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Exploring the impact of signal types and adjacent vehicles on drivers' choices after the onset of yellow

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HIGHLIGHTS

- Three signalized intersections after onset of yellow indication were observed.
- Intersections without monitoring devices widened the indecision zone.
- The presence of an adjacent vehicle affects drivers' choices after onset of yellow.
- A binary logistic regression was performed to investigate the influencing factors.

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ABSTRACT

Drivers' choices at signalized intersections may be made in great uncertainty after the onset of yellow, which creates potential hazards for road safety. These choices are analyzed and modeled based on field observations at three comparable signalized intersections in Changsha, China. The results show that intersections without monitoring devices widen the indecision zone, which can increase the risk of rear-end collisions and the uncertainty of drivers' decision-making. In addition, drivers are more likely to stop during the yellow interval at intersections equipped with a green signal countdown device (GSCD) than at those with a green signal flashing device (GSFD). Subsequently, according to the results of a binary logistic regression model (BLRM), drivers' decision making at the onset of the yellow indication is greatly influenced by the vehicle's spot speed, the distance to the stop line, and signal and monitoring devices. The presence of an adjacent vehicle with a short space headway can particularly motivate the following driver to make a go-decision after the first driver chooses to pass the intersection. However, a stop-decision by a driver in an adjacent lane can also prompt the following driver to stop.

1. Introduction

1.1. Background

Signalized intersections that are important junctions for urban road networks consist of complex components (the signal device, the stop line, the traffic light cycle, etc.) and are deemed the most frequent sites of traffic accidents. Half of these accidents involve either rear-end or right-angle collisions caused by the uncertainty and complexity of drivers' decision-making behavior in the dilemma zone [1]. The yellow signal reminds drivers that their green movement is being terminated and that a red signal will be exhibited immediately afterward. Accordingly, upon the onset of a yellow indication, a driver

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Notations

DTS	distance to the stop line at the onset of yellow;
ETTS	estimated time to the stop line at the onset of yellow;
FV	front vehicle;
FVA	front vehicle in the adjacent lane;
GSCD	green signal countdown device;
GSFD	green signal flashing device;
WO/FV	without front vehicle;
WO/FVA	without front vehicle in the adjacent lane;
FVAP	front vehicle in the adjacent lane proceeds; and
FVAS	front vehicle in the adjacent lane stops.

has two choices: either to stop before the stop line or to continue at the current speed or accelerate to the speed limit to cross the intersection before the red indication is triggered. Those choices may seem straightforward, but various problems are associated with drivers' decisions, including those related to the dilemma zone and the possibility of a red-light running (RLR) violation, which can affect the safety of signalized intersections. A stop-decision by the leading driver, combined with the following driver's decision to go, may result in a rear-end collision unless the following driver recognizes a collision as imminent and adjusts his/her behavior after the onset of yellow [2–4]. In summary, factors that have a great influence on drivers' behavior during the yellow interval include the signal light timing, the type of signalized device, the remaining time after the onset of the yellow signal, the adjacent vehicle, the spot speed and distance from the stop line at the onset of the yellow signal, and the driver's mentality.

1.2. Literature review

1.2.1. Car-following behavior

Drivers' behavior is related not only to the signal indication but also to the adjacent vehicles, especially for vehicles that maintain a close following state. Previous research has indicated that rear cars' speed and acceleration/deceleration vary with the state of front vehicles (FVs) when approaching a signalized intersection at the end of the green signal phase [5], which can influence the decision-making of the drivers of the following cars. Jiang and Lu studied car-following behavior in Shanghai, China, and revealed that the following cars' speed depended on the FVs' speed mainly when their space headway was less than 10 m, and the critical value of the car-following state for inexperienced drivers was 55 m [6].

In psychology, human mentality is affected by the group as follows: conformity is the act of matching attitudes, beliefs, and behaviors to group norms; social facilitation is the tendency for people to perform differently when in the presence of others than when alone; and deindividuation is a concept in social psychology that is generally thought of as the loss of self-awareness in groups that makes members become more dependent on groups [7]. All these studies revealed that groups can persuade people to follow a majority when most people perform the same actions. In addition, Gates' study indicated that vehicles had a higher probability of proceeding in the presence of a leading vehicle that run through an intersection after the onset of yellow [8]. However, Liu et al. found no statistical significance between platoons and drivers' behavior (aggressive pass, normal stop, and conservative stop) according to an ordered probit model based on an empirical study of six Maryland intersections [9]. Furthermore, some traffic-flow and car-following models were built to analyze commuters' trip cost [10–13].

1.2.2. Yellow dilemma zone

According to previous research, drivers' decision-making is related mainly to the vehicular spot speed and distance to the stop line at the onset of yellow [14]. However, drivers cannot easily make a good decision when approaching intersections because of poor intersection design and their hesitation. This problem, building on previously established terminology [8,15], is usually categorized in two general classes of dilemma zone conflict (Types I and II).

Gazis et al. defined the Type I dilemma zone as a region in which drivers can neither stop safely nor cross the intersections before the red signal is triggered [16]. In their study, a minimum safe stopping distance (SSD) is the critical distance to stop safely before the stop line. If a go-decision is made, the critical crossing distance (CCD) is the distance necessary to pass through before the signal turns red. If the driver is outside the CCD and within the SSD, he or she is caught in a dilemma zone, as shown in Fig. 1(a). In this situation, a rear-end collision may easily occur if the driver chooses to stop, and if the driver makes a go-decision, he or she will likely encounter an RLR violation or even a right-angle collision.

The Type II dilemma zone was first identified in a transport committee report produced by the Institute of Transportation Engineers [17]. The Type II dilemma zone is also termed the "indecision zone" in Gates' research because its boundary is dynamic and related to probability [8]. Sheffi and Mahmassani considered that the Type II dilemma zone was associated with the probability of stopping at different distances from the stop line at the onset of the yellow indication [18]. However,