A Hierarchical Bayesian Dual-Process Model Reveals That Recognition Memory May Be Mediated by a Single Process

Jeffrey N. Rouder & Mike Pratte

November, 2010
Symposium: Practical Benefits of Bayesian Data Analysis

Please note correct talk times:


11:30 - 11:50. Multiple Comparisons and Power Make Sense in Bayesian Analysis. John K. Kruschke, Indiana University, Bloomington.
Cognitive Structure
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The Skill Acquisition Nightmare

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From Aggregation

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Example: Recognition Memory

**PROPOSITION: Dual-Process Theory**

- Two core processes: Recollection, Familiarity
Example: Recognition Memory

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- For each item-by-person combination, there is a mixture of recollection and familiarity.
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▶ Two core processes: Recollection, Familiarity
▶ Recollection and familiarity parameters may vary across people and items.
▶ For each item-by-person combination, there is a mixture of recollection and familiarity.
▶ Mixture is core cognitive process.
PROPOSITION: Dual-Process Theory

- Two core processes: Recollection, Familiarity
- Recollection and familiarity parameters may vary across people and items.
- For each item-by-person combination, there is a mixture of recollection and familiarity.
- Mixture is core cognitive process.
- Mixture is NOT because some items are mediated by familiarity and others are mediated by recollection.
We aggregate data across items or people (or both) to tabulate rates (e.g., hit rate). Seemingly necessary, does aggregation conflate core structure with variation across items and people?
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Seemingly necessary.

Does aggregation conflate core structure with variation across items and people?
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Recognition Memory Nightmare

Dual-Process: $\hat{r} \approx 0.25$.

Even though no recollection in process.

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A Hierarchical Bayesian Dual-Process Model Reveals That Recognition Memory May Be Mediated by a Single Process
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Big Picture

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2. To avoid aggregation, we need hierarchical nonlinear models (HNLM)
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3. Bayesian nonlinear hierarchical models are tractable
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2. To avoid aggregation, we need hierarchical nonlinear models (HNLM)
3. Bayesian nonlinear hierarchical models are tractable
4. Using Bayesian analysis to solve hard problems that we could not otherwise solve.
Big Picture

Bayesian Hierarchical Applications From My Lab:

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Bayesian Hierarchical Applications From My Lab:

- **RT Modeling**: Rouder et al. 2004, Pmetrika; Rouder et al. 2005, PBR; Rouder et al. 2008, PBR; Rouder et al 2010, PsycRev

- **Subliminal Priming**: Rouder et al. 2007, PBR; Morey et al. 2008, JMP; Rouder & Morey, 2009, PsycRev; Morey et al., 2009, Pmetrika

- **Process Dissociation**: Rouder et al., 2008, JEPG

- **Recognition Memory**: Rouder & Lu, 2005; Rouder et al., 2007, Pmetrika; Morey et al., JMP, 2008; Pratte et al. 2010, JEPLMC; Pratte & Rouder, JMP, soon.
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Dual-Process: \( \hat{r} \approx .25 \)
QUESTION: Is the often-observed asymmetry in ROCs a simple artifact of aggregation?
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APPROACH: Analysis w/ a hierarchical dual-process model that separates people and item effects from core processes.
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APPROACH: Analysis w/ a hierarchical dual-process model that separates people and item effects from core processes.

SPECIFICS:
- Recollection indexes asymmetry.
- Q: Is there any evidence of recollection if item and participant effects are modeled?
Hierarchical Dual Process Model

- PARADIGM: Vanilla Recognition Memory
- TASK: Vanilla Confidence Ratings
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Recentered Familiarity

New Parameterization

\[ d(n) \quad d(s) \]

Density

Familiarity

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PARAMETERS:

- $r_{ij}$: Probability of recollection for $i$th subject and $j$th item
- $d(n)_{ij}$: Baseline familiarity for the $i$th subject and $j$th item
- $d(s)_{ij}$: Studied-item familiarity for the $i$th subject and $j$th item

Middle criterion set to 0
Remaining criteria are unique to each participant
Hierarchical Dual Process Model

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Hierarchical Dual Process Model

Too Many Parameters!
Hierarchical Dual Process Model

Constraint Through Additive Models:

**Baseline Fam.**: \( d_{ij}^{(n)} = \text{grand mean}^{(n)} + \text{person}_{i}^{(n)} + \text{item}_{j}^{(n)} \)

**Studied Fam.**: \( d_{ij}^{(s)} = \text{grand mean}^{(s)} + \text{person}_{i}^{(s)} + \text{item}_{j}^{(s)} \)

**Recollection**: \( r_{ij} = F \left( \text{grand mean}^{(r)} + \text{person}_{i}^{(r)} + \text{item}_{j}^{(r)} \right) \)
Hierarchical Dual Process Model

PRIORS:

\[ \sigma_k^2 \sim \text{Inverse Gamma}, \quad k = 1, \ldots, 6 \]
Evidence for Recollection?

Big Experiment:
- 240 items at study, 480 items total
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- 95 people

Testament to the power of Bayesian analytic methods

Focus on grand mean of recollection.
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Two Processes?

- Do People Who Exhibit High Recollection Exhibit High Familiarity?
- Do Items That Elicit High Recollection Elicit High Familiarity?
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Selective Influence Over Processes

Recollection Enhancement:
- Shallow: Count Vowels
- Deep: Produce a related word

Familiarity Enhancement:
- Perceptual Match vs. Mismatch: Font, Case, Modality

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Induce a Familiarity Effect

RESPONSE DEADLINE

- Boldini, et al, 2004
- With Long Deadline:
  Big LOP Effects, No Match/Mismatch Effects
- With Short Deadline:
  No LOP Effects, Moderate Match/Mismatch Effects
Expt 2: With Deadline

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Experiment 3

High Recollection, Low Familiarity

- Short Study List (80 vs. 240 items)
- Response Deadline
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Conclusions: Recognition Memory

1. Asymmetry in ROCs reflects underlying core processing.
2. Hierarchical model reveals strong correlation between recollection and familiarity.
3. Perhaps there is a single latent process driving both.
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- Specific Dual Process Model
  - Familiarity is normal, equal-variance
  - Recollection is all-or-none
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- Don’t Miss:
  - Rouder A Nonparametric Definition and Test of Single Process in Recognition Memory, 10:20a, Sunday, Mississippi Room.
Conclusions: Bayesian Modeling

1. Hierarchical modeling allows us to separate variation in item and participant effects from cognitive processes.
2. Provide uncontaminated view of process.
3. Bayesian analysis makes hierarchical nonlinear modeling tractable (and fun).

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Thank You