EMPIRICAL CONSTRUCT DIAGRAMS

Diagramming The Structure Of Variables In Empirical Research Studies

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Data visualizations facilitate knowledge construction about **data**, both in the classroom and research practice. But ***we lack similarly powerful tools*** for representing **the conceptual structure of studies** that generate these data.

The power of diagrams in learning and science communication

Diagrams are commonly used in **science education** to communicate *physical relations* (e.g. molecular notations, biological cell illustrations) *illustrate abstract concepts* (e.g.hierarchies, systems diagrams) and even for *solving problems* (e.g. free body diagrams, conditional probability trees).

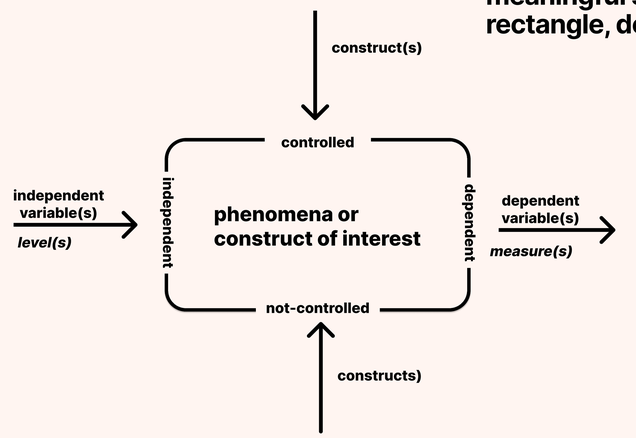
The use of diagrams in **scholarly communication** is *comparatively sparse*. In the case of psychology and other empirical behavioural sciences, readers will most likely find diagrams : (1) illustrating the *structure of new theories or models*, (2) *procedure diagrams* illustrating the sequence of activities experienced by study participants or (3) *structural equation models,* an analysis technique for exploring the (mathematical) relationship between variables in a proposed conceptual model. Of these examples, only *structural equation models* have a formalized graphical syntax, while the others are often ad-hoc and idiosyncratic.

EMPIRICAL CONSTRUCT DIAGRAMS

make *explicit* the central theoretical construct(s) involved in an empirical study and how the associated variables are *varied*, *measured*, *controlled*, or left *uncontrolled.*

GRAPHICAL SYNTAX

The syntax of the Empirical Construct Diagram (ECD) consists of the meaningful spatial layout of labelled variables around a central rectangle, describing the phenomena or construct of interest.

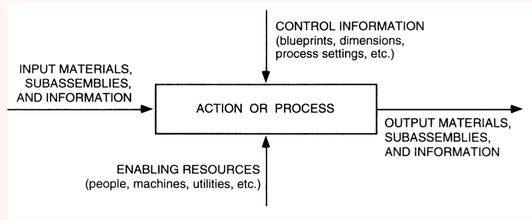


The spatial placement of each variable is determined by the role the variable plays in the study.

Independent variables are depicted as rightward arrows flowing *into* the phenomena, and **dependent** variables as arrows flowing *outward*. Other variables (or more general constructs) that are believed to effect the phenomena are depicted as arrows flowing from the top if they are **controlled**, or from the bottom if left **uncontrolled.**

As space allows, variables can be annotated with further information, such as the levels of a (categorical) independent variable, or the modes of measurement for each dependent variable.

Inspiration for Empirical Construct Diagrams comes from the *IDEF0 diagram* first developed by Douglas Ross for the U.S. Air Force, for the purpose of identifying and classifying functions and subroutines of software systems. The IDEF0 was later presented by Russell Barton in *Graphical Methods for the Design of Experiments* (1999), a text surveying how diagrammatic tools can be useful in structuring the (immense) design space of experiments in **industrial engineering**, where answering a research question often requires multiple series of experiments systematically varying hundreds of potential variables.



I have adapted the IDEF0 structure to support the goal of communicating the conceptual model underlying an empirical research study.

EXAMPLE

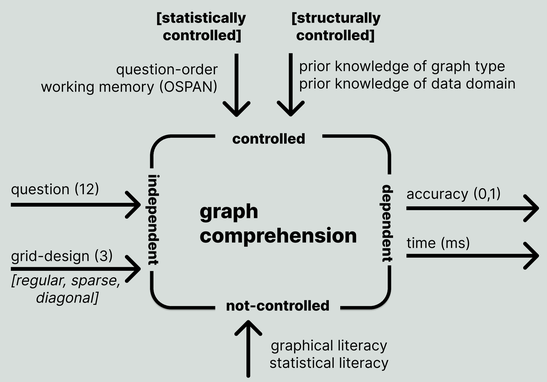
The diagram (at *right)* depicts the variables involved in a (graph comprehension) experiment described via the methods section text (*at left)*.

Methods. To test our hypotheses about how graph grid design might affect triangle graph comprehension, we recruited 475 undergraduate students to participate in our study, in exchange for course credit. Twenty-two participants were excluded for failing attention-check questions, yielding 453 participants for analysis (gender: 27 % male, 70 % female, 2 % other; age: 18 - 36 years).

The study employed a multilevel design with one fixed and two random factors. The fixed independent variable was *grid-design* with three levels (regular, sparse, diagonal), while questions and participants were designated as random factors. Participants were nested within grid-design conditions, and questions were fully crossed with condition. Thus, each participant was randomly assigned to one grid-design, in which they completed all the questions. Response accuracy and time were measured for each question.

Participants started the study by completing informed consent, followed by a visual OSPAN assessment of working memory. If participants finished the OSPAN task, they were then directed to the primary experimental task (graph reading task with 12 questions).

from (Fox, 2022)



How the diagram augments the text

Although the METHODS text describes the independent (grid-design) and dependent (time, accuracy) variables, it does *not* describe the other factors the researcher thinks are likely to influence graph comprehension, but are not controlled in the design of the study (i.e. graphical and statistical literacy). Often, discussion of these factors are only found in *limitations* or *discussion* sections of manuscripts.

The diagram also includes two prior knowledge factors that are structurally controlled via the design of the stimuli, which are are described in a different section of the manuscript.

Taken together, the diagram provides a more complete representation of the researcher's conceptual model of the factors that may affect the phenomenon (graph comprehension), integrating text typically communicated in different sections of research manuscripts.

APPLICATIONS

I propose that **empirical construct diagrams (ECDs)** may serve as **effective graphic organizers** in both the communication and instruction of empirical psychological science. ECDs make explicit the relationship between variables, measures, tasks and theoretical constructs in empirical research, crucial aspects of understanding and evaluating studies, that are most often communicated via text, distributed across different sections of research publications.

INSTRUCTION

instructors might consider leveraging diagrams in **active learning activities** where (for example) students working in small groups draw ECDs based on excerpts of methods text from research papers. In **content courses** students might then *critique* what other factors (i.e. alternative explanations) of the phenomenon could exist, based on what they've learned about the topic of study. ECDs could also be presented as **summary note-taking artifacts** in classes where learners are expected recall the details of classic research studies.

RESEARCH & COMMUNICATION

In my own research practice, I have found ECDs to be effective **tools for thinking** about (and quickly recording!) the (construct) design of potential research studies, and as **tools for communicating** the conceptual model underlying study design decisions, especially in interdisciplinary contexts.

If you are interested in discussing the further evolution of Empirical Construct Diagrams, using or evaluating them in your teaching or research activities, or discussing other approaches for diagramming research methods, please reach out! ***amyraefoxphd@gmail.com***