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Modeling anger and aggressive driving behavior in a dynamic choice–latent variable model

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ABSTRACT

This paper develops a hybrid choice–latent variable model combined with a Hidden Markov model in order to analyze the causes of aggressive driving and forecast its manifestations accordingly. The model is grounded in the state–trait anger theory; it treats trait driving anger as a latent variable that is expressed as a function of individual characteristics, or as an agent effect, and state anger as a dynamic latent variable that evolves over time and affects driving behavior, and that is expressed as a function of trait anger, frustrating events, and contextual variables (e.g., geometric roadway features, flow conditions, etc.). This model may be used in order to test measures aimed at reducing aggressive driving behavior and improving road safety, and can be incorporated into micro-simulation packages to represent aggressive driving. The paper also presents an application of this model to data obtained from a driving simulator experiment performed at the American University of Beirut. The results derived from this application indicate that state anger at a specific time period is significantly affected by the occurrence of frustrating events, trait anger, and the anger experienced at the previous time period. The proposed model exhibited a better goodness of fit compared to a similar simple joint model where driving behavior and decisions are expressed as a function of the experienced events explicitly and not the dynamic latent variable.

1. Introduction

Aggressive driving in the United States accounts for one third of vehicular crashes and two thirds of the resulting fatalities (Martinez, 1997). It may be defined as "operating a motor vehicle in a selfish, pushy or impatient manner, often unsafely, that directly affects other drivers" (Neuman et al., 2003). According to Shinar (1998), both the characteristics of the driver and the driving situation contribute to aggressive driving. For example, certain frustrating events occurring on the roads evoke frustration such as a short green interval and a car blocking traffic, which are according to Shinar, "illegitimate events that frustrate drivers' legitimate expectations". On the other hand, some trait factors also contribute to aggressive disposition such as hostility and extroversion (Shinar, 1998).

Several studies have identified a significant relationship between anger experienced while driving and risky or aggressive driving behavior (Arnett et al., 1997; Deffenbacher et al., 2003; Nesbit et al., 2007). Deffenbacher et al. (2003) concluded from a driving simulator experiment that angry drivers are twice as likely to be involved in accidents. A considerable number of these studies were based on the state–trait anger theory proposed by Spielberger et al. (1983).

1.1. The state–trait anger theory

Anger may be conceptualized through the state–trait anger model proposed by Spielberger et al. (1983) which differentiates between two modes of anger: state anger and trait anger. Spielberger et al. (1983) defined trait anger as a chronic tendency of experiencing state anger, or propensity towards anger, while state anger was described as a measure of feeling angry like expressing anger at a particular time. They developed the state–trait anger scale (STAS), which is a 30-item questionnaire measuring state anger and trait anger (15 items each).

Spielberger (1988) then combined the STAS with the anger expression scale (AX) (Spielberger et al., 1985) in order to develop the state–trait anger expression inventory (STAXI), which is a 44-item questionnaire assessing the intensity of anger at a

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particular time and the means of anger expression. The questionnaire included two 10-item subscales which are the state anger subscale (SAS) and the trait anger subscale (TAS) in addition to three subscales distinguishing among different types of anger expression labeled as: anger-in, anger-out, and anger control. Anger-in refers to the tendency of suppressing one's anger inside. Anger-out refers to the tendency of expressing anger physically or verbally. Anger control refers to the tendency to control one's temper using adaptive methods.

In 1999, Spielberger introduced the STAXI-2, a revised version of STAXI which included 42 of the 44 original items in addition to 15 new items. In this revision, five items were added to the state anger scale, and the anger control subscale was replaced with two subscales labeled as anger control-in and anger control-out. Three subscales were extracted from the state anger subscale: feeling angry, feeling like expressing anger physically, feeling like expressing anger verbally. On the other hand, two subscales were extracted from the trait anger subscale: whether people have an overall angry or hotheaded temperament or whether people tend to respond with anger when they feel they are being treated unfairly or being criticized by others (Spielberger, 1999).

1.2. Driving anger

Deffenbacher et al. (1994) extended Spielberger's definition to include driving anger, which they defined as a personality trait that is related to trait anger but is more situation-context bound. Driving anger was defined as the frequency and intensity of experiencing anger behind the steering wheel. A 33-item driving anger scale (DAS) was developed with six subscales labeled as hostile gestures, illegal driving, police presence, slow driving, discourtesy, and traffic obstructions. According to Deffenbacher et al. (2000), individuals with high driving anger are more likely to engage in aggressive driving behavior, risky maneuvers, traffic violations, and automobile accidents.

The British version of the driving anger scale (UK DAS) was used by Laujen and Parker (2001) to study the relationship between self-reported driving aggression and self-reported general aggressiveness, measured using the aggression questionnaire (AQ) (Buss and Perry, 1992). The results indicated that self-reported general aggressiveness is related to self-reported aggression on the roads. In addition, different types of aggression (physical aggression and verbal aggression) were found to be correlated with driving aggression.

Deffenbacher et al. (2002) then introduced the driving anger expression inventory (DAX) which consisted of 62 items reflecting how people express their anger while driving. After asking 290 participants to fill out the questionnaire, the authors deduced four different means of driving anger expression: verbal aggressive expression (insults, cursing, yelling, etc.), personal physical aggressive expression (e.g., engaging in physical fights with other drivers or pedestrians), use of a vehicle to express anger (flashing the headlights, cutting off the other driver, etc.), and the adaptive/constructive expression (relaxation and focusing on safe driving).

Several studies have examined the effect of each anger mode on aggressive driving. Nesbit et al. (2007) reviewed several surveys/questionnaires to examine the relationship between different modes of anger (trait anger, state/mood anger, and driving anger) and aggressive driving. Although the researchers were able to develop significant correlations between aggressive driving (expressed through driving violations, accidents, and physical or verbal aggression) and each type of anger, they could not find significant differences in these correlations between each type of anger. On the other hand, Deffenbacher et al. (2001) found significant correlations between state anger experienced while driving and risky and aggressive behavior.

1.3. Integrated driving behavior models

Traditional driving behavior models (such ascar following models, lane changing models, passing models, etc.) aim at explaining independent driving behaviors (Toledo, 2003). After reviewing these models, Toledo (2003) concluded that an integrated model which captures interdependencies between the different driving behaviors such as acceleration and lane changing is needed.

Therefore, Toledo proposed an integrated driving behavior model expressing acceleration and lane changing as a function of drivers' short term goals and short term plans. In this model, short term goals are defined by the target lane, while a short term plan represents the target gap a driver chooses to reach his/her target lane. In order to execute the short term plan, a driver executes certain actions such as acceleration and lane changing. Toledo (2003) developed a four-level decision making process (target lane, gap acceptance, target gap, and acceleration), where the target lane and target gap were considered as latent variables. According to Toledo (2003), this model captures three interdependencies across driving actions which are causality (where the decisions made at the lower levels of the decision making process are conditional on those made at the higher levels), unobserved variables (where the plans are latent and an individual specific latent variable with an assumed distribution is used to model unobserved driver/vehicle characteristics such as aggressiveness, driving skill, or acceleration capabilities of the vehicle), and state dependency (where a driver performs one action of the short term plan then re-evaluates the plan and decides on the following action).

Choudhury (2007) extended Toledo's framework and developed an advanced model utilizing Hidden Markov Models where the actions of a driver depend on the current latent plan, which depends on previous plans and anticipated future conditions. Choudhury (2007) applied this model for four traffic scenarios: freeway lane changing, freeway merging, urban intersection lane choice, and urban arterial lane changing. Choudhury (2007) then showed that latent plan models exhibit a significantly better goodness-of-fit compared to simpler models where latent plans are ignored. However, Choudhury (2007) also treated drivers' aggressiveness as a static continuous latent variable to capture heterogeneity among drivers (agent effect).

1.4. Aggressive driving behavior models

While these integrated models have been developed for general driving behavior, studies focusing on modeling aggressive driving behavior have not yet captured all of the factors affecting aggressive driving (which according to Shinar (1998) can be attributed to the driver and to the situation). In addition, these models did not account for the three interdependencies suggested by Toledo (2003) (causality, unobserved variables, and state dependency).

A few studies modeled aggressiveness or aggressive driving behavior as a function of contextual and situational factors. Hamdar et al. (2008) used structural equation modeling to develop an aggressiveness propensity index (API) for signalized intersections as a function of five situational factors (traffic performance dimension, intersection geometry dimension, signal timing, law enforcement dimension, and transit dimension). Similarly, Benavente et al. (2007) focused on the effect of general roadway characteristics (roadway type, number of lanes, median type, etc.) on aggressive driving related crashes in Massachusetts using logistic regression models.