Tutorial: Meta-Analytic Methods for Cognitive Science

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Meta-analysis is a powerful yet underused tool in cognitive science. It allows researchers to leverage entire bodies of literature to get a broad and quantitative overview of a particular phenomenon, thereby promoting theory development, and to make more precise estimates of effect sizes, which enables robust planning of prospective studies (e.g. through power-analyses). In this tutorial, we will introduce meta-analysis as a tool with which to inform everyday research, and provide participants with hands-on experience conducting their own meta-analysis. We will also present an online platform we have developed for conducting meta-analyses in the field of language development: MetaLab (http://metalab.stanford.edu).

Keywords: meta-analysis; reproducibility

Significance

The empirical social sciences are in crisis: Many subfields are plagued by issues of low reliability and validity of their findings (Ioannidis, 2005; Open Science Collaboration, 2013, 2015). It has become evidently clear that any single study is limited both in interpretability and in scope, as it is a noisy estimate of the underlying effect size, often measured unreliably due to low power, and it only measures an effect in one setting. Meta-analysis is a powerful tool that allows quantitative aggregation of effect sizes across studies in a particular field. Meta-analyses can provide three key pieces of information. First, they allow an estimation of the presence of bias in a field of work. Second, they yield more realistic measures of the size of main effects and their variability, allowing researchers to better inform their power analyses and obtain more accurate estimates of desirable sample sizes. Third, by providing a framework in which different studies can be compared in a quantitative way, meta-analyses allow the exploration of relationships between variables previously not compared in a single study, thereby further developing theories based on a broad overview of a particular phenomenon. In sum, meta-analyses allow both consumers and producers of a given field of work to gain a better appreciation of that research, and they enable researchers to make both practical decisions (such as sample size) and theoretical decisions (such as predictions for particular variables) that are grounded in empirical data.

Despite the salient benefits of using meta-analysis, cognitive scientists use meta-analyses relatively rarely. The most likely reason is that we lack the training to carry out and use meta-analyses effectively. Indeed, meta-analyses traditionally rely on a very few people painfully entering large bodies of research, with little ready-to-use support tools and educational materials available. In addition, the general benefits of meta-analyses, for instance the possibility of conducting power analyses, are often neither evident nor accessible to individual researchers who lack training on this simple tool. Moreover, if a meta-analysis already exists, potential re-users of this valuable data may feel that its value diminishes as time goes on, since traditional meta-analyses remain static after publication, aging quickly as new results emerge. Finally, even if researchers may be keen on utilizing an extant meta-analysis, they may be uncertain about how to deal with "mixed apples and oranges" or the presence of a publication bias.

The goal of this tutorial is to empower participants to harness the power of meta-analyses. We will start with a broad introduction to meta-analysis as an analytical tool. Participants will then get hands-on experience conducting and reusing a meta-analysis in an interactive session. By the end of the tutorial, participants will have a better understanding of the practical and theoretical utility of meta-analysis, as well as working knowledge about how to go about conducting their own meta-analysis, or reusing an extant meta-analysis.

Additionally, we will introduce participants to a novel tool called MetaLab (http://metalab.stanford.edu; Bergmann et al., 2015; Lewis et al., 2015). MetaLab is an online platform that aggregates meta-analyses on topics related to language development (e.g., phoneme discrimination and word segmentation; Tsuji & Cristia, 2014; Bergmann & Cristia, 2015). MetaLab facilitates the learners' and users' task in three ways. First, it supplies templates and analysis scripts, streamlining the process of learning about and conducting a meta-analysis. Second, it supports community-augmented meta-analyses (CAMA; Tsuji, Bergmann, & Cristia, 2014), allowing a meta-analysis to be conducted and extended by multiple researchers, both reducing the workload of the individual researcher as well as allowing for dynamic extensions to always include the newest results. Third, for each meta-analysis conducted in the MetaLab framework, we provide free and easy-to-use tools for power analysis and data exploration.

A broad range of researchers will benefit from this introduction to meta-analysis: Novices to a particular research subfield who are in need of a robust overview can turn their

literature review into a meta-analysis with a few additional steps, providing themselves and the whole research community with a valuable resource. Any researcher faced with new requirements for publishing in top-tier journals, such as providing a reason for sample size decisions, will profit from being familiar with the concept and uses of meta-analyses, including thinking in terms of effect sizes rather than significance and being able to carry out a prospective power analysis.

Structure

This one-day tutorial will introduce participants to the method of meta-analysis, providing a hands-on step-by-step guide to use the MetaLab infrastructure for conducting a meta-analysis, working on it collaboratively, and sharing it with the research community.

We will lead participants through the steps of a meta-analysis based on a pre-selected topic. The topics of literature search and study selection, which precede the actual meta-analysis, will be covered briefly. Participants will be walked through the steps of a meta-analysis with a theoretical and practical component to each step of the process.

1. Coding of variables (2h)
   (a) Theory: How to decide on independent and dependent variables to be included; which pieces of information are mandatory and optional
   (b) Practical: Set-up of a spreadsheet in standardized format, deciding on variables to be included, explain in what format to code variables in order for them to be included in quantitative analyses, coding of one preselected article (different article for each participant)
2. Effect size calculation (1h)
   (a) Theory: Introduction to different types of effect sizes, their calculation, and how to transform between them
   (b) Practical: Effect size calculation for paper coded
3. Meta-analysis (2h)
   (a) Theory: Introduction to meta-analytic regression, choice of model, choice of moderator variables, correction for publication bias, and interpretation of analysis output
   (b) Practical: Putting together the papers coded by each participant and conducting a meta-analysis
4. Integration with MetaLab and use of extant meta-analyses (1h)
   (a) Theory: Advantages of making a meta-analysis publicly available, and how to use extant meta-analyses for informing new study design
   (b) Practical: Examples of power analysis, study design decisions, including, but not restricted to use of MetaLab infrastructure.

Each participant will need a laptop, but no additional materials are required for the tutorial.

Organizer Credentials

All authors have conducted meta-analyses in their field: ST, AC: (Tsuji & Cristia, 2014); ML, MF: (Lewis & Frank, 2015), CB, AC: (Bergmann & Cristia, 2015). ST, CB and AC have proposed the concept of CAMAs (Tsuji et al., 2014) and provided online tutorials for facilitating meta-analysis for researchers in the cognitive sciences. ST, ML, and CB have taught the basics of meta-analysis, including theoretical and hands-on parts, in graduate level university classes and lead meta-analysis workshops. They have also presented the CAMA and MetaLab frameworks on international conferences (Bergmann et al., 2015; Lewis et al., 2015). All authors have collaborated to develop the MetaLab infrastructure and tutorial materials since 2/2015 (together with Mika Braginsky and Page Piccinini).

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