Modeling Anger and Aggressive Driving Behavior in a Dynamic Choice-Latent Variable Model

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Outline

• Aggressive driving
• Research objectives
• Data collection approach
• Experimental design
• Descriptive results
• Model
• Conclusion
Aggressive Driving

• Aggressive driving is a major cause of driving errors and accidents (about one third of crashes in the US).

• Defined as “a combination of moving traffic offenses so as to endanger other persons or property” (NHTSA, 1997)

• Causes: engineering factors, behavior of other drivers, and individual characteristics
  – **State anger**: provoked by frustrating events on the road
  – **Trait anger**: “global or chronic tendency of experiencing anger” (Spielberger, 1988)

State-trait anger theory
Aggressive Driving (cont.)

- Manifestation: risky or offensive driving behaviors such as:
  - Speeding
  - Running red lights
  - Sudden braking
  - Weaving in and out of traffic
  - Honking the horn
  - Lower time-to-collision
Previous Work

• Various survey instruments to measure driving anger (e.g. State-Trait Anger Scale, Driving Anger Scale, etc.)
• Many descriptive studies of driving anger and aggressiveness
• No previous mathematical model that quantifies the dynamics of driving aggressiveness as a function of driving anger
Research Objectives

• To mathematically represent the state-trait anger theory by modeling the dynamics of driving anger, its causes, and manifestations.

• Such a model can be used to test the impacts of engineering interventions and policies on reducing driving anger and increasing road safety.
Data Collection Approach

• Experiment using a mid-level driving simulator, whereby participants drive through 9 signalized intersections in a suburban context
Treatment intersections: with events that trigger anger

Order of treatment scenarios is shuffled across participants.
Experimental Design

Control intersections: no events
Scenario 1: Short Green Interval

• As subject approaches the intersection, the signal light turns from red to green for a few seconds.

• Then the light turns yellow then red again before the subject passes.
Experimental Design (cont.)

Scenario 2: Blocked Intersection
Experimental Design (cont.)

Scenario 3: Ambient Red Light Violations
Data Collection

• Participants were a self-selected sample of 102 university students at the American University of Beirut (AUB).
• Those who felt dizzy and stopped the experiment, drove recklessly, or had accidents while driving were removed from the analysis.
• Sample size for analysis: 81 students
### Descriptive Results

#### Red Light Violations

<table>
<thead>
<tr>
<th>Intersection Number</th>
<th>Intersection Type</th>
<th>Number of Violations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Treatment (1 frustrating event)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Treatment (1 frustrating event)</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Treatment (1 frustrating event)</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Control</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Treatment (2 frustrating events)</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Control</td>
<td>8</td>
</tr>
</tbody>
</table>

- Probability of red light violation was 4.9%.
- 23.4% of participants violated red lights.
- Incremental intensification of anger
Descriptive Results

Speed and Acceleration

- **Maximum Speed (m/s)**
  - Intersection Number 1 to 9
  - Control
  - Incremental intensification of anger

- **Maximum Acceleration (m/s²)**
  - Intersection Number 1 to 9
  - Control

- **Standard Deviation of Speed (m/s)**
  - Intersection Number 1 to 9
  - Control
Modeling Framework

- $SA_t$: state anger at intersection $t$
- $S_t$: scenario variables (short green, blocked intersection, violations by others) at intersection $t$
- $y_t$: choice of red light violation at intersection $t$
- $O_t$: speed (max. and std. dev.) and acceleration (max.) at intersection $t$
- $T$: number of intersections
Modeling Framework (cont.)

• Discrete choice model:
  – At every intersection, choose to cross on red or not (based on latent state anger)

• Latent variable model:
  – Structural equation of state anger, and manifestations of state and trait anger

• Hidden Markov model:
  – Evolution of latent state anger over intersections
Latent Variable Model

Structural Equations: State Anger at Time $t$

\[
SA_{n,t} = Cte_{SA_t} + \beta_{SA(t-1)}SA_{n,t-1} + \beta_{SS}S_{n,t} \\
+ \beta_{TA}TA_{n} + \epsilon_{n,t}
\]
Latent Variable Model (cont.)

Measurement Equations: State Anger at Time \( t \)

- Indicators of state anger: speed and acceleration
- \( O_{l,n,t} = \alpha_{SA,l} + \lambda_{SA,l}SA_{n,t} + \omega_{l,n,t} \)
Measurement Equations: Trait Anger

- Indicators of trait anger: self-reported anger (survey)
- \( I_{r,n} = \alpha_{TA,r} + \lambda_{TA,r} \cdot TA_n + \nu_{r,n} \)
Choice Model

- Choice $y$ (cross on red or not) is based on utility maximization.
- $U_{i,n,t} = \alpha_i + \beta_{SA} S_{A,n,t} + \epsilon_{i,n,t}$
Likelihood Function

- Joint probability of the sequence of choices, speeds, and accelerations at the 7 intersections and the survey indicators of trait aggressiveness

- Conditional likelihood as a function of SA and TA, and then integrate over SA and TA

\[
f(y_n, I_n, O_n | S_n) = \int_{TA=-\infty}^{+\infty} \int_{SA=-\infty}^{+\infty} P(y_{n,T} | S_{A_n,T}) \cdot g(O_{n,T} | S_{A_n,T})
\]

\[
\int_{SA_{T-1}=-\infty}^{+\infty} P(y_{n,T-1} | S_{A_n,T-1}) \cdot f_2(S_{A_n,T} | S_{n,T}, S_{A_n,T-1}, TA_n) \cdot g(O_{n,T-1} | S_{A_n,T-1}) \ldots
\]

\[
\int_{SA_1=-\infty}^{+\infty} P(y_{n,1} | S_{A_n,1}) \cdot f_2(S_{A_n,2} | S_{A_n,1}, S_{n,2}, TA_n) \cdot g(O_{n,1} | S_{A_n,1}) \cdot f_2(S_{A_n,1} | S_{n,1}, S_{A_n,0}, TA_n)
\]

\[
h(I_n | T A_n). f_1(T A_n | X_n) dTA. dSA_1. dSA_2 \ldots dSA_T
\]
Estimation Results
(Python Biogeme, MSL with 70,000 draws)
Main Findings

• State anger:
  – Individuals with higher trait anger tend to experience state anger more intensely.
  – “Blocked intersection” and “violations” scenarios induce more frustration compared to the short green scenario.
  – State anger at one intersection positively influences state anger at the following intersection.

• Red light violations:
  – Subjects become more likely to violate a red light as they experience more state anger.

• Speed and acceleration:
  – The higher the state anger, the higher the values of maximum speed, standard deviation of speed, and maximum acceleration following the events that trigger anger.
Conclusion

• Developed dynamic mathematical model of state-trait anger theory in the context of driving
• Insights from model consistent with expectations
• Model can be used to assess and prioritize policy measures for mitigating aggressive driving behavior.
Conclusion (cont.)

Limitations

• Validity and realism of the simulator
• Simulator sickness and dizziness
• Small sample size
• Self-selection possibility
Conclusion (cont.)

Extensions

• Cross-cultural comparison of aggressive driving behavior: AUB vs. George Washington University students