14th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications

Simulator-Based Study of the Response Time and Defensive Behavior of Drivers in Unexpected Dangers at an Intersection

Myeongkyu Lee[1)] Sehan Kim[1)], Daehyun Jung[1)], Hyojun Lee[1)], Jihun Choi[2)], Hyunseo Han[2)] and Ji Hyun Yang[1)]

Kookmin University, Seoul, Republic of Korea[1)]

National Forensic Service, Wonju, Republic of Korea[2)]

Humans & Vehicle Automation Laboratory

Laboratory website QR Code

INTRODUCTION

A. Background

Large numbers of traffic accidents are reported every day worldwide. In particular, intersection traffic accidents accounted for approximately 40% of all crashes in 2008 in the U.S. [1], which is a nonnegligible proportion.

B. Objective

This study intends to build a database on drivers' perception response time (PRT) under dangerous circumstances at intersections.

METHOD

A. Purpose and Hypotheses

The purpose of this study is to assess drivers' PRT and prevent potential accidents in the simulated dangerous situation by analyzing the acquired data. The following hypotheses were proposed and tested.

- $H_{perception/reaction}$: There exist differences in drivers' mean PRT/vehicle data according to demographic characteristics (age/gender).
- $H_{accident}$: There exist differences in mean PRT/vehicle data depending on accident occurrence.

B. Independent Variables and Dependent Variables

The independent variables were demographic characteristics and accident occurrence. Age and gender were selected as the participants' demographic characteristics. (Table 1) (Mean = 43.91 years, SD = 13.99 years). The subjects were classified into different age groups, namely, 20s, 30s, 40s, 50s, and 60s. The subjects were divided into male and female drivers by gender. (Table 1)

Table 1. Number of participants by demographic characteristics

	20s	30s	40s	50s	60s	Total
Male	15	15	22	15	16	83
Female	16	15	10	17	14	72
Total	31	30	32	32	30	155

The dependent variables were acquired when drivers avoided dangerous situations.

1) Perception time (PT): The time between the appearance of a danger and the time point of the driver's last eye fixation toward the dangerous event [1-3].

2) Accelerator Release Time (ART): The time between the occurrence of the dangerous event and the initiation of releasing the accelerator pedal [4–6].

3) Brake Reaction Time (BRT): The time between the occurrence of the dangerous event and the initiation of braking [4, 7].

4) Steering reaction time (SRT): The time between the appearance of a threat and the initiation of steering input. (Condition: a steering angle > 10°, and the angular speed of steering wheel rotation > 15 °/s) [5].

5) Steering-wheel Angle (SA): The difference between the angle rotated from the moment at which the danger occurs and the maximum rotation angle over a 2.5-s time window [2, 9]. (°).

6) Steering-wheel Speed (SS): The difference between the steering speed from the moment at which the danger occurs and the maximum steering speed rotated over a 2.5-s time window (°/s). [2, 9]

7) Accident occurrence: Whether the participants were involved in an accident [10].

C. Experimental Design

1) Scenario: When the drivers pass through the intersection with speeds of 60kph and 80 kph, an oncoming vehicle approaches the intersection from the right crossing against the red light with a TTC of 2.5 s. (Figure 1). (IRB Approval Numbers. 1st year: KMU-201914-HR-205, 2nd year: KMU-202005-HR-234).

2) Equipment: A driving simulator and eye trackers owned by Kookmin University's Humans Vehicle Automation Laboratory were used in the experiment. (Figure 1)

Figure 1. Scenario (left) and driving simulator for data acquisition (right)

RESULTS

A. Descriptive Statistics

The results of descriptive statistics by age and gender are in Table 2. Avoidance-related data results are as follows. In the experiment, there were 60 accident cases and 239 no-accident cases.

Table 2. Descriptive statistics by independent variables (Data: Mean (SD))

	PT	ART	BRT	SRT	SA	SS
All	0.560 (0.141)	0.674 (0.156)	0.917 (0.217)	1.485 (0.473)	-59.650 (94.378)	-75.336 (128.127)
20s	0.535 (0.140)	0.657 (0.148)	0.961 (0.186)	1.534 (0.476)	-80.583 (107.896)	-113.59 (118.822)
30s	0.547 (0.181)	0.686 (0.109)	0.923 (0.281)	1.549 (0.234)	-84.559 (95.023)	-95.178 (107.905)
40s	0.537 (0.131)	0.709 (0.189)	0.830 (0.182)	1.521 (0.534)	-73.321 (114.787)	-99.694 (178.119)
50s	0.589 (0.123)	0.679 (0.116)	0.932 (0.188)	1.214 (0.385)	-25.355 (66.804)	-16.361 (95.757)
60s	0.595 (0.113)	0.649 (0.198)	0.934 (0.219)	1.678 (0.496)	-37.651 (61.239)	-46.427 (77.167)
male	0.563 (0.149)	0.671 (0.163)	0.909 (0.199)	1.455 (0.443)	-75.602 (102.392)	-98.376(137.808)
female	0.557 (0.132)	0.676 (0.150)	0.925 (0.236)	1.560 (0.543)	-17.871 (50.622)	-14.993 (70.733)

RESULTS (continued)

B. Inferential Statistics

Two-way analysis of variance (ANOVA) and independent sample t-test were used. ($\alpha = 0.05$)

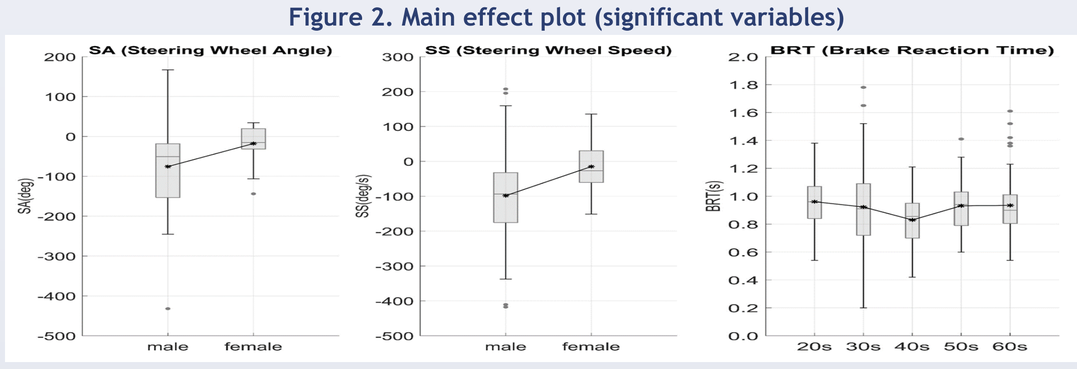
1) Gender: Significant differences were found between males and females in SA, and SS. ($F(1, 66) = 7.682$, $p = 0.007$; $F(1, 66) = 8.332$, $p = 0.005$). There is no significant difference in PT, ART, BRT, and SRT. ($F(1, 230) = 0.017$, $p = 0.898$; $F(1, 129) = 0.0002$, $p = 0.990$; $F(1, 289) = 0.031$, $p = 0.860$; $F(1, 66) = 0.105$, $p = 0.747$).

→ Female drivers turned the steering wheel by smaller rotation angles and at slower rates than male drivers to avoid dangerous situations. Thus, men were found to respond more aggressively to avoid dangerous events. (Figure 2)

2) Age: A significant difference was found in terms of BRT. ($F(4, 289) = 2.772$, $p = 0.028$).

→ A Bonferroni test was performed to test dependent variables with significant differences. (modified alpha = $0.005(0.05/{}_5C_2)$). BRT was significantly faster among the participants in their 40s (0.83s) than among the participants in their 20s (0.96 s). ($p = 0.001$) (Figure 2).

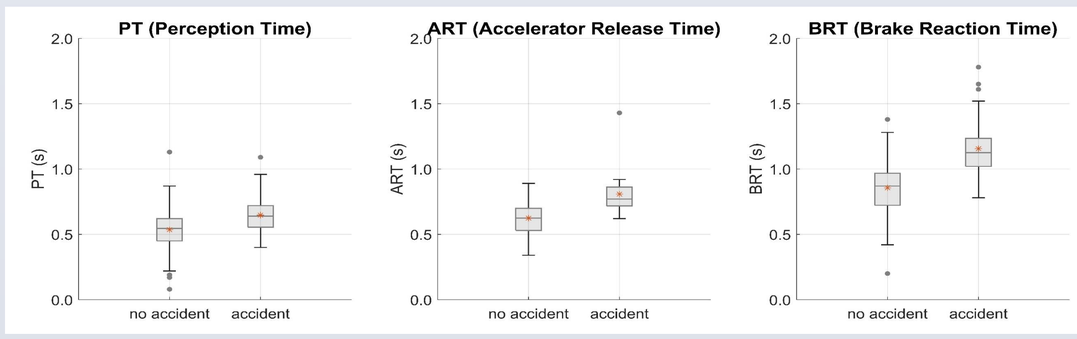
Figure 2. Main effect plot (significant variables)



3) Accident occurrence: Significant differences were found in drivers' PT ($df = 238$, $t = -5.319$, $p < 0.001$), ART ($df = 137$, $t = -7.19$, $p = 0.026$), and BRT ($df = 297$, $t = -11.433$, $p < 0.001$). The average PT, ART, and BRT in the accident cases was significantly longer than the value in the no-accident cases. (Figure 3)

→ If the time to perceive and respond to a dangerous event takes longer and the pressure applied to the brake pedal is inadequate, the probability of collision occurrence increases for the same TTC.

Figure 3. Plot of significant differences in variables by accident occurrence



CONCLUSION

A. Research Summary

We simulated possible dangerous situations that could occur at intersections by using a simulator. The data collected from 155 participants were used in the analysis. In terms of demographic characteristics, the participants were recruited as evenly as possible in terms of their age and gender. Consequently, we were able to obtain drivers' PRT, including PT, ART, BRT, and SRT; vehicle data, including SA and SS; and accident occurrence.

B. Expected Effects

1) The data gathered from 155 drivers involved in a dangerous event will allow us to predict the typical characteristics of drivers and vehicle data.

2) The percentile of new drivers can be determined. Drivers belonging to the lower percentile ranks are likely to drive in a careless and negligent manner, not focus on driving tasks, or have slower reaction times.

3) The study findings are expected to contribute toward road safety improvement by providing a reference base for designing roads, including drivers' mean reaction/perception times.

REFERENCES

[1] ISO 15007-1 (2014). Road vehicles—Measurement of driver visual behaviour with respect to transport information and control systems-Part 1: Definitions and parameters.

[2] Lee, M., Kim, S., Kim, J, & Yang, J. H. (2022). Simulator study on the response time and defensive behavior of drivers in a cut-in situation. International Journal of Automotive Technology, 23(3), 817-827.

[3] Recarte, M. A., & Nunes, L. M. (2003). Mental workload while driving: Effects on visual search, discrimination, and decision making. Journal of Experimental Psychology: Applied, 9(2), 119. https://doi.org/10.1037/1076-898X.9.2.119.

[4] Society of Automotive Engineers (2015). Operational definitions of driving performance measures and statistics. https://doi.org/10.4271/J2944_201506

[5] Olson, P. L., & Sivak, M. (1986). Perception-response time to unexpected roadway hazards. Human Factors, 28(1), 91–96.

[6] Donmez, B., Boyle, L. N., & Lee, J. D. (2007). Safety implications of providing real-time feedback to distracted drivers. Accident Analysis & Prevention, 39(3), 581–590.

[7] Johansson, G., & Rumar, K. (1971). Drivers' brake reaction times. Human Factors, 13(1), 23–27.

[8] D'Addario, P., & Donmez, B. (2019). The effect of cognitive distraction on perception-response time to unexpected abrupt and gradually onset roadway hazards. Accident Analysis & Prevention, 127, 177–185. https://doi.org/10.1016/j.aap.2019.03.003.

[9] Chai, M. (2019). Drowsiness monitoring based on steering wheel status. Transportation Research Part D: Transport and Environment, 66, 95–103.

[10] Vollrath, M., & Fischer, J. (2017). When does alcohol hurt? A driving simulator study. Accident Analysis & Prevention, 109, 89–98.

CONTACTS

Contacts: Ji Hyun Yang, Ph.D. yangjh@kookmin.ac.kr