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

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Outline

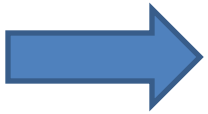
- Aggressive driving
- Research objectives
- Data collection approach
- Experimental design
- Descriptive results
- Model
- Conclusion

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

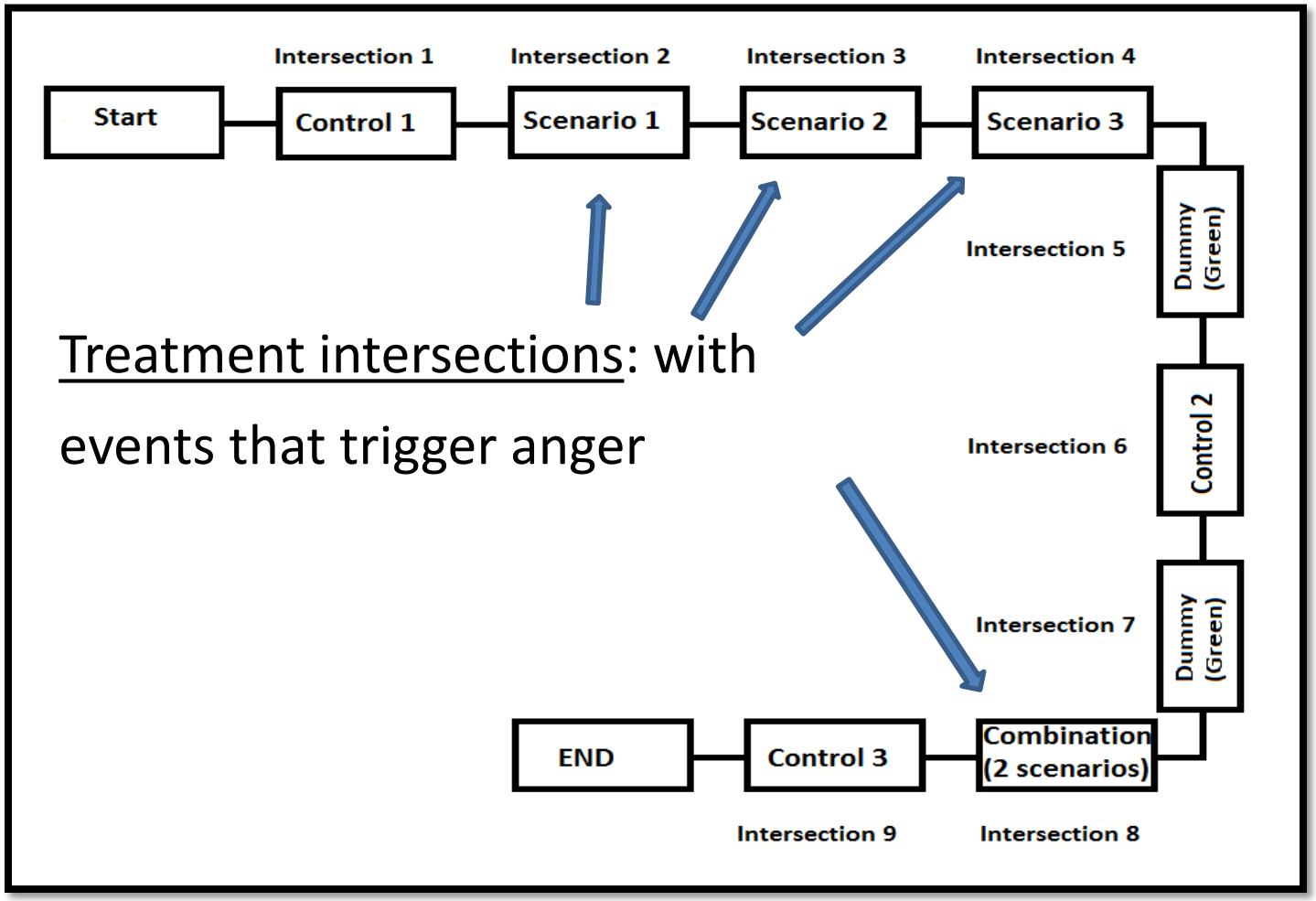
- To mathematically represent the state-trait anger theory by modeling the dynamics of driving anger, its causes, and manifestations

- 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

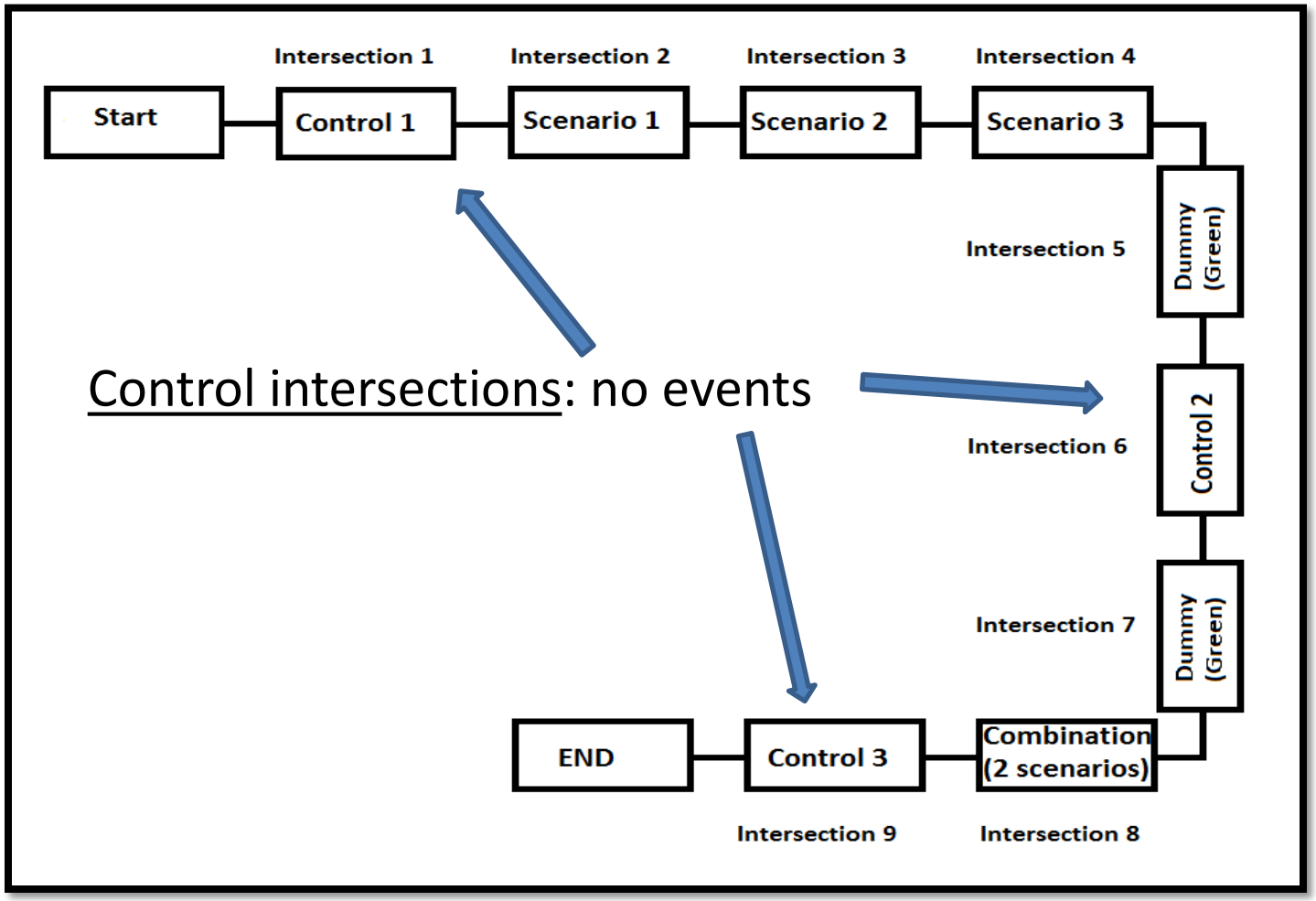
- Experiment using a mid-level driving simulator, whereby participants drive through 9 signalized intersections in a suburban context

Experimental Design



Order of treatment scenarios is shuffled across participants.

Experimental Design



Experimental Design (cont.)

Scenario 1: Short Green Interval

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

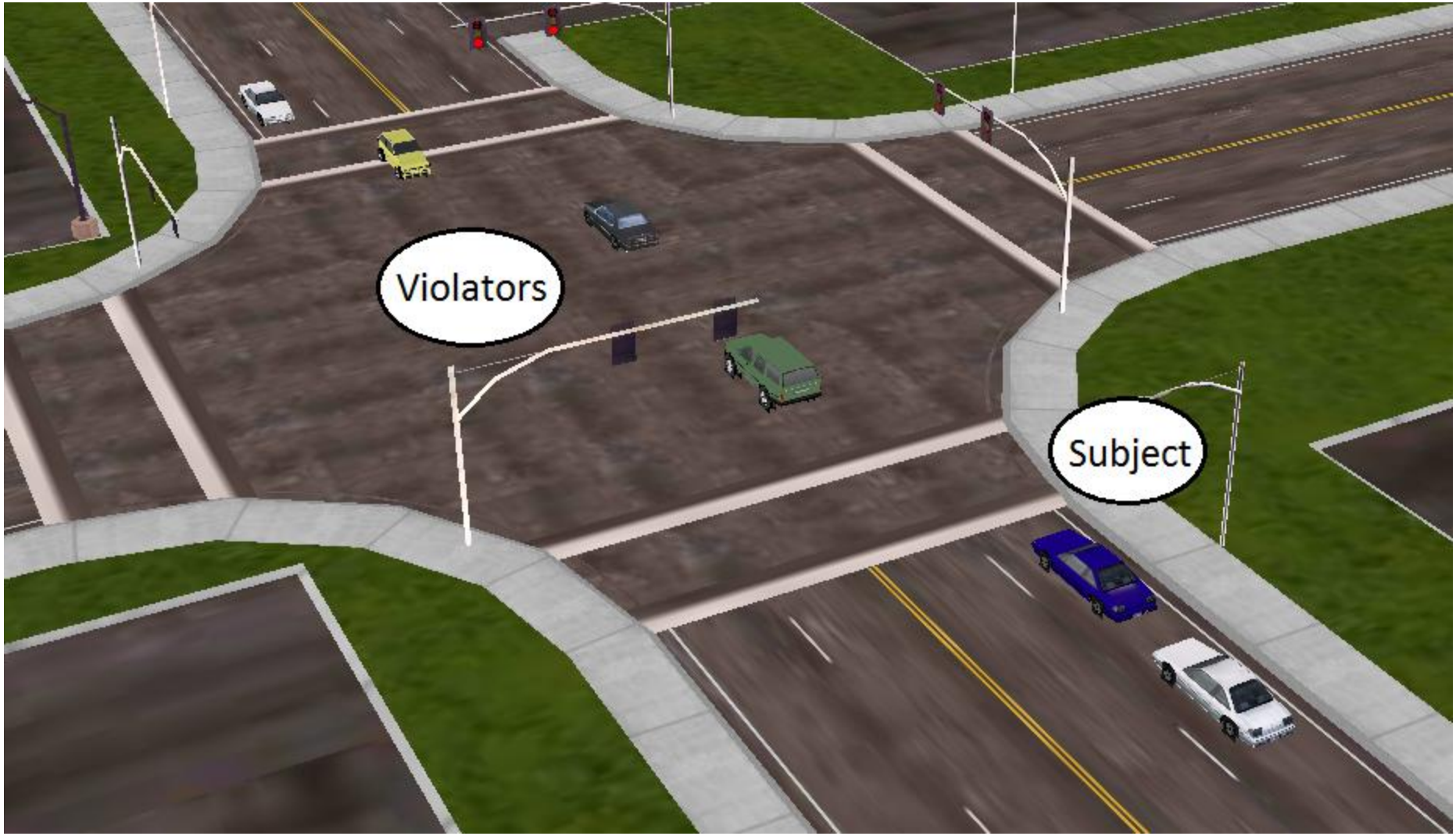
- Then the light turns yellow then red again before the subject passes.

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

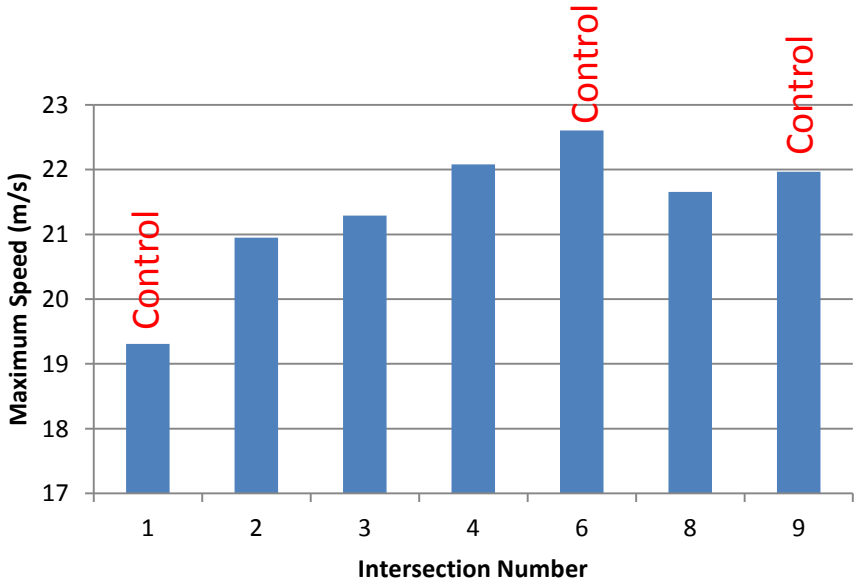
Red Light Violations

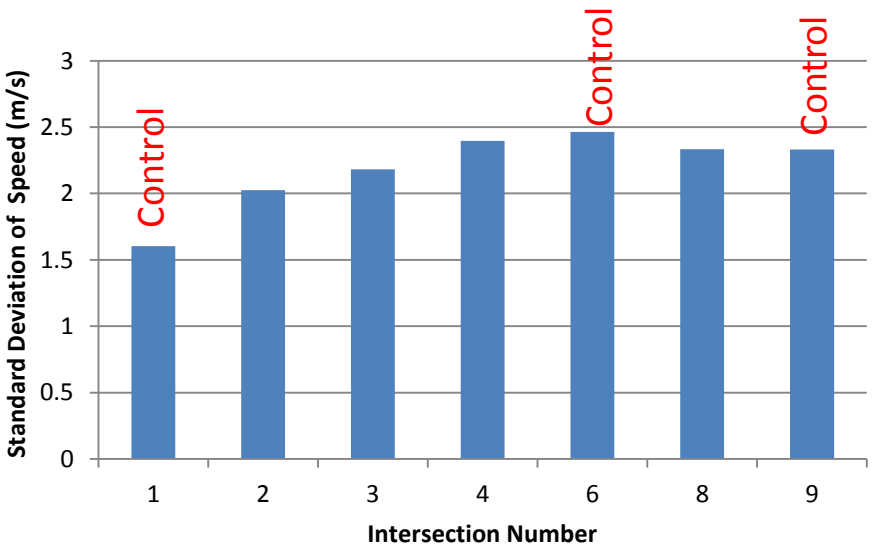
Intersection Number	Intersection Type	Number of Violations
1	Control	0
2	Treatment (1 frustrating event)	2
3	Treatment (1 frustrating event)	4
4	Treatment (1 frustrating event)	8
6	Control	1
8	Treatment (2 frustrating events)	5
9	Control	8

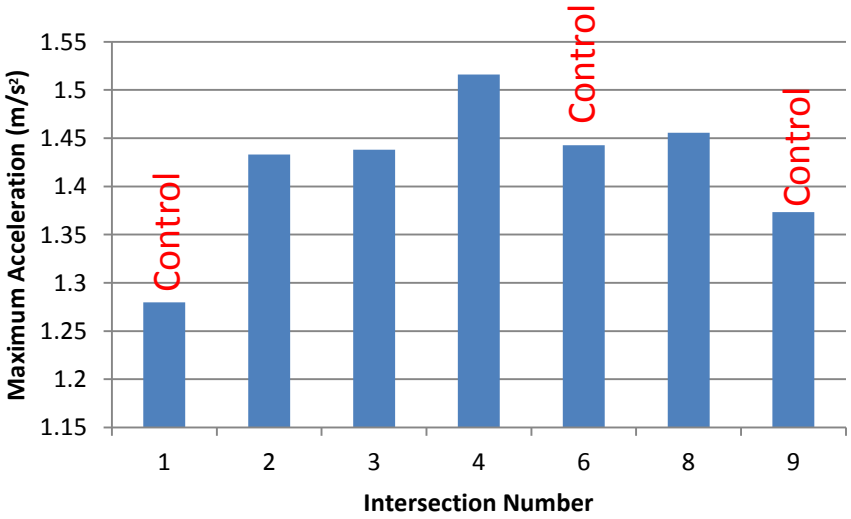
- **Probability of red light violation was 4.9%.**
- **23.4% of participants violated red lights.**
- **Incremental intensification of anger**

Descriptive Results

Speed and Acceleration

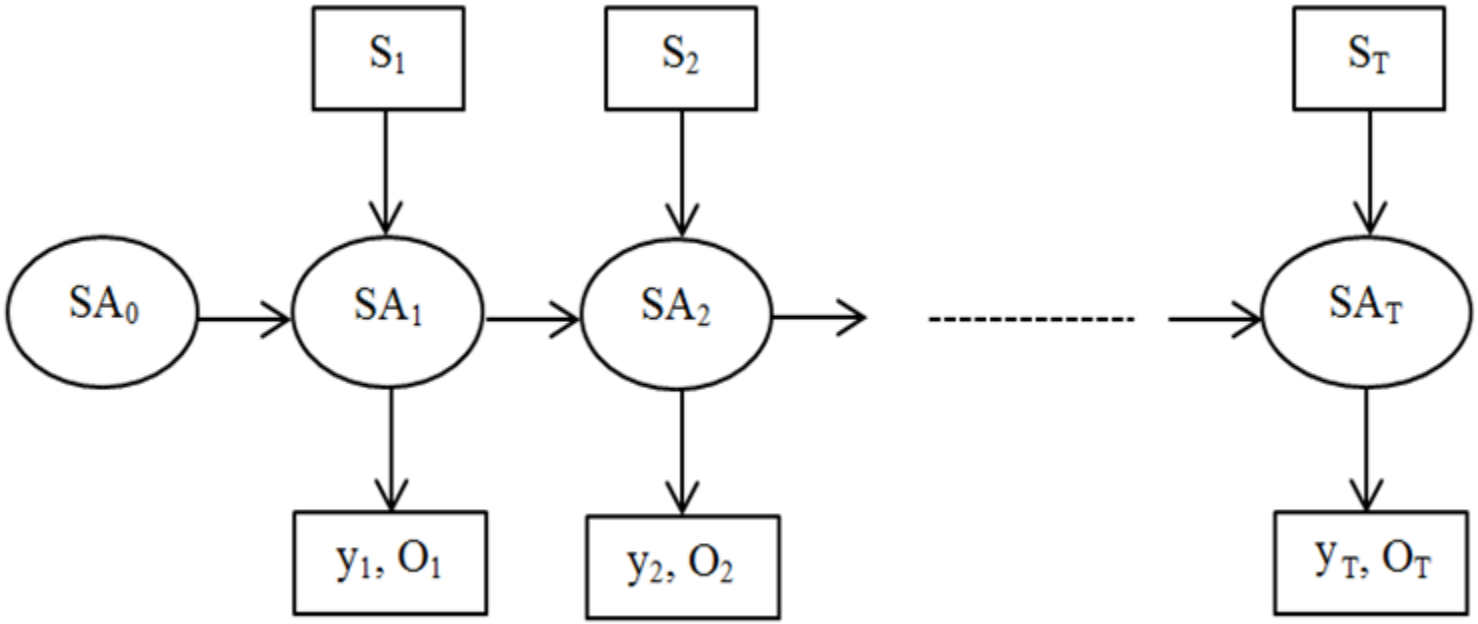






- **Incremental intensification of anger**

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

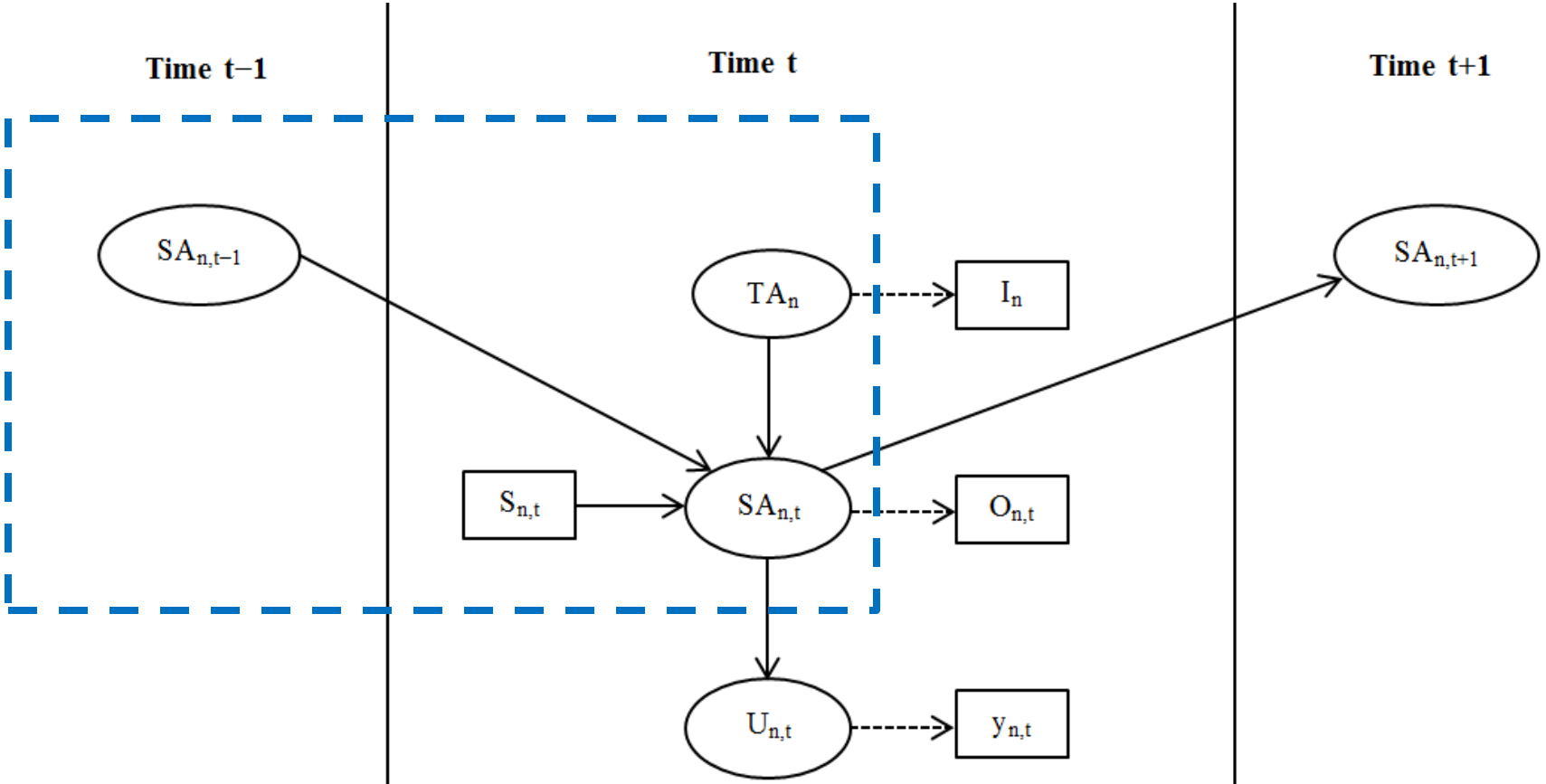
Modeling Framework (cont.)

- 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*

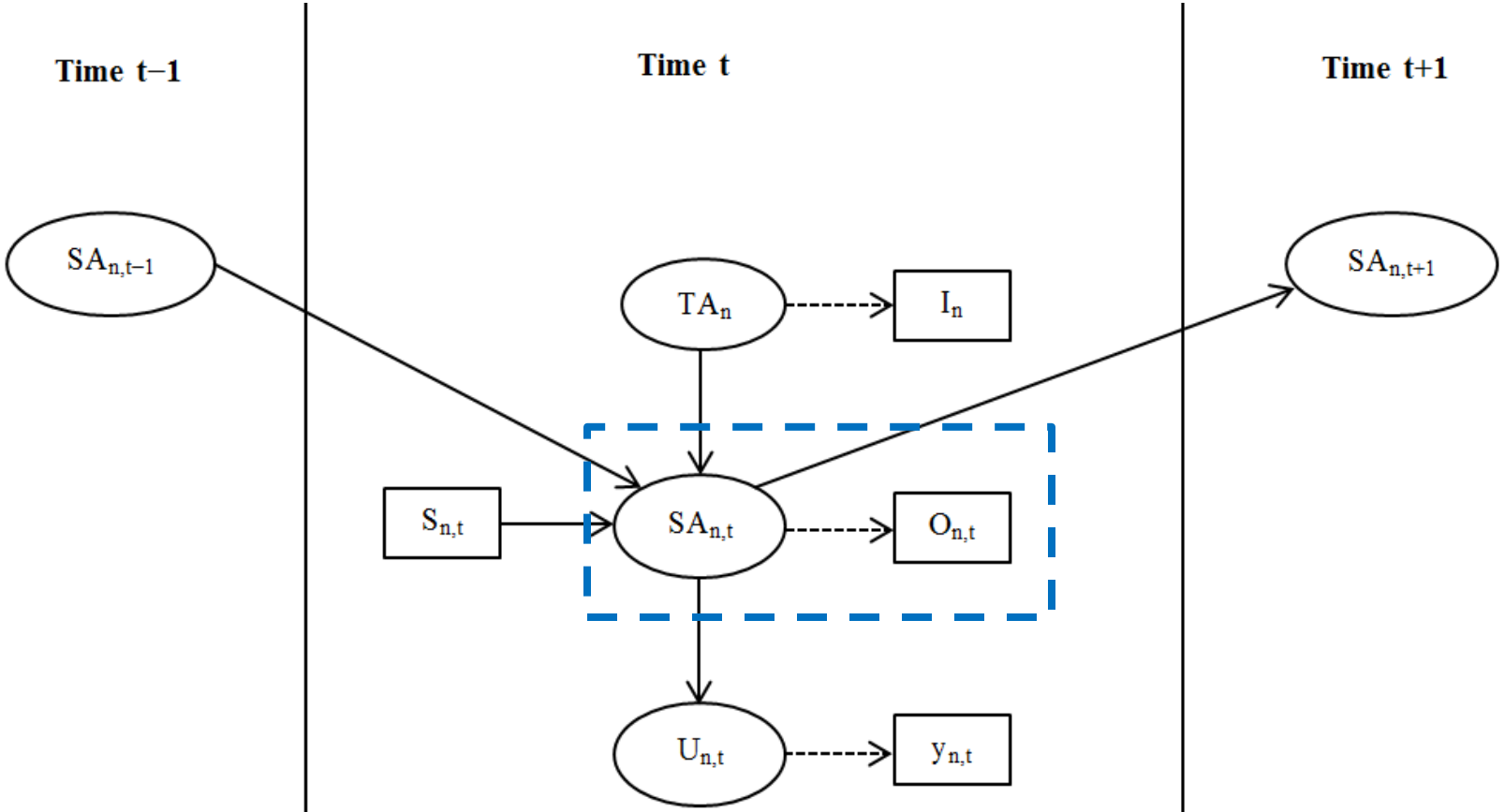
$$SA_{n,t} = Cte_{SA_t} + \beta_{SA(t-1)} SA_{n,t-1} + \boldsymbol{\beta_S S_{n,t}} + \beta_{TA} TA_n + \epsilon_{n,t}$$



Latent Variable Model (cont.)

Measurement Equations: State Anger at Time *t*

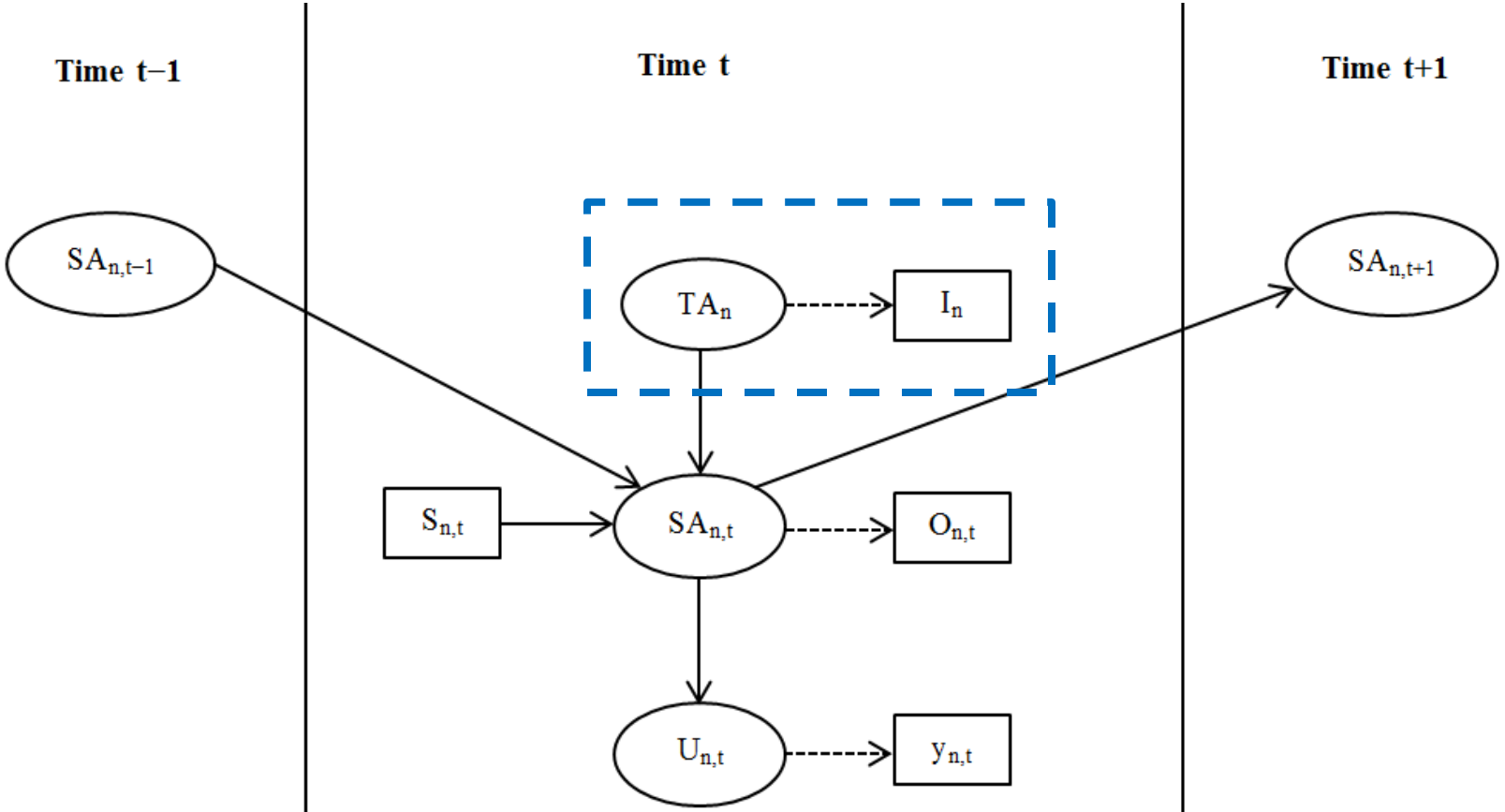
- Indicators of state anger: speed and acceleration
- $O_{l,n,t} = \alpha_{SA,l} + \lambda_{SA,l} SA_{n,t} + \omega_{l,n,t}$



Latent Variable Model (cont.)

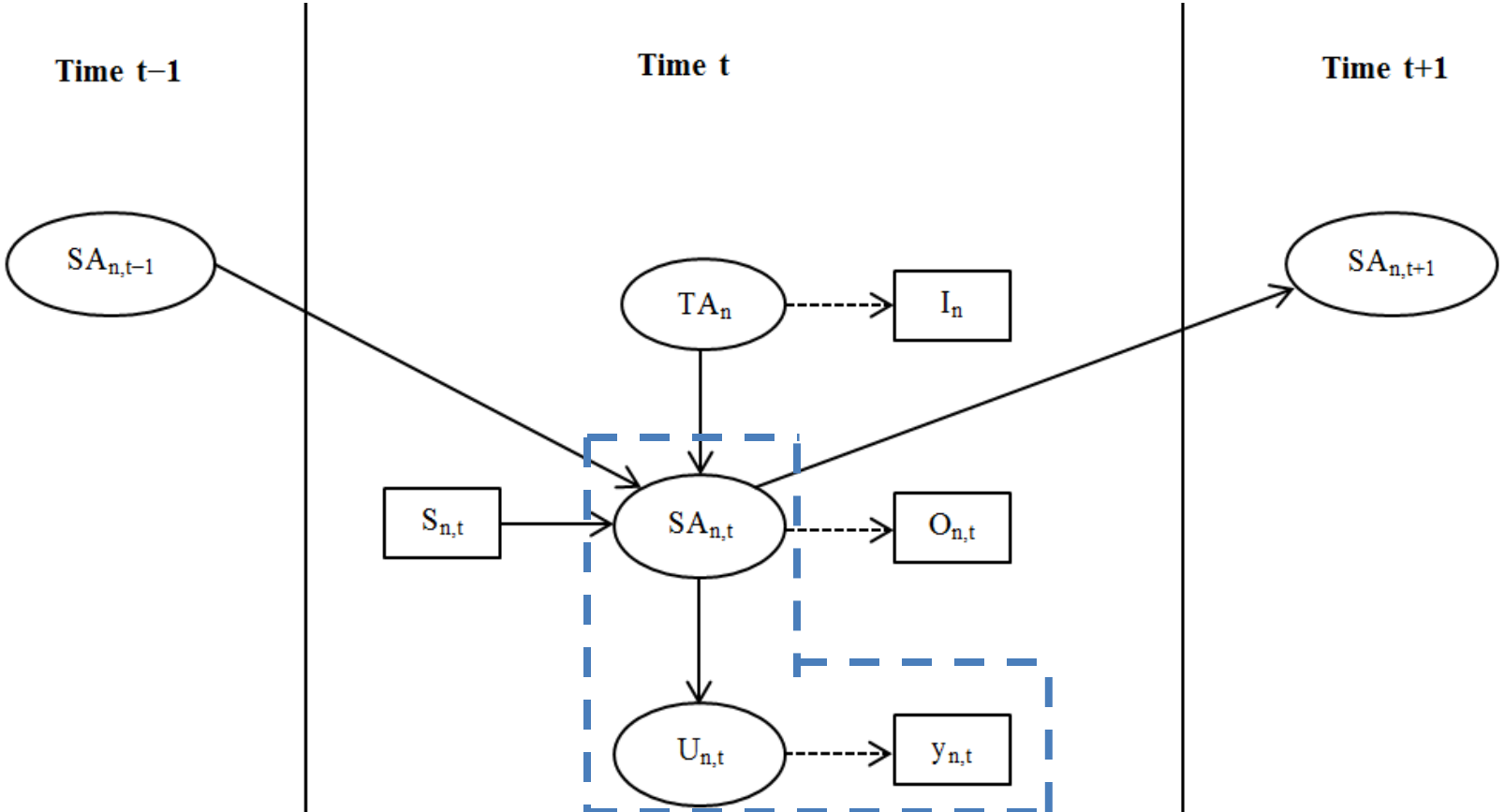
Measurement Equations: Trait Anger

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



Choice Model

- Choice *y* (cross on red or not) is based on utility maximization.
- $U_{i,n,t} = \alpha_i + \beta_{SA} SA_{n,t} + \varepsilon_{i,n,t}$



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

$$f(\boldsymbol{y_n}, \boldsymbol{I_n}, \boldsymbol{O_n}|\boldsymbol{S_n}) = \int_{TA=-\infty}^{+\infty} \int_{SA_T=-\infty}^{+\infty} P(y_{n,T}|SA_{n,T}) \,.\, g(\boldsymbol{O_{n,T}}|\ SA_{n,T})$$

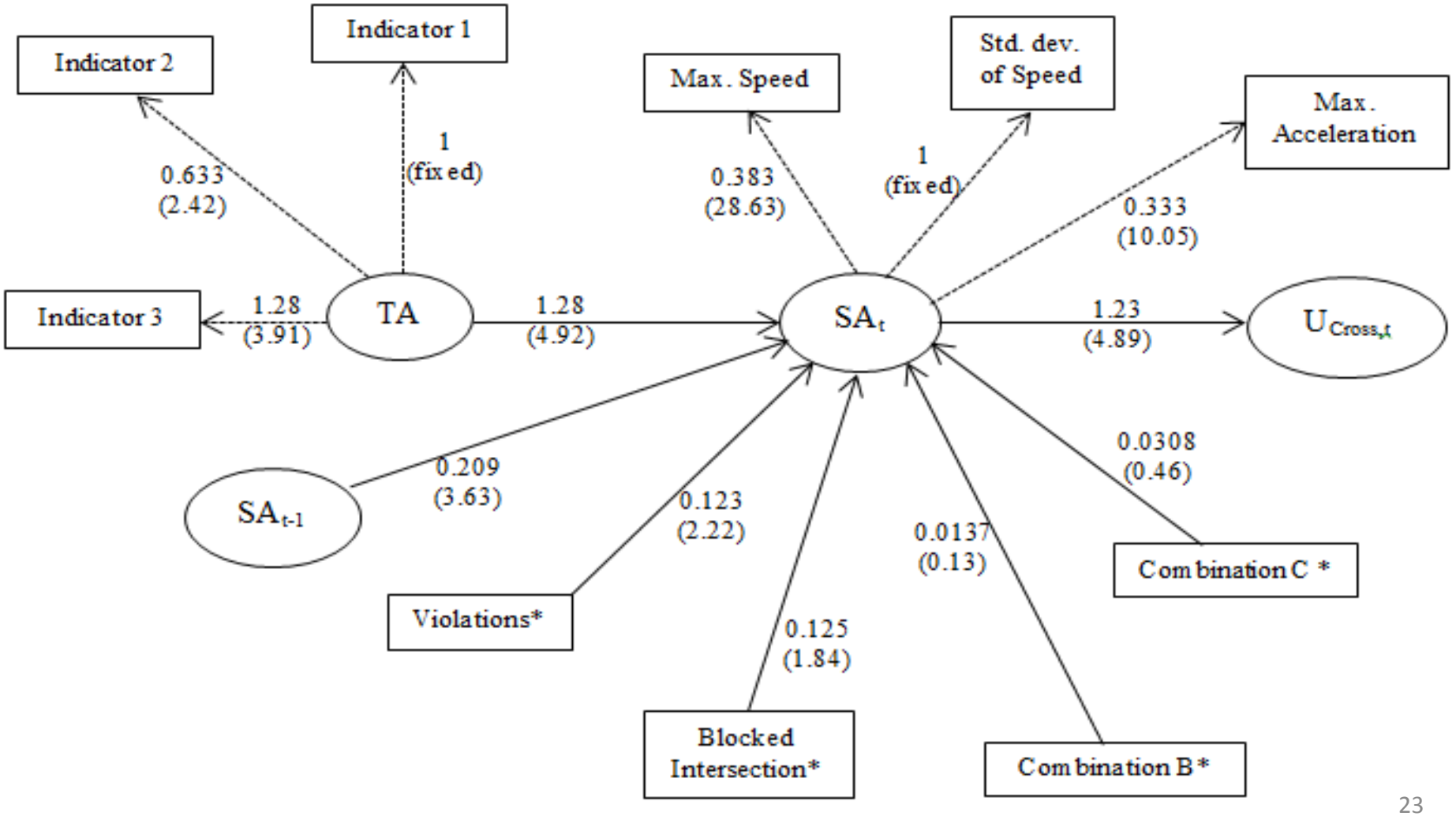
$$\int_{SA_{T-1}=-\infty}^{+\infty} P(y_{n,T-1}|SA_{n,T-1}) \,.\, f_2(SA_{n,T}|\boldsymbol{S_{n,T}}, SA_{n,T-1}, TA_n) \,.\, g(\boldsymbol{O_{n,T-1}}|\ SA_{n,T-1}) \ldots$$

$$\int_{SA_1=-\infty}^{+\infty} P(y_{n,1}|SA_{n,1}) \,.\, f_2(SA_{n,2}|SA_{n,1}, \boldsymbol{S_{n,2}}, TA_n) \,.\, g(\boldsymbol{O_{n,1}}|\ SA_{n,1}) \,.\, f_2(SA_{n,1}|\boldsymbol{S_{n,1}}, SA_{n,0}, TA_n)$$

$$h(\boldsymbol{I_n}|TA_n) \,.\, f_1(TA_n|\boldsymbol{X_n})\ dTA \,.\, dSA_1 \,.\, dSA_2 \ldots dSA_T$$

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

(M. Danaf, S. Hamdar, M. Abou-Zeid, and I. Kaysi, (2014), "Comparative Assessment of Aggressiveness at Signalized Intersections Using Driving Simulators: An Exploratory Case-Study", paper presented at the 93rd annual meeting of the TRB).