Cyclist Behavior to Avoid Vehicle Collisions Using Drive Recorder Videos

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1 INTRODUCTION

Since bicycles travel at high speeds and are frequently involved in traffic accidents, reducing bicycle fatalities and injuries is one of the most important issues in traffic safety. In car-to-cyclist collisions, the perpendicular configuration occupies the largest proportion of these collisions. Driver responses in lateral intrusions of cyclists at intersections have been examined [1,2], focusing on the drivers' braking reaction time and the time-to-collisions (TTC). Cyclist behavior can also have a significant influence on car-to-cyclist collision occurrence. Cyclist behavior has been investigated in naturalistic conditions and using in-depth accident data. In addition, the videos of drive recorders provide useful information on the cyclist behaviors [3]. This study investigated cyclist behavior with the drive recorder of cars in near-miss incidents and collisions.

2 METHOD

To examine the cyclist avoidance behavior in emergency situations, car-to-cyclist perpendicular incidents were extracted from the near-miss database. The avoidance maneuvers of drivers and cyclists were classified into three types according to who initiated the avoidance behaviors: (1) Near-misses avoided by cyclists, (2) Near-misses avoided by car drivers, (3) Near-misses avoided by both cyclists and car drivers.

228 car-to-cyclist perpendicular conflicts of drive recorder were used in this research: 165 near-miss data were from Tokyo University of Agriculture and Technology; 63 collision data were collected by this research project from the Aichi taxi association and Nagoya taxi association.

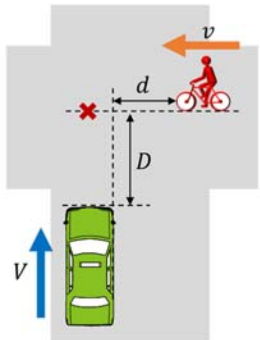


Figure 1: Parameters examined in car-to-cyclist perpendicular conflicts

In this study, the relationship between the cyclist behavior, the velocity and the distance of both the cyclists and car was examined. The car velocity was determined based on the output of the drive recorder with time. The velocity of the cyclists and the distance between the cars and the cyclists were measured based on video images. The car and cyclist traveling velocity and the distance to the collision point (path crossing point) are defined as V, v, D and d, respectively (Figure 1). The car and cyclist velocity as well as the car and cyclist distance to the trajectory cross point at the time when the cyclist can be visible from the driver (t_a) are denoted as V_a, v_a, D_a and d_a, respectively. Logistic analysis was applied to the probability of avoidance behavior of cyclist (w/ avoidance behavior 1; w/o 0) using the above parameters.

3 RESULTS

3.1 Cyclist avoidance behavior and its effectiveness

The number of near-miss incidents and collisions classified by cyclist and driver avoidance behavior is presented in Table 1. There are 85 cases of cyclist avoidance behavior: among them 31 cases are avoided by both cyclist and driver avoidance behavior, and 54 cases are which only the cyclist took an avoidance behavior (near-miss is successfully avoided by the cyclist's avoidance behavior instead of the car driver's avoidance behavior). On the other hand, the cyclist does not take avoidance behavior in 143 cases: among them the driver's avoidance behavior is observed in 80 cases, while the driver's avoidance behavior is not observed in 63 cases (collisions).

Figure. 2 shows the relationship of TTC_b and the car velocity V_b at the time of the car's brake onset t_b in the near-miss incidents with and without cyclist avoidance behavior. When the required acceleration of the car ($V_b/2\,TTC_b$) is higher than the braking performance limit (a = 5.2 m/s² [3]), the car cannot stop before reaching the collision point. The cases where cyclists do not take avoidance behavior are distributed in the right area of the car's braking performance limit ($V_b/2\,TTC_b < 5.2\ \mathrm{m/s^2}$), and car drivers can avoid the collision by car braking. Of the 85 near-miss incidents with cyclist avoidance behavior, 14 cases are where the cyclists are beyond the car's braking limit. These 14 cases would have resulted in a collision if the cyclist had not taken an avoidance behavior, indicating that cyclist avoidance behavior is effective in avoiding collisions.

Table 1: Number of cases with and without cyclist and driver avoidance behavior.

		Car driver		
		w/ avoidance behavior	w/o avoidance behavior	Total
Cyclist	w/ avoidance behavior	31	54	85
	w/o avoidance behavior	80	63 (collision)	143
	Total	111	117	228

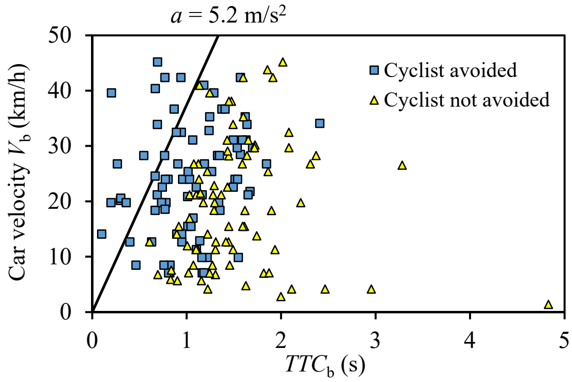
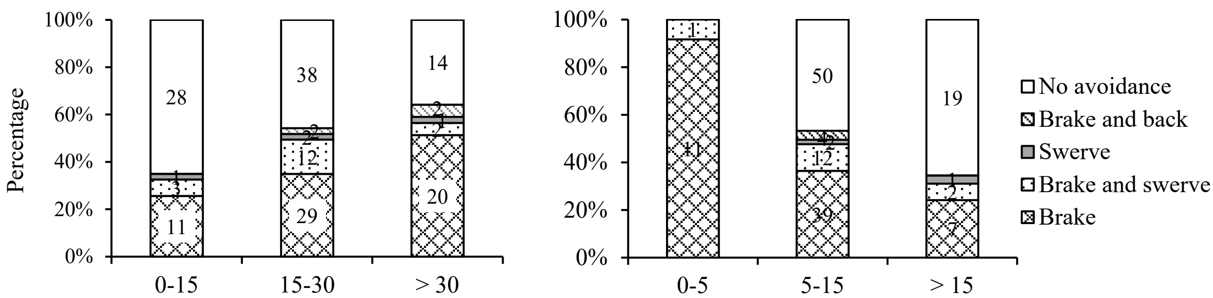


Figure 2: Relationship between TTC_b and the car velocity V_b at the time of brake onset t_b with/without cyclist avoidance behavior in near-miss incidents (the line shows the braking limit). Note: collisions are not included.

The percentage of the cyclist behavior with different car velocities V_a is shown in Figure 3(a). The percentage of avoidance behavior of cyclists increases as the car velocity increases. Among the types of cyclist avoidance behavior, the primary behavior is bicycle braking. Some cyclists use swerving or apply both braking and swerving to avoid collisions. In addition, 4 cyclists apply braking and reverse the bicycle to avoid accidents.

Figure 3(b) shows the percentage of the cyclist behavior with cyclist velocity v_a. The trend of cyclist behavior with the cyclist velocity is opposite to that with the car velocity. The percentage of the avoidance behavior of cyclists decreases as the cyclist velocity increases. Hence, cyclists tend to take avoidance behavior when the car velocity V_a is high and cyclist velocity v_a is low.



(a) Vehicle velocity V_a (km/h)

(b) Cyclist velocity v_a (km/h)

Figure 3: Cyclist avoidance behavior with car velocity V_a and cyclist velocity v_a when the cyclist is visible to drivers (t_a).

3.2 Cyclist velocity

The distribution of cyclist velocity at t_a in the cyclist avoided near-misses, cyclist not avoided near-misses, and collisions is shown in Fig. 4. The mean velocity in the cyclist avoided near-miss, cyclist not avoided near-miss and collision group is 9.9 km/h, 12.9 km/h and 13.5 km/h, respectively. The p-value of the mean velocity of the cyclist's avoided near-miss is significantly lower than that of the cyclist's not avoided near-miss and the collision (both $p < 0.001$). The cumulative distribution of cyclist velocity shows that the distribution of cyclist velocity in cyclist's avoided near-misses is smaller than the other two groups.

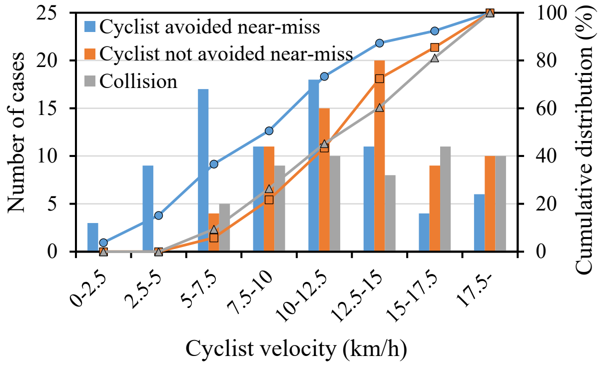


Figure 4: Cyclist velocity at the time when the cyclist is visible from the driver

3.3 Parameter determining initiation of avoidance behavior

The probability of a cyclist's initiating an avoidance behavior was expressed with explanatory variables in the logistic regression analysis. Car velocity V_a, car distance D_a, and cyclist velocity v_a at the time when the cyclist is visible were the primary parameters for determining a cyclist's initiation of avoidance behavior in near-miss incidents based on the p-value ($p < 0.001$).

$$P = \frac{1}{1 + \exp\left(-1.405 - 0.157\, V_a + 0.2476\, D_a + 0.1668\, v_a\right)} \tag{1}$$

In Eq. (1), the probability of cyclist's avoidance increases as the car velocity is higher and the distance between the cyclist and the collision point is smaller. Hence, a logistic regression was conducted using TTC_a instead of V_a and D_a. The probability of avoidance by cyclists using TTC can be expressed using two parameters as:

$$P = \frac{1}{1 + \exp\left(-2.5846 + 0.3048\, TTC_a + 0.1566\, v_a\right)} \tag{2}$$

The p-value of TTC_a is 0.0212, and v_a is <0.001, respectively. The prediction accuracy of the regression is 73.0% and 69.6% in Eq. (1) and (2). Basically, cyclists take avoidance behavior in emergency situation (small TTC) and when the cyclist velocity is low.

4 DISUCSSION

New findings are observed from drive recorder analysis for cyclist avoidance behavior in car-cyclist perpendicular conflicts. It is shown that cyclists took avoidance behavior based on the car's approaching velocity and distance. This is because cyclists judged whether to cross the street by recognizing the hazards based on TTC. Besides, cyclists also do not tend to take avoidance behavior if the cyclist's traveling velocity was high. This is probably because they are confident in crossing the street before the car arrives at the path crossing point.

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