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Investigate moped-car conflicts in China using a naturalistic driving study approach

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ABSTRACT

Problem: Mopeds are a popular transportation mode in Europe and Asia. Moped-related traffic accidents account for a large proportion of crash fatalities. To develop moped-related crash countermeasures, it is important to understand the characteristics of moped-related conflicts. *Method:* Naturalistic driving study data were collected in Shanghai, China from 36 car drivers. The data included 2,878 h and 78,296 km driven from 13,149 trips. Moped-car conflicts were identified and examined from the passenger car driver's perspective using kinematic trigger algorithms and manual video reduction. *Results:* A total of 119 moped-car conflicts were identified, including 74 high g-force conflicts and 45 low g-force events. These conflicts were classified into 22 on-road configurations where both similarities and differences were found as compared to Western Countries. The majority of the conflicts occurred on secondary main roads and branch roads. Hard braking was the primary response that the car drivers made to these conflicts rather than hard steering. *Discussion:* The identified on-road vehicle-moped conflict configurations in Shanghai, China may be attributed to the complicated traffic environment and risky behavior of moped riders. The lower prevalence of hard steering in Shanghai as compared to the United States may be due to the lower speeds at event onsets or less available steering space, e.g., less available shoulder area on Chinese urban roads. *Summary:* The characteristics of moped-car conflicts impact the design of active safety countermeasures on passenger cars. The pilot data from Shanghai urban areas suggest that countermeasures developed for China may require some modifications to those developed for the United States and European countries, although this recommendation may not be conclusive given the small sample size of the study. Future studies with large samples may help better understand the characteristics of moped-car conflicts.

1. Problem

Mopeds, including electric bikes, scooters, and internal combustion engine bikes, are a popular mode of transportation in Europe, Japan, and Taiwan, as well as in developing regions such as India, China, and Indonesia. It was estimated that there were more than 3 million mopeds in Shanghai, China in 2011, compared to only 2.7 million automobiles (More than Half Fatalities in Shanghai, 2011). More importantly, moped-related traffic accidents account for a large proportion of crash fatalities. Powered Two Wheeler (PTW, including motorcycles, scooters and mopeds) fatalities accounted for about 14% of all traffic fatalities in the United States in 2008 (Baer, Ayotte, & Baldi, 2010). Similarly, 7030 PTW fatalities occurred in European countries in 2005, accounting for 15% of all road traffic fatalities (PTW fatalities in Europe, 2015). In China, the risk associated with moped is even higher. It was reported that 47% of all crashes and 42% of all crash fatalities in Shanghai, China during 2010–2011 were related to mopeds (More than Half Fatalities in Shanghai, 2011). To develop countermeasures to reduce moped-related crashes, it is important to understand characteristics of moped-related conflicts. This study focused on three aspects regarding moped-car conflicts in urban areas of Shanghai, China: (a) to develop a conflict identification method for naturalistic driving study data; (b) to characterize traffic situations and environmental factors associated with the conflicts; (c) to characterize driver responses to the conflicts.

2. Method

Naturalistic driving study data were collected in Shanghai, China from 36 passenger car drivers (28 males, 8 females) as a part of a

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large-scale Shanghai Naturalistic Driving Study (NDS). It is important to note that as these data were recorded from the passenger cars, the moped-car conflicts were examined from the car driver's perspective. The participants were recruited in Shanghai, China via social media. All participants must have at least 1-year driving experience (averaged 6.6 years, ranged from 1 to 16 years) and have no traffic accident or violation in the most recent year. The participants' ages ranged from 25- to 60-year old and averaged 37-year-old. Each participant drove a provided vehicle for 2 months. The analysis included a total of 2878 h and 78,296 km driven from 13,149 trips. The five vehicles provided to the participants were General Motors (GM) production vehicles: one 2011 Cadillac DTS, two 2012 Chevrolet Cruzes, and two 2012 Buick LaCrosses. The vehicles were equipped with the NextGen Data Acquisition System (DAS) developed by the Virginia Tech Transportation Institute. The DAS collected continuous time-series driving data through high-resolution kinematic sensors, four video cameras, one forward radar, and the vehicle network.

The moped–car conflicts were identified via a two-step process. In the first step, kinematic triggers were used to scan through the entire kinematic time-series data to identify kinematic events characterized by a high lateral or longitudinal g-force, a high yaw rate, or a high steering wheel turning rate. This study adopted six kinematic trigger algorithms used by the Second Strategic Highway Research Program (SHRP 2) NDS (Dingus, et al. 2015; Guo, et al. 2016). The thresholds for kinematic triggers applied in this study are listed in Table 1. In addition, a filter utilizing vehicle speeds, deceleration g-forces, and vehicle idle durations was used to screen out the hard stop cases at traffic intersections. In the second step, manual video reduction was performed to examine if these kinematic events were truly moped-car conflicts. Information extracted via the reduction are shown in Table 2. These reduced data were used to characterize environmental factors associated with identified moped-car conflicts, such as scenario characteristics (e.g., intersection, straight road, T-junction) and road type (e.g., expressway, residential path). Due to a temporary DAS equipment error on the default longitudinal g-force level (affecting 8 trips of 1 driver's), some low g-force deceleration (0–0.25 g) events were also captured by the longitudinal deceleration trigger. We considered them "low g-force events," as compared to high g-force events identified by normal trigger thresholds.

3. Results

A total of 119 moped-car conflicts were identified in this study, including 74 high g-force events (0.4 g+) and 45 low g-force events. The high g-force conflict rate is 2.57 cases per 100 h driven and 0.95 cases per 1000 km driven. The conflict rate with 0.65 g + longitudinal deceleration is 0.064 cases per 1000 km driven. This rate is higher than the conflict rate of 0.053 per 1000 km driven observed in SHRP 2 in the United States including all target types and crash types (Hankey, Perez, & McClafferty, 2016), suggesting that moped-car conflicts occur more frequently in China than in the United States.

The on-road configurations of moped-car conflicts are shown in Table 3. There were 22 different configurations, for example, the moped suddenly swerved into the car's intended path from an adjacent lane (#4); the moped cut into the car's intended path perpendicularly from the left at an intersection (#10); the moped cut into the intended path of an oncoming car that was turning left at an intersection (#8); the crossing moped cut into the car's intended path on a straight road (#3). Table 3 also provides the relative frequency of each conflict scenario and the corresponding confidence interval.

Table 1
Kinematic Triggers and Thresholds.

Kinematic trigger	Threshold
Longitudinal deceleration	0.4 g, 0.5 g, 0.65 g
Lateral acceleration	(refer to SHRP 2)
Longitudinal jerk	(refer to SHRP 2)
Steering evasive maneuver	(refer to SHRP 2)
Swerve evasive maneuver	(refer to SHRP 2)
Yaw rate	(refer to SHRP 2)

Table 2
Information extracted in data and video reduction.

Reduction method	Variable	Description
Auto	Event ID	Kinematic event ID
Auto	File ID	Trip ID
Auto	Event start time	Kinematic event start time using kinematic trigger
Auto	Event end time	Kinematic event end time using kinematic trigger
Auto	Trip start time	Trip start time, using power supply data
Auto	Trip end time	Trip end time, using power-supply data
Auto	Trip duration	Trip duration, using power-supply data
Auto	Event type	Kinematic trigger type
Auto	Trigger threshold	Threshold used for kinematic trigger
Auto	Speed filter	Threshold of speed filter
Auto	Before speed	In a 5-s window before the identified segment started
Auto	After speed	In a 10-s window after the identified segment ended
Manual	Moped related	0 = not related; 1 = related
Manual	Traffic light	1 = intersection/T-joint/access has traffic light control; 0 = no traffic light
Manual	Degree of conflict	0 = no moped involvement (not moped conflict) 1 = little involvement (not moped conflict) 2 = complex conflict 3 = severe conflict
Manual	Conflict configuration category	on-road configuration category, ranges from 1 to 22
Manual	Radar detection	0 = radar cannot detect conflict 1 = radar can detect conflict (clear signal evidence) 99 = radar data not available
Manual	Conflict notes	Researcher notes for video reduction for conflicts
Manual	Radar notes	Researcher notes for radar data reduction
Manual	Road category	1 = expressway; 2 = main road (4 lanes); 3 = secondary main road (2 or 3 lanes); 4 = branch way (no road line); 5 = residential path
Manual	Barrier	1 = barrier between non-motorized/motorized lanes 0 = no barrier
Manual	Weather	1 = normal; 2 = rain; 3 = fog; 4 = snow
Manual	Lighting condition	1 = bright (day) 2 = not as bright as 1 (rainy day, dawn/evening) 3 = dark (night, tunnel, etc., need headlight on)
Manual	Road environment	1 = straight road; 2 = intersection; 3 = curved road; 4 = parking lot; 5 = commercial/residential exits

The exposure of environmental factors of these moped-car conflicts is shown in Table 4. Conflicts with 0.5 g+ longitudinal decelerations have the similar prevalence at intersections to that on straight roads, while conflicts with moderate longitudinal decelerations (0.4–0.5 g) occurred at intersections more frequently than on straight roads. In contrast, the low g-force conflicts (0–0.25 g longitudinal decelerations) occurred more often on straight roads than at intersections. In addition, the majority of the conflicts occurred on secondary main roads (with speed limits between 30 and 50 km/h) and branch roads (with speed limits between 20 and 40 km/h). Moreover, conflicts with moderate (0.4–0.5 g) and low (0–0.25 g) longitudinal decelerations occurred more frequently on a road with no barrier between motorized and non-motorized lanes. Among the 119 identified moped-car conflicts, only two high g-force conflicts involved evasive steering response. The remaining 117 conflicts only involved evasive braking without hard steering.

4. Discussion

The characteristics of the Shanghai moped-car conflicts are somewhat consistent with those reported by European PTW studies. For

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