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An Exploratory Survey of Drivers' Knowledge of Right of Way at Freeway On-Ramp Merging Areas

THIS PAPER EXPLORES DRIVERS' KNOWLEDGE REGARDING THE RIGHT OF WAY AT FREEWAY ON-RAMP MERGING AREAS, INCLUDING THEIR ACTIONS WHEN DRIVING AT THOSE AREAS. A SAMPLE OF 530 OHIO DRIVERS PARTICIPATED IN MAIL AND ONLINE SURVEYS THAT ASSESSED THEIR DEMOGRAPHIC CHARACTERISTICS, KNOWLEDGE OF RIGHT OF WAY, AND MERGING PRACTICES.

BY DEOGRATIAS EUSTACE, PH.D., P.E., PTOE, STEPHEN OWUSU-ANSAH, EIT, AND VAMSI K. INDUPURU

INTRODUCTION

Motor vehicle crashes are one of the leading causes of death in the United States.[1] The most recent data available show that in 2006 there were almost 6 million police-reported motor vehicle crashes in the United States where a total of 42,642 people were killed and an additional 2.6 million were injured.[2] The majority of these motor vehicle crashes occurred at intersections or within the intersection influence areas.[2] Traffic conflicts occur at intersections due to traffic streams moving in different directions interfering with each other, and as a result they become areas with high potential for traffic crashes compared with non-intersection areas of the roadways.[3] In order to reduce the potential conflict points, access to a freeway is only provided through grade-separated intersection ramps (also known as interchanges). Freeways play a major role in providing mobility due to their high operational speeds and their being fully access controlled. Like other intersections, freeway-ramp areas have also been identified as locations highly prone to crashes as compared to other segments of freeways.[4–6] A number of studies have been conducted to determine the causes and characteristics of crashes that occur at freeway ramps in order to devise and apply preventive countermeasures to reduce the occurrences of such crashes. Most of these studies have focused on developing and calibrating factors that contribute to traffic crash occurrences such as highway geometry, traffic volume, ramp location, and type of interchange.[4,7–10] Other studies analyzed the type and patterns of crashes on urban freeways.[5,11]

For instance, a study by McCartt et al[5] highlighted types and characteristics of ramp-related crashes, which showed that the type of crashes that occur at entrance ramps and exiting ramps are generally different. The most common type of crashes at exit ramps involve vehicles running-off the road while speeding. For the entrance ramps, sideswipe and cut-off crash types are the most frequent ones, with lack of yielding of right of way involving merging drivers from entrance ramps identified as a major cause. What is not clear, however, is whether at-fault merging drivers (from entrance ramps) know who had a right of way at the freeway merging area. In the present study, we assumed that most of these at-fault drivers think that they have a right of way over drivers already on mainlines. To date, we have not found any study that has examined the factors that influence on-ramp merging drivers not yielding the right of way to freeway mainline traffic. In particular, the contribution of drivers' knowledge of who has the right of way at the freeway-entrance ramp merge area has not been addressed. By determining what drivers know about right of way at the freeway merge area, including their driving actions, appropriate countermeasures such as education, engineering, and legislative actions can be implemented as future crash countermeasures.

In addition, some states' driver's license testing handbooks inform new drivers to accelerate at on-ramps to attain the freeway mainline speed. This is also in accordance with the American Association of State Highway and Transportation Officials (AASHTO) guidelines whereby auxiliary (acceleration) lanes are provided in order to minimally affect the through traffic operations.[12] Normally no yield sign is needed for ramps having standard-length acceleration lanes. The abovementioned reasons may also cause some on-ramp merging drivers to think that they share

equally the right of way with the mainline traffic; this misconception may be one of the contributing causes of collisions at on-ramp merging areas.

Furthermore, traffic safety studies acknowledge that certain demographic factors contribute to most of the motor vehicle crashes. For instance, gender and age differences in traffic crash involvement are well documented. The youngest and oldest drivers are more likely to be involved in motor vehicle crashes; similarly, younger males are more likely than younger females to be involved in motor vehicle crashes.[13–15] On the other hand, females older than 50 years of age are more likely than the same age males to be involved in fatal crashes.[15] Specifically, half of fatal crashes involving old drivers (80 years and older) tend to occur at intersections, and young drivers (16–24 years old) have a risk of being involved in traffic crashes to the order of 2.5 times higher than that of other drivers.[16] Therefore, in the present study, we assumed that gender and age will be associated with drivers' knowledge of freeway merging areas' right of way.

Particularly, the objective of this paper is twofold: to explore the knowledge of drivers concerning who has the right of way between the one on mainline lanes of a freeway and the one entering the freeway through the on-ramp junction lane and to explore the drivers' actions when driving in the vicinity of freeway-entrance ramp merge areas, whether driving on the freeway mainline lanes or entering through the ramp junction lanes.

KNOWLEDGE TESTING AND LICENSING FOR NEW DRIVERS

In the United States, individual states are responsible for issuing driver's licenses in their jurisdictions. Each state requires a driver's license applicant to take and pass a written test as one of the requirements before the license is issued. For most states the department of motor vehicles (DMV) or bureau of motor vehicles (BMV) is the state agency authorized by law to oversee the process of driver testing and license issuance. The driver's test normally examines the applicant's knowledge and understanding of issues such as road signs, rules of the road, vehicle operation, and so forth. The state agency develops a driver's license testing handbook, which becomes the main source of driving-related knowledge for most drivers. The license applicant is expected to review the handbook before taking the written test.

Since the study reported in this paper was conducted in Ohio, the state driver's license handbooks of Ohio and neighboring states of Kentucky, West Virginia, Michigan, Pennsylvania, and Indiana were reviewed for content comparison purposes. One non-Midwestern state of Florida, whose handbook could easily be obtained online, was also reviewed. Each handbook has a section that advises drivers on how to enter a freeway.[17–23] Although the detail and clarity differ somewhat, most of the reviewed states advise drivers to do the following for entering the freeway safely:

- On the entrance ramp, begin checking for an opening in traffic and signal for your turn;
- Use the acceleration lane to speed up to the freeway speed. Try to adjust your speed so that you can move into the traffic when you reach the end of the acceleration lane; and
- Merge into traffic when you can do so safely. You must yield the right of way to traffic on the expressway. You can't always count on other drivers moving over to give you room, but do not stop on an acceleration lane unless traffic is too heavy and there is no space for you to enter safely.

Olsen and Hostetter[24] studied different entrance ramp configurations by observing merging behaviors and suggested some driving behaviors to be discouraged, such as merging earlier by using less of the available acceleration area, unnecessary hesitation before merging, and slowing unnecessarily. The Olsen and Hostetter recommendations on preferred entrance behaviors agree with the reviewed state drivers' manuals instructions. Some of the handbooks include figures that show the proper way of merging into the freeway.[18,19,20,22]

METHODS

Survey Instrument Development

We developed a 21-item questionnaire that covered needed information such as driver's demographics, experience with on-ramp related crashes, merging driving actions, and knowledge with regard to right of way at freeway merging areas. It constituted of multiple choice and open-ended questions where appropriate. A full questionnaire is available in Eustace and Indupuru.[25] In this paper, only questions that asked the respondents to describe their usual driving actions when driving in the vicinity of the freeway merging areas, knowledge about the right of way, and proper freeway merging via on-ramp junctions are discussed. Since this study was designed to use human subjects as a source of data collection, approval to survey human subjects was sought and received from our university's Institutional Review Board (IRB) prior to conducting data collection.

In an effort to ensure content validity of the instrument, three senior professors knowledgeable in traffic safety were consulted to review the instrument, and their suggestions were implemented. In addition, an attempt was taken to assess the face validity of the survey instrument by conducting a pilot test of the survey by administering it to randomly selected drivers in our institution. The results from this pilot data collection were also instrumental in the questionnaire refinement and in determining whether the questions were well understood by the targeted respondents. The reliability of the instrument was not established due to different question formats and styles used (yes/no, multiple choice, and open-ended responses).

Data Collection

We used local published telephone books from the greater metropolitan Dayton area and the greater metropolitan Cincinnati area for names and addresses after the original plan of obtaining data from the Ohio Bureau of Motor Vehicles and Indiana Bureau of Motor Vehicles was not successful. We used a systematic random sampling approach in selecting a sample of 1,500 individual names, including their addresses from the phone books' listings. The main limitation of using this procedure is that we could not predetermine the age and gender of the respondents. In addition, drivers not listed in the telephone books could not be

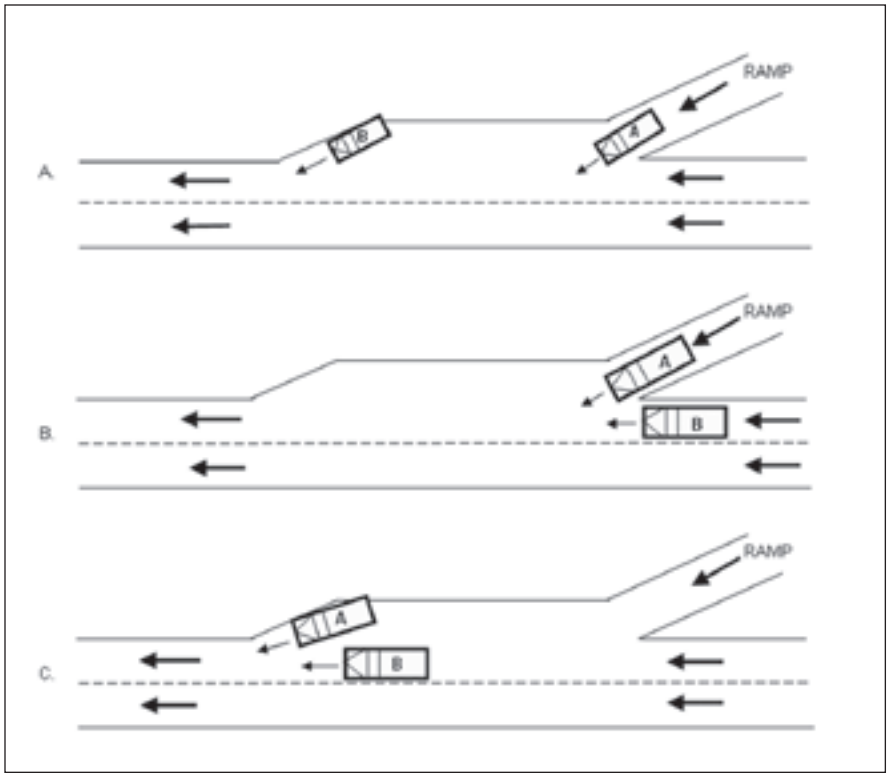

Figure 1. Graphics used for right-of-way knowledge questions.

Table 1. Characteristics of the study sample (N = 530).

Age Group/Gender	Students N (%)	Non-Students N (%)	Combined N (%)
≤ 19	46 (28.8)	0 (0.0)	46 (8.7)
20–25	94 (58.8)	9 (2.4)	103 (19.4)
26–44	13 (8.1)	84 (22.7)	97 (18.3)
45–54	4 (2.5)	109 (29.5)	113 (21.3)
55–64	3 (1.9)	101 (27.3)	104 (19.6)
65+	0 (0.0)	67 (18.1)	67 (12.6)
Total	160 (30.2)	370 (69.8)	530 (100)
Male	93 (58.1)	180 (48.6)	273 (51.5)
Female	67 (41.9)	190 (51.4)	257 (48.5)

included in the sample. As expected, the sample was biased towards older drivers and completely missed teenage drivers. The reason for underrepresentation of teenage drivers may be that most of them do not live independently or don't head a household and therefore they are not listed in the telephone books. Also, studies have shown that mail questionnaire responses tend to be lower for younger respondents.[26] Then it was decided to get an augmented sample from our university students. An online questionnaire was administered to 1,500 university students who were also selected by use of systematic random sampling.

For the mail survey, a cover letter was prepared stating the intent of the survey and assuring the respondents of their anonymity.

A total of 376 completed surveys were received by mail, representing a response rate of 25 percent. In addition, 163 completed responses were extracted from the online survey, accounting for about 11 percent. Respondents who reported that they don't drive were omitted from the analysis.

Three driving action questions were open ended as we did not want to influence the respondents from guessing the correct responses from possible choices. The questions were as follows: (1) When approaching a freeway from an entrance ramp, what do you normally do before entering the highway? (2) When driving on a freeway and you see a vehicle entering from a ramp, what do you normally do? (3) When approaching a freeway on a single-lane ramp with a YIELD sign, what actions do you normally take before entering the highway?

The graphics shown in Figure 1 were used to clarify the three knowledge questions. Figure 1A was included in a question that asked respondents to identify the vehicle that was entering the freeway correctly. Figures 1B and 1C asked the respondents to identify which vehicle has to yield the right of way to the other. All these questions included five choices with only one being the correct response.

RESULTS

After removing the respondents who reported that they don't drive, a total of 530 responses were determined to be eligible for analysis. The sample contained 273 males (51.5 percent) and 257 females (48.5 percent) while 370 (69.8 percent) came from the non-student sample (mail survey) and 160 (30.2 percent) were students (online survey). Table 1 summarizes the sample data.

The open-ended driving action responses were carefully coded and then summarized into correct driving actions and incorrect driving actions. For example, for the merging onto the freeway question, if a respondent says that "I speed up," it was coded as one of the incorrect driving actions; if a respondent says "safe or smooth merge by adjusting speed," it was coded as one of the correct driving actions. For the merging from a ramp question, 67.4 percent of the responses were coded as correct driving actions. Interestingly, 29.2 percent of the respondents were likely to enter the freeway without extra caution; they think that speeding up to the freeway speed is the only requirement for proper freeway entrance. However, this percent drops to just 6.2 percent when a YIELD sign is

Table 2. Summary of driver's driving actions in terms of correct and incorrect actions by respondent type and gender.

Item Question	Driver Responses by Respondent Type (N = 530)						Driver Responses by Gender (N = 530)					
	Correct Actions, N (%)			Incorrect Actions, N (%)			Correct Actions, N (%)			Incorrect Actions, N (%)		
	Student	Non-student	Combined	Student	Non-student	Combined	Male	Female	Combined	Male	Female	Combined
Your actions when approaching a freeway from a ramp	108 (67.5)	249 (67.3)	357 (67.4)	52 (32.5)	121 (32.7)	173 (32.6)	184 (67.4)	173 (67.3)	357 (67.4)	89 (32.6)	84 (32.7)	173 (32.6)
Your actions when approaching a freeway from a YIELD-signed ramp	94 (58.8)	323 (87.3)	417 (78.7)	66 (41.3)	47 (12.3)	113 (21.3)	197 (72.2)	220 (85.6)	417 (78.7)	76 (27.8)	37 (14.4)	113 (21.3)
Your actions when driving on a freeway and you see a vehicle entering from a ramp	148 (92.5)	349 (94.3)	497 (93.8)	12 (7.5)	21 (5.7)	33 (6.2)	247 (90.5)	250 (97.3)	497 (93.8)	26 (9.5)	7 (2.7)	33 (6.2)

posted on the entrance ramp, and correct responses were consequently 78.7 percent. Although it may seem that a YIELD sign reduces the confusion (by reducing the number of drivers who said that they simply speed up), the YIELD sign is not required if the acceleration lane of standard length is provided. Most of the ramps with the YIELD sign are old and they don't have enough length for merging vehicles to accelerate; therefore, YIELD signs are provided for safety reasons. One point should be clear here: A YIELD sign is not required at an entrance ramp with a standard length of acceleration lane in order to allow drivers to be able to accelerate and merge at a speed almost equal to that of oncoming traffic. It is interesting to note that for a question on driving actions while on the freeway when the driver sees a vehicle attempting to merge from a ramp, 93.9 percent reported acting properly as opposed to 67.4 percent when the same drivers were merging from the entrance ramps. Table 2 summarizes the results of reported correct and incorrect driving actions by the type of respondent and by gender.

The responses to the right-of-way and merging knowledge questions are summarized in Tables 3 through 5. Responding to the question of which vehicle is entering the freeway correctly between the one entering directly from the ramp (incorrect entrance) and the other entering after reaching at the end of the acceleration lane (correct entrance), only 69.4 percent of respondents selected the correct answer. While 16.4 percent of them said that both vehicles are entering correctly, 6.4 percent thought that both of them are entering incorrectly. Results of items on which vehicle has to yield to the other are very interesting. When the vehicle is entering incorrectly (Figure 1B), most respondents (87.5 percent) correctly identified that the entering vehicle is supposed to yield to the one already on the highway, but when the same vehicle is entering correctly (Figure 1C), the correct responses drop to 67.5 percent.

Table 3. Responses to the right-of-way knowledge question "which vehicle is entering correctly?" (Figure 1a) by respondent type.

Item Choice	Students, N (%)	Non-Students, N (%)	Combined, N (%)
Vehicle A	4 (2.5)	18 (4.9)	22 (4.2)
Vehicle B*	115 (71.9)	253 (68.4)	368 (69.4)
Both of them	22 (13.8)	65 (17.6)	87 (16.4)
None of them	12 (7.5)	22 (5.9)	34 (6.4)
I am not sure	7 (4.4)	12 (3.2)	19 (3.6)
No response	0 (0.0)	0 (0.0)	0 (0.0)
Total	160 (100.0)	370 (100.0)	530 (100.0)

*Correct response.

Analysis of Driving Actions and Knowledge of Different Driver Groups

The responses to the driving actions and knowledge questions, which were recoded into "correct" and "incorrect" responses, were statistically tested (using chi-square test of independence) based on the following groups of drivers: age (age groups), gender (male/female), and sample source (student/non-student). Only those that were significant at 5 percent significance level are discussed. Responses to the item that asked drivers' actions when driving on a freeway and they see a vehicle entering a freeway were significantly different by age and gender. The gender differences were significant, with χ^2 (1, N = 530) =

Table 4. Responses to the right-of-way knowledge question "which vehicle has to yield the right of way to the other? (Figures 1b and 1c) by respondent type.

Item Choice	Figure 1B (wrong entrance)			Figure 1C (correct entrance)		
	Students, N (%)	Non-Students, N (%)	Combined, N (%)	Students, N (%)	Non-Students, N (%)	Combined, N (%)
Vehicle A*	141 (88.1)	323 (87.3)	464 (87.5)	97 (60.6)	260 (70.3)	357 (67.4)
Vehicle B	15 (9.4)	30 (8.1)	45 (8.5)	54 (33.8)	87 (23.5)	141 (26.6)
The first vehicle	1 (0.6)	3 (0.8)	4 (0.8)	2 (1.3)	4 (1.1)	6 (1.1)
None of them	3 (1.9)	5 (1.4)	8 (1.5)	2 (1.3)	8 (2.2)	10 (1.9)
I am not sure	0 (0.0)	9 (2.4)	9 (1.7)	5 (3.1)	11 (3.0)	16 (3.0)
No response	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total	160 (100.0)	370 (100.0)	530 (100.0)	160 (100.0)	370 (100.0)	530 (100.0)

*Correct response.

10.484, p = 0.001. Based on observed versus expected counts, males expressed more incorrect driving actions when driving on the freeway and they see vehicles attempting to merge from a ramp. For age, the differences were significant with χ^2 (5, N = 530) = 15.101, p = 0.010. Based on observed versus expected counts, the under-26 and 65-plus age groups expressed more incorrect driving actions when they are on the freeway and see another vehicle attempting to merge from an entrance ramp than other age groups.

Responses to the item that asked drivers' actions when entering a freeway via a ramp signed with a YIELD sign were significantly different by gender and age. The gender differences were significant, with χ^2 (1, N = 529) = 15.024, p = 0.000. Based on observed versus expected counts, males expressed more incorrect driving actions when entering a freeway via a YIELD-signed ramp. Age responses were significantly different, with χ^2 (5, N = 529) = 69.303, p = 0.000. Based on observed versus expected counts, the under 26 and 65-plus age groups expressed more incorrect driving actions when entering a freeway via a YIELD-signed ramp.

For an item that asked which vehicle is entering the freeway correctly, (merging knowledge question) gender was the only group that showed significant differences. The differences were significant, with χ^2 (1, N = 529) = 8.335, p = 0.005. The observed versus expected counts imply that the percentage of males who correctly answered this question was significantly higher than that of females.

When comparing the responses of student and non-student samples, they are significantly different on only two items: actions the driver does when entering a freeway via a YIELD-signed ramp and on a knowledge question that asked which vehicle has to yield the right of way when the merging vehicle is entering incorrectly. For the entering actions, the responses were significantly different, with χ^2 (1, N = 530) = 54.264, p = 0.000. Based on observed versus expected counts, the student sample expressed more incorrect driving actions when entering a freeway via a YIELD-signed ramp. For the right-of-way knowledge question, the differences were significant, with χ^2 (1, N = 530) = 4.814, p = 0.034. The observed versus expected counts imply that the percentage of respondents who correctly answered this question from a non-student sample was significantly higher than that of the student sample.

DISCUSSION AND CONCLUSION

The type of traffic crashes that occur most frequently at the freeway entrance ramps suggest that there is a yielding problem on the side of the merging on-ramp drivers. The reasons for the on-ramp merging drivers not yielding the right of way are not clear and, to the best of our knowledge, we have not found a study that has examined these issues. The current study was an initial attempt to gather responses from drivers regarding questions on the right of way at a freeway merge area, their driving actions (both when driving on the mainlines and when merging from the ramp), and whether they know the proper way of merging into the freeway.

This study was exploratory; the results should be interpreted with caution. First, the survey sample was limited, making it difficult to generalize it to the overall population of drivers in the United States. Second, mail and online surveys tend to have relatively lower responses (in this case 25 percent and 11 percent, respectively) and thus are prone to higher non-response biases. Despite the above limitations, the drivers' responses in this study provide important insights concerning drivers' knowledge of right-of-way issues at the freeway-entrance ramp merge areas. One surprising result was that only slightly higher than two-thirds of the respondents (69.4 percent) could identify the vehicle that was merging correctly into the freeway. We expected more knowledgeable drivers due to a higher percentage of mature and experienced drivers being overrepresented in this study. Most states' driving handbooks include a figure similar to the one used in Figure 1a advising proper freeway entrance and proper use of the acceleration lane.[18,19,20,22] The reasons for lower than expected understanding of proper freeway entrance and proper merging are not clear. However, it may be, in part, due to Ohio's handbook not including the figure that shows the proper location of the merging area.[17]

Almost nine out of 10 (87.5 percent) recognized that the vehicle already on the freeway has the right of way over the one merging from the entrance ramp if the entering vehicle is cutting through directly

Table 5. Responses to the right-of-way knowledge questions by gender.

Item Question Asked	Driver Responses (N = 530)					
	Correct Responses, Number (%)			Incorrect Responses, Number (%)		
	Male	Female	Combined	Male	Female	Combined
Which vehicle is entering correctly (Figure 1A)	205 (75.1)	163 (63.4)	368 (69.4)	68 (24.9)	94 (36.6)	162 (30.6)
Which vehicle has to yield the right of way to the other (Figure 1B)	241 (88.3)	223 (86.8)	464 (87.5)	32 (11.7)	34 (13.2)	66 (12.5)
Which vehicle has to yield the right of way to the other (Figure 1C)	177 (64.8)	180 (70.0)	357 (67.4)	96 (35.2)	77 (30.0)	173 (32.6)

into the freeway main lanes, which is an incorrect way of merging.[18,19,20,22] The most interesting finding is that when the same vehicle is entering the freeway correctly after using the acceleration lane as required, only about two-thirds (67.5 percent) were able to identify that the vehicle on the main lanes has the right of way. The implications from these results are twofold. First, if the right-of-way knowledge responses reflect the drivers' actual driving strategies, then there is a possibility of a good number of drivers entering the freeways at lower speed because they enter when they have not accelerated enough to reach highway speed. Second, there is a danger for entering drivers who believe they have the right of way because they will attempt to enter even if there are not enough gaps in the through mainline's traffic stream. This is supported by findings from the McCartt et al[5] study that reported that entering drivers are at fault most of the time because they don't yield the right of way to the mainline traffic. In addition, the drivers' self-reported driving actions support this finding as we found out that only two-thirds (67.2 percent) reported acting properly when entering the freeway.

The good news for merging drivers is that most drivers on the freeway mainlines perform proper actions when seeing a vehicle attempting to merge from entrance ramps. Two reasons may be behind this desirable driving behavior. Either some drivers may be trying to be courteous to others, or they may assume that the entering vehicles have the right of way over them. For age, the under-26 and 65-plus age groups significantly expressed more incorrect driving actions when driving in the vicinity of freeway-ramp merging areas as compared with other age groups. Interestingly, gender difference was significant for several items. Males significantly expressed more incorrect driving actions when driving in the vicinity of freeway-ramp merging areas compared with females. However, males showed significantly higher knowledge regarding the merging knowledge question. This is supported by a study by Storie[27] that found that females were more likely to drive more carefully but that males were more skillful and knowledgeable yet more likely to be involved in risky driving.

Even though the sample may not be representative of Ohio's drivers due to sampling not strictly adhering to advanced sampling techniques, the results show a possible right-of-way knowledge problem in Ohio that indicates the need for rigorous further investigation. Therefore, there is a need to investigate further the relationship between the drivers' knowledge of right of way at the freeway merge area, driver actions, and yielding problems using a larger and a more representative sample of driving community whose results may play a major role in devising preventive countermeasures for avoiding freeway merging ramp crashes.

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