Open-Source Tools for Relational Network Derivation, Visualization and Task Generation

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Abstract

Relational reasoning is suggested to be a cornerstone of human higher cognition, and therefore a prime subject of psychological and artificial intelligence research. Human relational abilities are extremely generative, allowing individuals to flexibly adapt to novel environments. Unfortunately, this generativity also complicates research on complex relational cognition because visualizing the network of relations that governs an individual’s behavior, or establishing such complex relational control in the lab is difficult and cumbersome, resulting in an empirical basis that is limited to *relatively* simple phenomena. The current paper describes a set of open source resources that we hope can facilitate research into complex relational reasoning. We provide a set of tables that can be used to automate relational derivation in computer programs and illustrate their value in three tools derived from them to automatically (1) visualize a relational network of baseline and derived relations, (2) generate a match-to-sample procedure with user-defined task parameters and (3) generate a set of syllogistic reasoning problems provided user-specified task characteristics. We hope these tools can help researchers overcome (some of) these limitations and as such facilitate research on more complex relational behavior that underpins complex human cognition.

**Keywords**. Relational Reasoning, Relational Networks, Syllogistic Reasoning, Relation Derivation, Open Source Software

Introduction

The human capacity for relational reasoning is suggested to be a cornerstone of complex cognition and intelligent behavior (e.g., Hayes et al, 2001; Penn et al., 2008; Halford et al., 2010; Gentner & Smith, 2013; McLoughlin et al., 2020) and has received increasing research attention in fields such as behavioral psychology, cognitive and neuropsychology, linguistics and computer science. Across these research fields, procedures involving complex relational reasoning are developed to assess the ability in an experimental context (e.g., the relational abilities index, Stewart et al., 2016, Cummins et al., 2023), relate it to some other construct (e.g., fluid intelligence, Crone et al., 2009; Colbert et al., 2017) or to train the ability or those it is purported to underpin (e.g., Colbert et al., 2018; Dixon et al., 2022).

Smith & Hayes (2022) make point that AI research also increasingly makes use of relational algorithms with the hopes of achieving human-level flexibility and generativity (e.g., Santoro et al., 2020; Ninness and Ninness, 2020; …) but that the relational information they learn is often hidden in the black box-nature of their many hidden layers.

In order to explore the broader implications of assessing and training relational reasoning for complex issues in human cognition, it is necessary to have both highly specified tasks (e.g., see Cortes et al., 2021) and carefully crafted analytic and descriptive models. We will use the example of RFT to explain why that is so. RFT accounts for generativity in human language through a learned behavior of combining two or more previously trained relations into novel derived (not directly trained or reinforced) relations. For example, if *A* is less than *B* and *B* is less than C, one can also derive the relation between A and C (assuming a prior learning history

Results in massive relational networks and relational behavioral repertoires, barely matched by experimental procedures -> extrapolation

* Related work: Allen (1983), Smith & Hayes (22) -> Extended and applied!

Derivation tables and scripts + can be used to automate things - applications: visualization and task creation

Method

Relational Derivation Tables

Describe composition tables

Step-by-step description of script for derivation

Tutorials

Visualizing Relational Networks.

A first hurdle that researchers encounter in the study of complex relational behavior is due to the combinatorial explosion that occurs when even a relatively small number of relations is combined. One of the reasons that relational reasoning is such a powerful capacity is that it is generative: given information about n relations, one can derive n² novel relations from that information (Hayes et al., 2012)

* Tool for now can handle (all? combinations of) same, different, opposite, more than, less than, before, after, contains, is part of/during (but many relations share pattern of comparative relations in that they are similarly asymmetrical, e.g., father-son).

Generate a Match-to-Sample Task.

* Dominant procedure in RFT/behavior-analytic literature
* Input parameters
* Examples – 3 member equivalence class with varying training protocol, steele & hayes?,

Generate a Syllogistic Reasoning task.

In both RAI and cogneuro literature

Automatically and systematically vary parameters of task and generate virtually limitless trials.

Discussion

* Limitations: Limited to programmed relations or those that fit known patterns, until other patterns are discovered or generality of
* General patterns underlying multiple relations – possibility for scaling

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* **Ethics approval** (include appropriate approvals or waivers)
* **Consent to participate** (include appropriate statements)
* **Consent for publication** (include appropriate statements)
* **Availability of data and materials** (data transparency)
* **Code availability** (software application or custom code)
* **Authors' contributions** (optional: please review the submission guidelines from the journal whether statements are mandatory
  + Also referred to as **Open Practices Statement**
  + E.g., all materials and code along with tutorials are made available at the OSF (link).

References

Smith, P., & Hayes, S. (2022). An Open-Source Relational Network Derivation Script in R for Modeling and Visualizing Complex Behavior for Scientists and Practitioners. *Frontiers in Psychology, 13*. Article 914485. doi: 10.3389/fpsyg.2022.914485