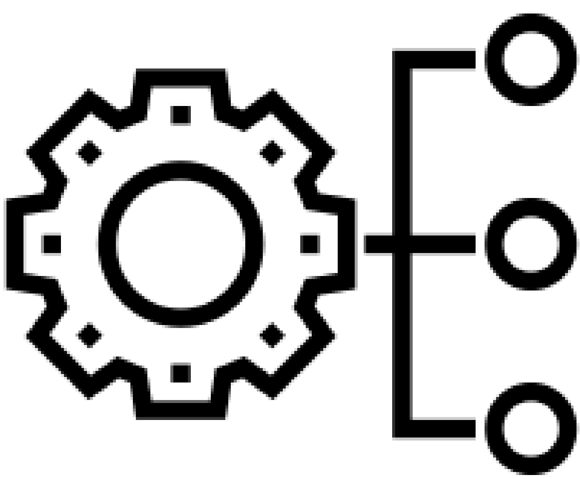
Contents

Chapter 1

Critical skills for meta-analyses and systematic reviews



An overview of quantitative synthesis tools associated with review processing.

Learning outcomes

1. Critically review peer-reviewed journal publications.
2. Engineer syntheses and solutions from published evidence.
3. Appreciate strengths of different synthesis tools and reporting.
4. Do a meta-analysis or systematic review.

Rationale

Scientific synthesis of all academic evidence from data to papers can promote evidence-informed decision making. Every contemporary discipline has some capacity to support and benefit from synthesis tools. Here, we develop a set of heuristics to support innovation and leverage evidence.

Structure

A overview of lessons provided in this resource to encourage development and use of synthesis tools relevant to your discipline and challenges.

lesson	topic	goal
1	Introduction to synthesis in science	Examine the scope and extent of synthesis in contempo
2	Quantitative synthesis tools	Explore conceptual and mental models for synthesis.
3	Evidence workflow reporting	Develop reporting documentation from a formal synthes
4	Meta-analysis in R	Develop a template for derived data for analyses, and c
5	Interpretation of meta-analyses	Examine model outputs from meta-analyses and interpr
6	Coursework	A summary of the steps needed to complete summative

Citation

Lortie, CJ (2023): Critical skills for meta-analyses and systematic reviews. figshare. Book. 10.6084/m9.figshare.21817644.v2

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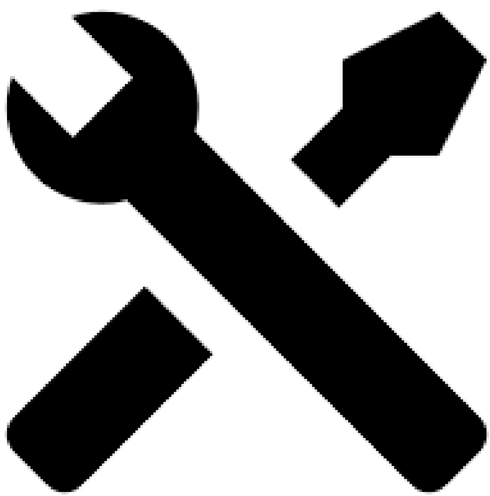
Code

Chapter 2

Quantitative synthesis tools



Learning outcomes

1. Hone your capacity to review scientific literature and scope critical ideas.
2. Transform your research expertise into formal scientific evidence.

3. Synthesize peer-reviewed science papers.

Context

To best explore conceptual and mental models for synthesis, a summary of the simple landscape of opportunities and more comprehensive mapping of synthesis and critical big-picture thinking in science is illuminating. Scientific synthesis is big picture, formal science that describe a set of studies on a pinpointed topic (Lortie, 2014). There are at least three simple and direct options that are amenable to a capture of the research associated with a scientific challenge that you have identified.

(1) Narrative review as a highlight, short commentary, or new idea paper that is a snapshot of the key findings from a field research summarizing the main discoveries and/or listing the most critical research gaps. Papers like these are often called **Insights**, **Forum**, or **Ignite**.

(2) Systematic reviews are similar to narrative reviews, but clear criteria are listed explaining how you selected papers, i.e. these search terms were used in the Web of Science and only studies that had these key inclusion attributes were used. Systematic are more replicable because others can follow your steps and get the same set of papers and hopefully reach similar conclusions about the corpus of evidence. These reviews also typically provide some simple quantitative data about the set of studies such as number of countries where the research was done, total sample sizes, number of variables examined, or any attributes that describe what the research was for a specific detail. The narrative component is similar to the first option because it can state what we know and what do not but these reviews do so *much* more precisely. Even a few numbers go a long way to convincing people about the extent that we know or have studied a subject in science. Papers like these are often termed **Short Commentary** or **Mini-Review**.

(3) Meta-analyses are systematic reviews plus for each primary study you summarize, you capture the relative efficacy of the treatment tested. Papers like this are often termed **Reviews** or **Meta-analyses** but other terms can be used too. Note: in some fields of research the terms 'systematic review' and 'meta-analysis' are used interchangeably, but in most environmental sciences, meta-analyses always have a measure of the strength of evidence from each studied included in the synthesis whilst systematic reviews typically do not.

So for instance, narrative review might provide insights into vaccine research and report that we have tested three vaccine types but need to test more alternatives. A systematic review would state this too but mention how they checked the science, i.e. we checked 100 papers using these terms x,y, & z in The Web of Science, and it might also state how many people were tested in total across all studies. This is a more powerful synthesis. However, the gold standard would be the meta-analysis that summarizes all of the above but also reports how well each vaccine type tested actually works on average across all the studies.

Summary of options

synthesis	elements
narrative review	summary, insights, next steps
systematic review	summary, insights, next steps, explanation of how studies were selected in the review, can hav
meta-analyses	all of above possible but must also include an assessment of the strength of evidence of each s

Evidence framing

A more complex and comprehensive summary of the contemporary landscape of synthesis has been evolving. Framing scientific synthesis activities as an open, comprehensive, and diverse aggregation or summary of many forms of evidence expands our capacity to inform decision making. Contemporary synthesis science has innovated on evidence maps as a tool to show the evidence. This can be done through mapping evidence onto a geographic map to show where we know what we know (McKinnon et al., 2015). Evidence maps can also be less literal and map out knowledge as tabular or bubble plots that focus more on the relative frequencies of what we know about different concepts within a synthesis (Miake-Lye et al., 2016). This approach has also been framed as 'evidence maps for evidence gaps' because it can become abundantly clear where evidence is missing in terms of research or ideas (O'Leary et al., 2017). Importantly, decision making has also evolved to more substantially rely on synthesis science to inform strategy (Thomas-Walters et al., 2021). There has also been a drive to thus enable and support more synthesis to build capacity and connect disparate fields of research for more holistic solution sets (Ladouceur and Shackelford, 2021).

Challenge

1. Review the literature from your field of research from the perspective of synthesis. Explore whether a simple three-paper typology is relevant or if the field has begun to incorporate and frame knowledge via other inference tools including these or even others. Methods, concepts, semantics, ontologies, etc. any forms of evidence aggregation that advances insight, innovation, and knowledge production.

2. Familiarize yourself with the scientific synthesis options that can describe and capture the state-of-the-art research for your specific challenge.

3. Select and refine your topic by populating a table with key terms.

4. Check Google Scholar and The Web of Science trying these different terms.

5. Document the relevant frequency of synthesis studies using these terms. Filter to most cited or the last three years of research only if the evidence is too extensive or if you suspect there is a key temporal bias or change

within the field of inquiry.

6. Repeat process for primary studies. Contrast the primary study focus with a synthesis focus.

7. Do a cursory read of the abstracts of the synthesis studies.

8. Identify other terms including synonyms and antonyms that you may have not included.

9. Reflect on this challenge and ensure the terms you used and the papers you have are studying the dimension of the challenge you want to summarize.

10. Decide if it makes sense to do a short narrative, systematic review, or meta-analysis (at least at this point in time).

Products

1. A clear vision of the challenge you want to tackle.

2. A set of ideas, papers, and the outcome that you ultimately are likely to provide.

3. The landscape of evidence you need to examine a process or challenge across many studies.

Resources

Slide deck

Template to contrast relative frequencies of synthesis versus primary studies

Reflection questions

1. What synthesis studies have most informed or inspired your understanding in your field?

2. Is there evidence that is most needed by stakeholders right now that needs to be compiled or derived?

3. Was there any indication that the focus of the synthesis studies you retrieved differed from the primary studies?

4. Do synthesis studies advance theory or depth of knowledge more rapidly than well-executed primary studies or experiments?

Chapter 3

Quantitative synthesis workflow reporting

Learning outcomes

1. Develop a checklist for reading systematic reviews and meta-analyses.
2. Document a quantitative synthesis process.
3. Consolidate understanding of key synthesis elements from the literature.

Context

Evidence implementation and reuse is a non-trivial process in most disciplines. It is crucial that experts are able to use, reuse, and implement synthesis findings. This process of critical appraisal furthers a novel, big-picture view of scientific findings associated with single studies. This can take the form of a perspective that routinely weights relative evidence by purpose, reason, and other findings to improve decision making by stakeholders, the public, and other scientists. Application of this process to published peer-review evidence can be limited by transparency, level of reporting, missing data, meta-data articulation, and limited moderator reporting. Hence, ten simple rules for evidence reuse were proposed were broadly to highlight these and other challenges in synthesis science (Lortie and Owen, 2020). Critical reading of meta-analyses is also a powerful skill for all experts (Shrier, 2015). This thinking and evaluation process has also been developed into a more prescriptive set of ten questions to apply to any published meta-analysis or systematic review (Nakagawa et al., 2017). These questions strengthen the reuse of current meta-analyses and provide a checklist for reporting in future systematic reviews and meta-analyses.

Checklist reporting

List from (Nakagawa et al. 2017):

1. Is the search systematic and transparently documented?
2. What question and what effect size?
3. Is non-independence taken into account?
4. Which meta-analytic model?
5. Is the level of consistency among studies reported?
6. Are the causes of variation among studies investigated?
7. Are effects interpreted in terms of biological importance?
8. Has publication bias been considered?
9. Are results really robust and unbiased?
10. Is the current state (and lack) of knowledge summarized?

Purpose

Good reporting is supported by good thinking. Purpose prevails. A primer for systematic reviews and meta-analysis in the sports science clearly articulates a clear and direct purpose delineation process for syntheses (Impellizzeri and

Bizzini, 2012).

Goals checklist

List from (Impellizzeri and Bizzini 2021):

1. Identifying treatments that are not effective.

2. Summarizing the likely magnitude of benefits of effective treatments.

3. Identifying unanticipated risks of apparently effective treatments.

4. Identifying gaps of knowledge.

5. Auditing the quality of existing trials.

Collectively, these how-to papers suggest that it would be ideal if synthesis reporting exceeded the norms and standards associated with primary research reporting to enable next-level synthesis and reproducibility. Nonetheless, it is easy to get lost in the technical details. Consequently, purpose, audience, and reuse should be kept at the forefront of reviewing, reporting, and doing scientific syntheses. These ideas can be mobilized for knowledge mining even in the early steps of evidence retrieval and reviewing for inclusion in a synthesis project.

Challenge

1. Apply the checklist to a systematic review and meta-analysis in your discipline published a number of years ago and again to a more recent synthesis study.

2. Check whether the derived data were also published for each synthesis paper.

3. Check main text of each and supplements and note whether a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist or flow diagram with provided (Page et al., 2021).

4. Do a primary publication research query using Google Scholar and/or The Web Of Science for your specific process. Document the relative frequency of reporting by search terms (complete template provided below).

5. Review a small subset of the papers (screen only) and test out the PRISMAstatement R package for this scoping review (Wasey, 2019).

Products

1. A checklist for review and reporting of these specific syntheses.

2. A pilot literature dataset of the literature for a search(es) for a synthesis.

3. A PRISMA statement flow chart for use in retrospective pilot reporting (Page et al., 2021).

Resources

Slide deck

A synthesis review literature template

PRISMA statement arguments for R package

Reflection questions

1. Was there evidence for a change in better synthesis reporting practices in your discipline?

2. Were the derived data reported in syntheses or would it be possible to update/repeat a published synthesis in your discipline?

3. Does the flow chart to reviewing and reusing research align with your cognitive modality and critical thinking approach to evidence?

Chapter 4

Meta-analysis in R

Learning outcomes

1. Format data for meta-analyses in R.
2. Explore the capacity of the R package metafor.
3. Pilot statistics for two datasets.

Context

Try out these ideas in a meta-analysis. Securing derived data to replicate an existing synthesis was not common historically, but it is now becoming increasingly viable with open science influences on these contributions. How to do a meta-analysis is well described in the peer-reviewed literature (Field and Gillett, 2010) and numerous books to name a few (Koricheva et al., 2013). Doing meta-analyses using the R programming language is similarly well articulated - particularly from the documentation associated with the package metafor (Viechtbauer, 2017). There are no bad choices in R with well over 100 packages associated with and supporting meta-analyses conservatively listed at 151 packages. The output of Stata (an application specific to many medical meta-analyses), the R package meta, and metafor were virtually identical in several test cases (Lortie and Filazzola, 2020). Ten criteria are proposed in contrasting R packages for this task specifically, but at the current time, metafor is the most commonly used and extensively documented. Hence, consider tackling the challenges here with this package as a robust starting point and entry in meta-statistics.

The 5 primary steps for meta-analyses in R.

1. Secure primary data.

2. Build conceptual model for factors, reponses, and moderators.
3. Calculate effect size(s).

4. Fit appropriate meta-model.

5. Explore significance levels, heterogeneity, and bias.

Challenge

1. Download a dataset and explore applying metafor to the data.
2. Check the published report and examine whether you reached reasonably similar conclusions.

3. Repeat with a second example from another discipline and consider testing another metafor function.

discipline	dataset
environmental science	[Wind turbine effects on birds 2005 synthesis](https://figshare.com/articles/d
environmental science	[Wind turbine effects on birds and bats data 2017 synthesis](https://figshare.
health	[Preventing exercise-induced bronchoconstriction data](https://figshare.com/a
community ecology	[A synthesis shrub facilitation studies testing for increases in community diver
education	[Education data meta-analysis 2020](https://figshare.com/articles/dataset/M

Products

1. Two R scripts for meta-analysis.

2. A sense of data structures needed for meta-analyses in the R package metafor.

Resources

metafor documentation
Bookdown free books

Reflection questions

1. Did the analytical process differ significantly from primary-data workflows?

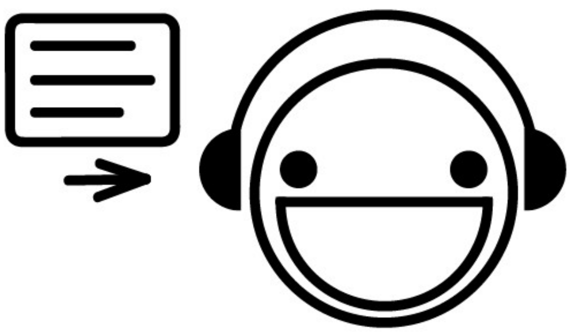
2. Do meta-models in R sufficiently report outcomes to assess strength of evidence?

3. What other steps would be an appropriate addendum to this process?

4. What relational or qualitative elements might be worthwhile to consider adding to meta-analyses and their interpretation for stronger evidence framing and reuse?

Chapter 5

Interpretation and assessment



Learning outcomes

1. Interpret meta-analyses.

2. Leverage meta-analyses to inform decision making.

3. Appreciate extent of synthesis tools capacities to direct inference.

Context

Interpreting meta-analyses and systematic reviews effectively and fairly is critical for the advancement of scientific theory. Conceptual and methodological developments in many fields currently rely on syntheses to evaluate the relative merit of contrasting options (Halpern et al., 2020). Importantly however, meta-analyses can fail (Kotiaho and Tomkins, 2002). The **representativeness** of the evidence is crucial because the intent and purpose of the primary studies should in principle align with the purpose of the synthesis (as discussed previously). The **selection process** for evidence and the statistics can introduce **biases** and lead to potential spurious interpretations of the relevance of a hypothesis for instance. Failure to find support for a hypothesis does not necessarily mean that this is not a conceptually valid endeavor or that it does not explain the functioning of a specific system. Sparse evidence or **publication biases** can skew negative results in meta-analyses and lead to erroneous interpretations because of the evidence. What we know about the world (or the functioning of the world) may not match what we know about the science about the world. However, support for hypotheses in spite of biases and evidence limitations is likely to be representative of the underlying processes and patterns in a system. Consequently, meta-analyses can be evaluated, at times based on evidence volume, as more one-sided versus two-sided tests of concepts or methods. Heterogeneity and moderator analyses will also temper the assessment capacity for a meta-analysis to succeed in functioning as a knowledge engineering tool.

Evaluation and use of meta-analyses is relevant to society at large. Controversy can be resolved or obfuscated by these syntheses (Vrieze, 2018). Two key factors play into the public reuse arena. The interpretation process and the relative strength of the derived evidence between syntheses that diverge in their conclusions. The collision of ideas can be exacerbated when synthesist scientists do not transparently and clearly report findings. This can be further magnified when the media and others directly reuse a published meta-analysis. The other factor, strength of evidence, must be transparently and accurately handled within each meta-analysis by better reporting. Lack of supporting derived data and inadequate reporting of the study populations (of papers) that comprise contrasting meta-analyses impede quantitative contrasts of syntheses. Description of the differences between studies within a synthesis is foundational to a better mapping of science onto 'scientific truth' (Ioannidis, 2005). We must set a higher standard for synthesis reporting (Haddaway et al., 2018) and adopt more open science components into these projects. Finally, education and discussion within a synthesis of how well that specific process functioned in summarizing an evidence hierarchy must be developed.

Challenge

1. Select a meta-analysis or systematic review with extensive reporting. Assess whether the interpretations are well supported by the evidence that was incorporated in the synthesis.

2. Explore one of the case studies provided in this short course and examine the sensitivity of the conclusions to reductions in the volume of evidence.

3. Test full versus reduced models in one of the examples, statistically, to explore moderator influences on net outcomes.

Products

1. A set of evidence from a meta-analysis with a sense of study quality.
2. A simple script to explore the statistical interpretations of meta-analyses done in R.

Resources

Slide deck

ROSES RepOrting standards for Systematic Evidence Syntheses: pro forma template

Reflection questions

1. Do primary studies need to be scored for quality?
2. Do single large primary studies inform meta-analyses more than many smaller trials or experiments?

3. Is there a mechanism qualitatively or quantitatively to demonstrate representativeness and address matching truths to a system?

Chapter 6

Coursework

Summative assessment

If you are completing this course of study for credit, here is the summative evaluation.

Product 1: evidence maps

Design an 'evidence map for evidence gaps' or 'evidence map as a geographic map' for a topic of your choice in your expertise or domain of research.

1. Select a topic and pilot appropriate search terms to populate a representative and reasonable set of peer-reviewed publications. Use The Web of Science or other relevant bibliometric resource. Secure at least 50 papers for first review.

2. Review these primary studies for relevance, available data, concept of interest or hypothesis directly tested, and other criteria identified for your synthesis.

3. Generate a PRISMA workflow diagram and briefly describe exclusion criteria.

4. Using the included instances, compile frequency of study of key concepts of these primary studies.

5. Identify the country of study or more specific geographic estimate of study locations.

6. Record sample sizes of each independent trial from each study.

7. In processing the list of studies, keep track of potential key measures, outcomes, factors, and also moderators for future and deeper synthesis work on this topic.

8. If there is an existing systematic review on this topic or set of key terms and it was published at least 2-years ago, it is viable to update this synthesis work. Do the above steps and if a reasonable number of returns is present since date of synthesis publication (i.e. at least 50 recent primary papers), consider updating this work.

9. Generate your evidence map.

10. Briefly describe both the search process supporting the PRISMA workflow and the evidence map.

Rubric

criteria	description
PRISMA	flow chart completed, numbers reasonable, and criteria explained in brief below flow chart
clarity	clear visual, shows data and trends in what is known and what gaps can be explore in fut
evidence	representative, reasonable set of studies, list search terms in brief below evidence map and

Product 2: ignite commentary

Based on your synthesis work completed in product 1, provide a short < 2000 word Ignite format contribution appropriate for the journal Oikos that inspired this format of contribution to science.

1. Identify and describe the challenge or research question(s).

2. Succinctly summarize what is known.

3. Describe the evidence gaps and next steps for this specific field of research.

4. Highlight an implication of this synthesis process for readers.

5. Cite at least 5 papers relevant to the synthesis summarized as an Ignite paper here.

Rubric

criteria	description
challenge	clearly state hypothesis or research challenge
evidence	summarize what is known from your synthesis work in project 1 - ie evidence and formal but brief sc
gaps	list the gaps and explain next steps
implication	given the relative difference between known and next highlight an implication for researchers to cons
citations	recent citations, a few concept papers, and a few sample primary studies

Product 3: meta-analysis

Complete a meta-analysis in R for a subset of your studies.

1. Reuse the studies included in your synthesis in products above.

2. Extract the mean, sample size, and estimate for variance associated with these measures.

3. Compile at least 12-15 independent observations for analysis. These can be from a limited number of studies/papers provided the trials/experiments reported in a study or paper were independent. For instance, an experiment was replicated in 3 different grasslands in a paper and data were available for each. This is now commonly treated as independent replications if the ecology or science supports this. Evidence organized into papers is not necessarily single instances.

4. Identify at least one moderator (categorical or continuous) to explore in subsequent analyses.

5. Do a meta-analysis using metafor for simple grand mean effect of your key factor.

6. Explore heterogeneity and bias.

7. Repeat the meta-analysis and test your moderator.

8. The goal only 10-15 independent rows or observations here to pilot the statistical process and interpretation for your topic.

9. Generate a forest plot or meta-regression plot depending on your moderator.

10. Make a table of key results.

11. Aggregate the figure and table into a single document and provide a short 2-3 sentence interpretation.

Rubric

criteria	description
data	reasonable dataset collected
figure	clear forest plot or meta-regression plot with figure legend
table	table lists key statistics for either simple meta-analysis on grand means or with mode
interpretation	demonstrate that you have critically appraised and consolidated your understanding r

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