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A Hazard-Based Duration Model to Quantify the Impact of Work-Related Distraction on Taxi Drivers' Safety Performance: A Driving Simulator Study

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I. INTRODUCTION

Drawing inspiration from the previous studies, our research seeks to address several key gaps in the current literature. Firstly, taxi drivers have a notably high accident rate, which requires attention and thorough examination. Secondly, using different ride-hailing systems, we intend to investigate the work-related distraction effects. Thirdly, we intend to confirm the risk compensatory behavior exhibited by taxi drivers when exposed to different ride-hailing systems. Lastly, the interaction effects between taxi drivers' characteristics and distraction types (i.e., the observed heterogeneity) on their driving behavior, will be incorporated in our analysis. By addressing these gaps, we aim to provide valuable insights into enhancing road safety and understanding the implications of ride-hailing systems on taxi drivers' driving performance.

II. METHODS

1. experimental design

In this study, the simulator experiment encompassed a series of 6 driving trials for each participant, involving sudden brake events within two road environments (urban street with 50kph and motorway with 80kph) and three distraction scenarios. The sudden brake event was administered after each driver had followed the leading vehicle for a certain duration.

2. sample

A total of 51 male taxi drivers were recruited to participate in the driving simulator experiment. The characteristics of the participants were collected, including basic characteristic, safety perception and traffic violation record, and operational characteristic. During the experiments, each participant engaged in driving simulations encompassing 3 distraction scenarios and 2 road environments, resulting in a total sample size of 306 trials (51 participants × 6 experimental conditions). To assess the drivers' braking behavior, three performance indicators were extracted and defined as follows: (1) brake reaction time (BRT), refers to the time interval from the moment the leading vehicle initiating braking until the following vehicle applied the brakes; (2) time headway (THW), the collected THW represents the minimum distance between the following vehicle and the leading vehicle during the sudden brake event; (3) car-following distance (CFD), this indicator corresponds to the distance between the following vehicle's front bumper and the leading vehicle's rear bumper at the timestamp when the leading vehicle engaged its sudden brakes.

3. model specification

In this study, the hazard-based duration model is applied to model BRT and THW. The cumulative distribution function $F(t)$, is obtained (equation 1). In this study, the AFT model is preferred since it assumes that all explanatory covariates directly reduce or accelerate the duration time in a baseline survival function where all variables are zero. In AFT model, taking the logarithm of the survival time, T, gives the following equation 2 [1]. Additional assumption on the distribution of the duration variable is required. In this study, the Weibull distribution was selected since several study established that BRT and THW fit well with Weibull distribution (equation 3) [2-4].

$$F(t) = P(T < t) = \int_0^t f(t)dt \quad (1)$$

$$\ln(T) = \beta X + \varepsilon \quad (2)$$

$$h(t) = (\lambda P)(\lambda t)^{P-1} \quad (3)$$

Consider the simulator experiment setting, this study fitted the model with unobserved heterogeneity by introducing random effects or random parameters. For random effect, clustered heterogeneity and gamma heterogeneity were introduced. For random parameters, β_i represents the random parameters for driver i, where φ obeys the standard normal distribution [1].

$$\beta_i = \mu + \psi z_i + \Omega\varphi \quad (4)$$

III. RESULTS

1. Weibull duration model for BRT

BRT in both urban road and highway was analyzed using the Weibull duration model. The LR test revealed that both road types performed better with a grouped random parameters model. Then, the AIC is also minimized in the group random duration model. Thus, the Weibull AFT model with grouped random parameters is selected to model BRT. The model estimates for BRT on urban streets and motorways indicates that, both scale parameters are significantly different from 1.0, indicating a monotonic increase in the hazard function with the duration variable. Additional insight into parameter estimates was provided by computing the exponential for each coefficient $(\exp(\beta))$. The BRT is significant and positively influenced by the radio system. More specifically, compared to no distraction drivers, drivers distracted by radio system show a longer BRT, with 11% and 15% (urban street and motorway). Due to page limit, other characteristics were not analyzed in detailed here.

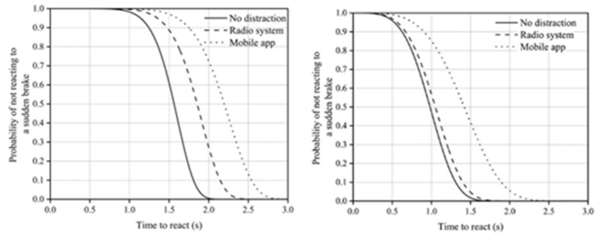
2. Weibull duration model for THW

Similarly, the Weibull duration model with grouped random parameters is also more suitable to fit the THW. The model estimates of THW on urban street and motorway indicated that the scale parameters are found to be significantly different from 1.0, indicating a positive relation between duration independence and the hazard function. The exponent values ($\exp(\beta)$) for each coefficient are calculated. The indicator for radio system is positively associated with THW, indicating that drivers with radio system distraction have a 7% and 3% (urban and motorway) lower THW than that of no distracted drivers. Intuitively, drivers try to avoid the hazards of radio distraction by employing risk-compensatory strategies.

IV. DISCUSSION

1. Effects of distractions on BRT

In general, the model results on BRT indicated that radio system and mobile app distract and increase drivers' BRT. It is in line with earlier findings that either acoustic or visual distracting elements have an impact on drivers' driving performance [5]. Additionally, see Figure 1, the probability of failing to react to the sudden brake event decreases with the time ending soon. Notably, the BRT of drivers with mobile app distraction is higher than drivers with radio system distraction, which suggests that visually-manual interactions provide deeper distracting effects on attention than auditory system, which is in line with previous research [5, 6]. It can be summarized that visual distraction entail shifting the eyes and attentive from the road to the mobile or other task, and hence impair drivers' ability to react to the hazard as well as the driving performance to a greater extent [3,4].

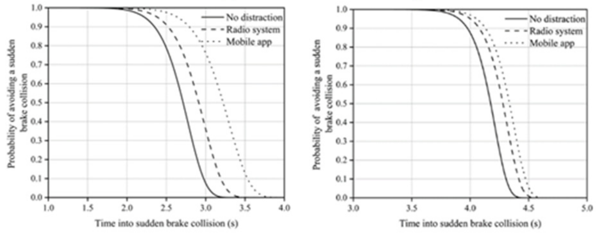


(a)Urban street (b) Motorway

Figure 1. Distractions difference in BRT under different driving condition

2. Effects of distractions on THW

The model results for THW revealed that the distractions of radio system and mobile app increase drivers' THW when they drove in the urban or motorway. This agrees with previous research that drivers would minimize the risk collision by adopting risk compensatory strategies, proactively lowering speed and enlarging the following distance [7]. Furthermore, the predicted probability of avoiding a sudden brake collision is shown in figure 2, suggesting a decreasing probability of avoiding a rear-end accidents with the elapsed time. Notably, the probability that a driver avoids a follow-up collision is consistently higher in the distracted driving condition than in the undistracted condition. A plausible reason for drivers' higher safety margin in distraction condition might be that taxi drivers typically adopt strategies to compensate for the risk of collision [7]. More specifically, it is clearly that drivers in the mobile app distraction have longer time for avoiding a rear-end collision than drivers distracted with radio system, indicating a safer distance in visual stimuli in comparison to auditory distraction.



(a) Urban street (b) Motorway

Figure 2. Distraction difference in THW under different driving conditions

V. CONCLUSION

This study evaluated the effect of various ride-hailing systems on the driving performance of taxi drivers during unexpected braking when following a car. The results suggest that taxi drivers distracted by radio system or mobile app show longer BRT. In spite of this, they would maintain a higher safety margin to mitigate the rear-end collisions. The findings of this study are expected to provide implications for improving road safety. (1) voice-based or hands-free interactions should be encouraged. (2) the importance of providing comprehensive safety training to taxi drivers cannot be overstated. (3) regulations should be formulated to address the frequent distractions caused by ride-hailing systems. In conclusion, it is imperative to take measures to mitigate distractions so that drivers and passengers can enjoy a safer driving environment.

VI. REFERENCES

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