Process Tracing for Dummies: Solutions for design, analysis and presentation

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Process tracing

• What is process tracing?

Process tracing is an experimental method used to capture process data during decision tasks

• Definition of process data:

Any data collected between the presentation of the stimuli and the final response given

Old School process tracing

• Verbal reports, manual retrieval (information boards)
• early computerized information boards: Mouselab for DOS
• Analysis done on ad-hoc indices
  – Aggregation over attributes/alternatives
  – Difficult to comprehend the multivariate nature of the process data
• Addresses but does not model individual differences

New School Process tracing

• New technologies for capturing process
  – Clickstream data on the web
  – MouselabWEB
  – Eye movements (trackers)
  – fMRI
• New graphical representations (Icon Graphs)
• More sophisticated models (multilevel):
  – Allow for finer tests of theories
  – Allow for modeling of heterogeneity

Goal of this talk

• Important recent developments make process data more useful
• Process data should be used more to enhance our theories and predictions

• Solutions for:
  – Design of process tracing experiments
  – Representations of process data
  – Statistical methods for analysis of process data
Design: MouselabWEB

- Goal: perform Mouselab-like process tracing experiments on the web (and in the lab)
- Approach: simple HTML/javascript available in recent browsers (works in 96%+ of browser usage)
  - Operating System Independent
  - No network delays: (Client-side, 1/60th second precision)
  - Fast and Easy: No plug-ins, small pages
  - No hassle server-side scripting (php/mySQL)
  - Easily extended: Open source (GNU license)

Features of MouselabWEB

- [http://www.mouselabweb.org/](http://www.mouselabweb.org/)
- **Designer** program to design pages with mouselabWEB and other questions
- **Datalyser** program to retrieve and replay a movie of the process data
- Web-based means:
  - Large numbers of respondents
  - A lot of heterogeneity in participants (not quite the average 20 year old student lab participant)
  - Specificity of respondents: targeting specific groups

Asian Disease

- How to represent process data?
- Multivariate nature of process measures
  - **Attention**: acquisition frequency and looking time
  - **Search patterns**: direction and variability of search
  - **Time dynamics**: attention and search over time
- Icon Graphs can be used to display all this in one graph, using a 2D display.

Representation: Icon Graphs

Methods: Data structure

- Many repeated observations within a participant
- Data structures are rich:
  - Attributes/alternatives
  - Time per acquisition
  - Time dependencies between acquisitions
  - Transitions between acquisitions
- Data are clustered:
  - First level: individual observations
  - Second level: design and participant variables (including individual characteristics and individual-difference measures)
Multilevel models

• Multilevel models allow investigating relations between lower-level predictors (e.g., attention to an option) and higher-level predictors (e.g., a measure of loss aversion on the participant level).
• Individual-level parameters (e.g., intercept, slopes, transition probabilities) become dependent variables:
  \[ \beta_{1i} = \text{Linkfunction}(\eta_0 + \eta_1 z_i) \]

Advantages of Multilevel models

• Flexible decomposition of process measures
• Tests of random and fixed effects of individual-difference variables on decision process
• Incorporation of ‘nuisance’ effects (e.g., spatial dependencies in information display, reading order).
• Works with unbalanced data

Another example

• Reference dependence (Tversky and Kahneman, 1991)

Reference Dependence

- Reference dependence (Tversky and Kahneman, 1991)
- Dependent variable: amount of attention to a box (frequency or time)
- 48 observations (6 boxes x 4 quarters x 2 trials) per participant
- Model some of the error variance by using random effects
- Dynamics over time are modeled using a linear and quadratic terms
- Choice is included in the model (to examine differences in process between A and B choosers)

Example of Multilevel analysis

- Model for Reference dependence
  - Dependent variable: amount of attention to a box (frequency or time)
  - 48 observations (6 boxes x 4 quarters x 2 trials) per participant
  - Model some of the error variance by using random effects
  - Dynamics over time are modeled using a linear and quadratic terms
  - Choice is included in the model (to examine differences in process between A and B choosers)

Results

- Attention changes dynamically over time from the reference option towards to chosen option
- Losses do not loom larger than gains
Results

• Random factors (capture individual variance on these factors) are significant:
  – intercept
  – trial
  – attention to loss
• Process data also predicts choice
• Multilevel model can be used to distinguish between different theoretical predictions about the process

Summary

• Synergy of new techniques, new representations, and new analysis methods
  – Sophisticated data collection on the internet increases diversity in samples
  – New graphical representations (e.g. Icon Graphs) help identifying what factors and differences are relevant
  – New multilevel analysis methods allow for actually modeling these effects, including individual differences

Summary

• Process data can tell why effects occur or do not occur and how individual differences might mediate this.
• Process data increases insight into cognitive processes underlying decision making
• Use process data yourself!

http://www.mouselabweb.org/