Analytic Methods in Accident Research 13 (2017) 52–64

Contents lists available at ScienceDirect

Analytic Methods in Accident Research

journal homepage: www.elsevier.com/locate/amar

Grouped random parameters bivariate probit analysis of perceived and observed aggressive driving behavior: A driving simulation study

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ARTICLE INFO

Article history:
Received 25 February 2015
Received in revised form 7 December 2016
Accepted 7 December 2016
Available online 21 January 2017

Keywords:
Aggressive driving behavior
Perception
Safety
Driving simulation
Statistical modeling
Bivariate probit
Random effects
Grouped random parameters

ABSTRACT

This paper uses driving simulation data and surveys conducted in 2014 and 2015 in Buffalo, NY, to study the factors that affect perceived (self-reported, based on surveys) and observed (as measured, based on driving simulation experiments) aggressive driving behavior. Perceived and observed aggressive driving behavior are likely to share unobserved characteristics. To simultaneously account for this cross-equation error correlation, and for unobserved heterogeneity and panel data effects, a grouped random parameters bivariate probit model is estimated. The results control and account for a number of socio-demographic, driving experience and exposure, and behavioral and other characteristics. The findings reveal that different variables play in how aggressive driving behavior is perceived and observed, and the results imply that some drivers may perceive their driving behavior as non-aggressive when it is aggressive (or the opposite). The grouped random parameters bivariate probit model results are compared to their univariate probit, full information maximum likelihood bivariate probit, bivariate probit model with random effects, and random parameters bivariate probit model counterparts, and the results reveal the statistical superiority of the former, in terms of explanatory power, model fit, and forecasting accuracy.

1. Introduction

With active and passive safety features being affluent in modern vehicles, and with technological gadgets and social media flooding the way of life, driving behavior over the last decades has significantly been altered. The reality of driving safer vehicles in combination with attention distractions has contributed to increased aggressive driving behavior incidents, such as speeding, braking abruptly (instead of progressively), and following closely other vehicles at unsafe distances, to name a few. However, it remains unknown whether this aggressive driving behavior is performed consciously. In fact, it

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http://dx.doi.org/10.1016/j.amar.2016.12.001
2213-6657/Published by Elsevier Ltd.

is likely that some drivers may perceive that their driving behavior is non-aggressive; however, due to the feeling of safety from the presence of modern vehicle safety features, some drivers may have formed an unconscious and habitual aggressive driving behavior. Interestingly, in a recent study that investigated the effect of driver education and police enforcement on aggressive driving behavior (Tarko et al., 2011), the majority of cited aggressive drivers were unaware that they committed a traffic violation or that they drove aggressively. This is an illustrative example that some drivers may perceive their driving behavior as non-aggressive, when in fact they are driving aggressively. And it is likely that the factors that affect the perceived and observed aggressive driving behavior may as well differ.

On the other hand, it is likely that some drivers may have been exposed to intense driving incidents, which may have inevitably altered the way they perceive driving behavior. For example, drivers that suffered a severe motor-vehicle injury or a fatality of a close family or friend (or a similarly intense driving incident), may change the way they perceive their driving behavior from non-aggressive to aggressive.

From a methodological perspective, perceived and aggressive driving behavior do not necessarily have to be affected by the same factors. At the same time, there may exist systematic variations among the unobserved characteristics of perceived and observed driving behavior. To account for such cross-equation error correlation, perceived and observed aggressive driving behavior can be simultaneously modeled as a system of equations (Anwaar et al., 2011, 2012; Washington et al., 2011; Anastasopoulos et al., 2012c; Bhat et al., 2014; Tran et al., 2015; Zhan et al., 2015; Anastasopoulos and Mannering, 2016; Zeng et al., 2016; Hong et al., 2016; Anastasopoulos, 2016; Serhiyenko et al., 2016; Shaheed et al., 2016; Sarwar and Anastasopoulos, 2016, 2017). Moreover, this paper uses driving simulation data and surveys, consisting of 41 participants, who conducted 205 driving simulation experiments. This adds an additional methodological challenge, in terms of unbalanced panel effects inherent in the data.

Taking into account all methodological considerations, this paper estimates a grouped random parameters bivariate probit model of perceived and observed (based on surveys and driving simulation experiments, respectively) aggressive driving behavior. This approach accounts for the cross-equation error correlation among the dependent variables, for panel effects by the conduction of multiple experiments by the same participant, and for other unobserved factors that may vary systematically across the participants. The results reveal that different factors affect how drivers perceive their driving behavior and how they are observed to drive, and the findings imply that some drivers may perceive their aggressive driving behavior as non-aggressive (or they may perceive their non-aggressive driving behavior as aggressive). To evaluate the underlying benefits of the proposed approach, a number of counterpart models are estimated (i.e., univariate probit, full information maximum likelihood bivariate probit, bivariate probit model with random effects, and random parameters bivariate probit), and the grouped random parameters bivariate probit model is found to be statistically superior, in terms of explanatory power and model fit.

2. Empirical setting

Several efforts have been put forth to thoroughly investigate aggressive driving behavior. For example, several studies conducted field experiments that involved data collection using moving vehicles or fixed cameras (Kaysi and Abbany, 2007; Paleti et al., 2010; Tarko et al., 2011). At the same time, a number of efforts concentrated on identifying aggressive driving behavior patterns through the use of driving simulation and survey data (Al-Shihabi and Mourant, 2007; Harder et al., 2008; AAA, 2009; Philippe et al., 2009; Rong et al., 2011; Calvi et al., 2012; Joanisse et al., 2013; Ouimet et al., 2013). In these studies, aggressive driving was identified as one of the primary factors leading to an accident or a fatality. Factors that were identified to affect the level of aggressive driving behavior included demographic and socio-economic characteristics (e.g., gender, age, income, etc.), traffic characteristics (e.g., traffic volume and traffic composition), weather conditions (e.g., rain, wind, snow, etc.), and pavement conditions (e.g., friction). The recent Strategic Highway Research Program 2 (SHRP 2) naturalistic driving study initiative is also expected to possibly reveal new factors that play in aggressive driving.

To demonstrate the potential of the grouped random parameters bivariate probit modeling approach, and to study the factors that affect perceived and observed aggressive driving behavior, driving simulation experiments were conducted and survey data were collected in 2014 and 2015 from student and employee participants at University at Buffalo. The driving simulation experiments were conducted at the New York State Center for Engineering Design and Industrial Innovation (NYSCEDII) Motion Simulation Laboratory. The used equipment included a six degrees-of-freedom motion platform with vehicle buck and surround screens. The 4-miles route design was based on the city of Buffalo, NY. The route went through local, collector and arterial roads, and included a deer-crossing zone, a school zone, and a construction zone, all noted with proper signage. During the nearly 10-min route, the participants would go through five stop signs, six traffic signals, and four speed limit changes. To follow the predetermined route, flashing guidance arrows were projected on the simulator's monitor, resembling Global Positioning System (GPS) directions.

The traffic during the driving simulation was designed to resemble morning uncongested conditions. The traffic was composed of approximately 90 percent passenger cars, and 10 percent trucks. Local roads were one-lane per direction, and collectors and arterials were two-lanes per direction undivided roads. At the construction zone, there was no lane closure; however, traffic cones were used to separate the lanes, and trucks were simulated to randomly enter and exit the traffic stream from the construction zone area.