Heuristic Models of Pedestrian Walking Direction Choice

Wei Zhu
Center for Adaptive Behavior and Cognition
Max-Planck-Institute for Human Development
Berlin, Germany

Harry Timmermans
Urban Planning Group
Eindhoven University of Technology
Eindhoven, The Netherlands
Motivation

• Do people aggregate information when they make choices? (As assumed in utility-based models)
• Or process options and information sequentially due to their bounded rationality? (e.g., Simon, 1956)
• Evidence is mixed. But in travel modeling, using compensatory models is still dominant.

• Purpose: From a practical point of view, to see whether heuristic models can be useful tools for modeling travel behavior.

• Use an example about how shopping pedestrians choose walking directions.
Model comparison

• Heuristic models
  – Conjunctive rule
  – Disjunctive rule
  – Lexicographic rule

• Compensatory models
  – Multinomial logit model
  – Mixed logit model
Data

- Data, pedestrians’ shopping dairies
- Wang Fujing Street, Beijing, 2004
- 760 respondents

Relevant factors:
- The previous direction, $d^Y$ ($Y=N,S$)
- Total retail floorspace, $q^Y$
- Length of pedestrianized street, $l^Y$
Heuristic models

- Conjunctive: All criteria must be satisfied in order to accept an alternative
- Factor thresholds $\delta_j$

\[
p_i = \begin{cases} 
1 & \text{if } x_{i1} \geq \delta_1 \land \ldots \land x_{ij} \geq \delta_j \\
0 & \text{otherwise} 
\end{cases}
\]
• Threshold heterogeneity

\[ p_1^N = \prod_x p_1^{N_x} \quad x = d, q, l \]
\[ p_1^{N_d} = \alpha^d (1 - d^N) + \beta^d d^N \]
\[ p_1^{N_q} = G^q (q^N - \alpha^q, \beta^q, \theta^q) \]
\[ p_1^{N_l} = G^l (l^N - \alpha^l, \beta^l, \theta^l) \]

If both directions are satisfactory or unsatisfactory, choose randomly

\[ p^N = p_1^N p_0^S + (p_1^N p_1^S + p_0^N p_0^S) 0.5 \]
\[ p_0^N = 1 - p_1^N \]
- Disjunctive: Only one criterion needs to be satisfied in order to accept an alternative

\[ p_i = \begin{cases} 
1 & \text{if } x_{i1} \geq \delta_1 \lor \cdots \lor x_{ij} \geq \delta_j \\
0 & \text{otherwise}
\end{cases} \]

Replace \( p_1^N = \prod_x p_1^{Nx} \) with

\[ p_1^N = \sum_x p_1^{Nx} - p_1^{Nd} p_1^{Nq} - p_1^{Nd} p_1^{Ni} - p_1^{Nq} p_1^{Ni} + \prod_x p_1^{Nx} \]
• Lexicographic: Compare attributes in descending importance until the attributes discriminate

\[ p_{1}^{N_{x_{j}}} = \text{Prob}(x_{j} \geq \delta_{j}) \quad \text{Higher state} \]
\[ p_{0}^{N_{x_{j}}} = \text{Prob}(x_{j} < \delta_{j}) \quad \text{Lower state} \]
\[ p_{B}^{N_{x}} = p_{1}^{N_{x}} p_{0}^{S_{x}} \quad \text{Better} \]
\[ p_{W}^{N_{x}} = p_{0}^{N_{x}} p_{1}^{S_{x}} \quad \text{Worse} \]
\[ p_{T}^{N_{x}} = 1 - p_{B}^{N_{x}} - p_{W}^{N_{x}} \quad \text{Tie} \]

If the sequence is \( d \rightarrow q \rightarrow l \)

\[ p^{N} = p_{B}^{N_{d}} + p_{T}^{N_{d}} p' \]
\[ p' = p_{B}^{N_{q}} + p_{T}^{N_{q}} p'' \]
\[ p'' = p_{B}^{N_{l}} + p_{T}^{N_{l}} 0.5 \]
Compensatory models

• Multinomial logit

\[ p^Y = \frac{\exp(v^Y)}{\sum_{Y'} \exp(v^{Y'})} \quad Y, Y' = N, S \]

\[ v^Y = \beta^d q^Y + \beta^q q^Y + \beta^l q^Y \]

• Mixed logit
  – Assumed parameters in MNL are normal distributions
## Results

<table>
<thead>
<tr>
<th>Model</th>
<th>$N^P$</th>
<th>LL</th>
<th>CAIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conjunctive</td>
<td>5</td>
<td>-966</td>
<td>1,975</td>
</tr>
<tr>
<td>Disjunctive</td>
<td>3</td>
<td>-987</td>
<td>2,000</td>
</tr>
<tr>
<td>Lexicographic $d \rightarrow q \rightarrow l$</td>
<td>5</td>
<td>-963</td>
<td>1,968</td>
</tr>
<tr>
<td>Lexicographic $d \rightarrow l \rightarrow q$</td>
<td>5</td>
<td>-962</td>
<td>1,968</td>
</tr>
<tr>
<td>Lexicographic $q \rightarrow d \rightarrow l$</td>
<td>4</td>
<td>-946</td>
<td>1,926</td>
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<tr>
<td>Lexicographic $q \rightarrow l \rightarrow d$</td>
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<td>-953</td>
<td>1,941</td>
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<td>Lexicographic $l \rightarrow q \rightarrow d$</td>
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<td>MNL standard</td>
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<tr>
<td>MNL with logged variables</td>
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<tr>
<td>Mixed logit</td>
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<tr>
<td>Parameter</td>
<td>Estimate</td>
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<tr>
<td>-----------------</td>
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<td></td>
<td></td>
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<tr>
<td>Prob of turning back</td>
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<tr>
<td>( \alpha^d )</td>
<td>0.381 *</td>
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<tr>
<td>Prob of following the previous direction</td>
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<tr>
<td>( \beta^d )</td>
<td>0.767 *</td>
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<tr>
<td>Threshold for floorspace</td>
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<tr>
<td>( \alpha^q )</td>
<td>17,999.620 *</td>
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<tr>
<td>( \beta^q )</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \theta^q )</td>
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<tr>
<td>Threshold for pedestrian street length</td>
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<tr>
<td>( \alpha^l )</td>
<td>348.636 *</td>
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<tr>
<td>( \beta^l )</td>
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</tr>
<tr>
<td>( \theta^l )</td>
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<tr>
<td>( N^C )</td>
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<td>( N^P )</td>
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<tr>
<td>LL</td>
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</tr>
</tbody>
</table>

Note: The symbols \( q \), \( d \), \( l \), and \( C \), \( P \) represent different parameters or variables in the model.
Conclusion

- Models of non-compensatory decision mechanisms can fit the data well. They can be practically useful for predicting travel behavior.

- Models of sequential processing do not rely on covariance, which may lower the risk of over-fitting. (When one reason suffices, why use another?)
Future directions

• Apply heuristic models on more complicated decision problems to test their general utility.

• Could transportation practices benefit from the sequential mechanisms in heuristic models? Is less-is-more effect possible?
Thank you

zhu@mpib-berlin.mpg.de
h.j.p.timmermans@tue.nl