The Influence of Familiarity with Traffic Regulations on Road Safety: A Simulated Study on Roundabouts and Intersections

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***Abstract*—International drivers who come from keep-right countries and drive in keep-left countries are frequently involved in road accidents due to unfamiliarity with keep-left traffic regulations. Due to unfamiliarity of the traffic regulation, the driver's performance and behaviour are subject to change. The objective of this study was to explore the effects of familiarity with traffic regulations on driving performance and behavior at roundabouts and intersections. To achieve this in a safe environment, twenty-one male familiar drivers and thirty- four male unfamiliar drivers participated in driving in a simulated keep-left traffic regulation. The factors observed were not fastening the seat belt, entering the driving simulation from wrong side, using an improper approaching lane, not signalling, speeding, driving against the traffic flow and using an improper exiting lane at each roundabout and intersection. Mann-Whitney U test was used to compare driving behaviour and performance between the familiarity groups. Unfamiliar drivers made significantly more driving mistakes on roundabouts than unfamiliar drivers. Also, some unfamiliar drivers got inside the vehicle from the passenger side instead of driver side and drove against the traffic flow inside the roundabouts. The implications for familiar and unfamiliar driving can be considered for future research development.**

Keywords*—*Driving behaviour; driving performance; familiarity with traffic regulations; road intersections; roundabouts

I. Introduction

An increasing number of students and tourists from keep-right countries (e.g., China, the United States (US) and Middle Eastern countries) are travelling to keep-left countries (e.g., New Zealand, the United Kingdom and Australia). Hence, the involvement of overseas drivers in road accidents abroad emerges as a potential road safety issue. Some drivers unfamiliar with the local road regulations experience difficulties in adapting their interactions with the road (e.g., keeping to the speed limit and driving with the traffic flow) and with the vehicle (e.g., controlling the direction indicator and windscreen wipers) to match the requirements of the new driving conditions [1], [2]. For instance, the Ministry of Transport in New Zealand, a keep-left country, reported that drivers from keep-right countries such as China Saudi Arabia, UAE, and Turkey, were the main group of overseas drivers involved in head-on collisions due to driving on the wrong side of the road [3]. Difficulties experienced by overseas drivers include the incorrect use of vehicle controls, signalling in time, keeping left and driving in the wrong lane.

While the problem of driving overseas is primarily considered in terms of road safety, little consideration is given to the use of concrete solutions and technology, such as in-vehicle information systems and gamification, to address differences in driving performance and behaviour between drivers who are familiar and unfamiliar with the local traffic system. Therefore, it is important to conduct scientific research on the ways unfamiliar drivers interact with the conditions of driving overseas and compare their driving performance with locals (i.e., familiar drivers) in order to provide a comprehensive insight into overseas drivers' vulnerability, support specific driving-assistance systems and reduce traffic violations as well as facilitating safe driving under unfamiliar conditions.

To gain a better understanding of the involvement of overseas drivers in road accidents and traffic violations when driving under unfamiliar traffic regulations, a simulated traffic environment was established to assess the way the rules of traffic regulation can affect driving behaviour and performance. An experimental task was designed to evaluate the driving behaviour and performance of drivers used to keep-right conditions when interacting with keep-left vehicle configurations and traffic systems prior to and while driving, especially at critical sections of roads (i.e., roundabouts and intersections). Although roundabouts and intersections optimise traffic flow [4], they are also associated with many vehicle accidents [1]. These sections of roads are associated with a relatively large number of driving tasks. While the seatbelt is fastened, the drivers need to perceive a lot of traffic information (e.g., the section of road, road signs, and the position of direction stalk), make critical decisions (e.g., slowing down or speeding up, and driving in the required travelling lane with the traffic flow)

[5], and then made a driving decision and act accordingly [6], The collisions that happen at roundabouts and intersections are likely to be due to the way the driver behaves and performs.

The objective of this research was to determine the effects of familiarity with traffic regulations on driving performance at roundabouts and intersections. It is hypothesized that (H1) drivers unfamiliar with the traffic regulation will commit more traffic violations on roundabouts and intersections than familiar drivers; and (H2) the risk at roundabouts and intersections is higher when overseas drivers drive under unfamiliar traffic regulations in comparison to familiar drivers.

The paper starts with an overview of the literature on the impact of familiarity with the interactions between drivers and unfamiliar elements of the traffic system. The methodology is then described in terms of the study sample, apparatus, driving scenario, experimental procedure, data acquisition and analysis. Then, the results are presented and discussed. At last, a summary of findings is presented.

II. Literature Review

The effects of familiarity with traffic regulations on driving performance have been insufficiently examined in transportation research [7]. However, some studies have acknowledged the interactions between drivers and unfamiliar elements of the traffic system (e.g., unfamiliar roads, vehicle configurations and traffic regulations), such as the behaviour of familiar and unfamiliar drivers in regard to a specific road condition (i.e., road familiarity).

Driving in unfamiliar routes is associated with some difficulties in terms of driving performance and mental workload. For example, the drivers in [8] showed low driving performance and high workload, and the situation was getting better when the drivers used to drive on those routes. However, drivers showed more respect for speed signs when driving in unfamiliar roads [9]. In terms of evaluating the risk subjectively, drivers evaluate the risk as higher when driving on unfamiliar roads in comparison to familiar roads [10]. The study [11] goes further and explores the risk perception in accordance with the driver's gender when driving in unfamiliar routes. That is, while male drivers perceived unfamiliar routes as riskier than familiar routes, female drivers tended to perceive familiar routes as riskier than unfamiliar routes. Compared to familiar drivers, unfamiliar drivers had shorter steering reaction times in case of the presentation of a peripheral object, longer braking reaction times in case of the presentation of an object at the front of the vehicle and kept a longer distance from the vehicle in front of their car [12]. Overall, familiar drivers were characterised by better awareness of surroundings and regulations compared to unfamiliar drivers [7].

In the context of driving under unfamiliar traffic regulations, most studies only examine the driving behaviour, performance and needs of unfamiliar drivers. Unfamiliar drivers were found to frequently ignore roads signs and road information and therefore did not drive under the road speed limit [13], [14]. Unfamiliar drivers also performed unnecessary and unsafe lane changes and did not use the direction indicator when lane departure was imminent [15], [16]. Moreover, some unfamiliar drivers entered roundabouts and intersections from the wrong side of the road [17], [18], [19]. Another study investigated the feedback and presentation mechanisms unfamiliar drivers preferred to help them to drive on specific sections of road. Unfamiliar drivers preferred the visual feedback that presents speed, navigation and direction indicator information concurrently with the performance of the driving task [20].

The study conducted by Yoh et al. [21] explored the driving behaviour of familiar and unfamiliar drivers under Japanese traffic regulations by analysing real-world driving accidents in Japan. While unfamiliar drivers were more likely to perform driving mistakes related to their understanding of traffic rules, familiar drivers committed more violations relating to speed. Also, Abbas et al. [22] studied the behaviour of two groups of drivers: Indigenous and non-Indigenous, where Indigenous drivers were the local drivers who were familiar with the local rules, the road conditions and the behaviour of other drivers in the road and non-Indigenous drivers were new to the local area. The study found that the drivers' responses to speed cameras were influenced by their familiarity with the road regulations.

When driving in unfamiliar traffic conditions, the driver might also be driving a vehicle with unfamiliar configurations. The vehicles that usually used in keep-left countries are right-hand -drive vehicles whose steering wheel is on the right. These vehicles often have the turn signal lever mounted on the right side of the steering column while the windshield wiper controls are mounted on the left side of the steering column. In contrast, left-hand drive vehicles have the steering wheel, signal lever and windshield wiper control the opposite way around. This can affect driving performance. Drivers from Japan (a keep-left country), for instance, were more likely to cross lane lines when driving a left-hand drive vehicle [23]. Additionally, some unfamiliar drivers misused the controls for the direction indicator and windscreen wiper [14], [18]. Another study [24] focused on the interaction between drivers, particularly ones who had mild cognitive impairment, and unfamiliar vehicles to discover the needs of a system to remind the drivers of performing some tasks, such as fastening the seatbelt. Drivers' behaviour regarding fastening seatbelt and speeding is discussed along with other driving behaviour in [25] to investigate the influence of culture on road safety when driving in familiar and unfamiliar environments.

Driving simulator is presented as a valid method for driving research [26]. It is used in a wide range of research (for example, [16], [27], [28], [8]) that explore the interactions between traffic elements under a condition of unfamiliarity. Due to unsafety of testing such interactions, experiments using driving simulator provide a safe observation environment [27], [8]. The driving simulator also allows researchers in [8] to systematically measure driving performance and workload under controlled conditions.

There is still a lack of research that compares the driving performances of familiar and unfamiliar drivers at roundabouts and intersections. Therefore, this study explores the influence of familiarity with traffic regulations on road safety using a driving simulator.

III. Methods

A. Sample

A total of 55 right-handed male drivers voluntarily took part in the driving simulator study. They were divided into two groups based on the traffic system the drivers were most familiar with driving in. The first group included 21 drivers who were only familiar with keep-left traffic regulations and held a valid driving license issued from a keep-left country. This group was titled "familiar drivers," as they were familiar with the traffic system of this study. The second group included 34 drivers who were only familiar with keep-right traffic regulations and who held a driving license issued in a keep-right countries. The second group was categorised as "unfamiliar drivers." The age range of both groups was between 20 to 35 years. The first group had a mean age of 27.048 years (SD = 4.318) with a mean driving experience of 4.762 years (SD = 2.548) and an average driving hours per week of 9.048 (SD = 10.072). The second group had a mean age of 24.441 years (SD = 4.215) and with a mean driving experience of 6.235 years (SD = 4.390) and an average driving hours per week of 15.353 (SD = 10.557).

B. Apparatus

A fixed-based driving simulator, Forum8 (see Figure 1), located at Macquarie University, was used for the study. The simulator was placed in a small room with its own door. Also, there was a large glass window between this room and an adjacent room through which the research could observe the driving session. However, the glass was covered with a blackout curtain during the driving session in order to provide a less distracting environment and minimise the changes in driving performance due to being watched by the researcher. Forum8 consists of a right-hand drive vehicle cockpit containing a force-feedback steering wheel, direction indicator and windscreen wipers levers, brake and gas pedals, a gear shifter, seatbelt and air-conditioner and multimedia control panel. The front of cockpit is attached to a three-screen display that provides a horizontal and a vertical field of view of 150 degrees and 30 degrees, respectively. The graphical interface was designed by UC-win/Road which is used to model the traffic system, including roads, road signs and texture, vehicles, and trees. Also, UC-win/Road records data in CSV and video logs. The data includes information on the vehicles, users on the road, and driving environment in addition to the interactions among those items for analysis purposes.

Fig. 1. Driving simulator.

C. Driving Scenario

The driving simulator experiment consisted of driving in a keep-left traffic system using a Forum8 simulator as described above. Randomly, a New South Wales (Australia) geographical area from UC-win/Road was selected. The entire driving track was dual-lane and had different road sections, including straight and curved roads, three four-way intersections and three four-exit roundabouts. The scenario had no traffic movements, such as pedestrians, cyclists or other vehicles. Road signs and textures were added in accordance with the Australian regulations. The driving scenario started from a fixed point and ended at another point. The scenario directed the drivers to drive through all intersections and roundabouts. The sequence and the required turning at each section were as follows: intersection (go straight-ahead), roundabout (turn right), intersection (turn right), roundabout (turn left), intersection (turn left), roundabout (head straight) (see Figure 2).

D. Experimental Procedure

Once the participants arrived, their driving license was checked for its validity and the country of issue. The whole experiment was then explained to participants. If the participants agreed to continue then they signed the consent form and filled out a questionnaire about their demographic information and driving experience. After the questionnaire was completed, the researcher provided the participant with instructions regarding driving rules at intersections and roundabouts in Australia. The participants then moved to the simulator room with the window uncovered to perform the training session which lasted up to 10 minutes. Under observation, participant gradually became accustomed to the vehicle and the simulated environment. After that, the glass was covered with a blackout curtain and the participant moved to the experimental session. At the beginning of the session, the driving task was introduced to participants with the instruction to follow the road directions presented on a map to reach the destination. Participants were reminded to respect all traffic laws. After completing the experimental session, prior to leaving the vehicle seat, the participants called the researcher. The researcher ensured that all required files were saved and then the participant

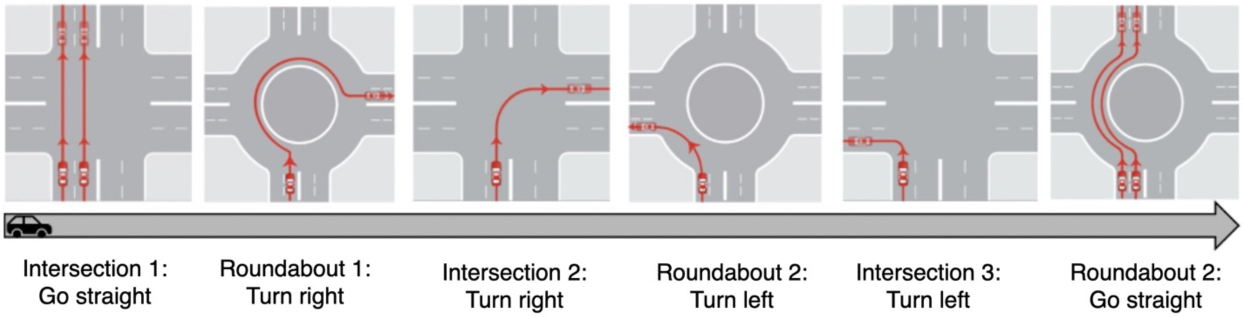

Fig. 2. The Sequence of road sections drive by the participants.

filled out the post-experiment questionnaire, which captured their driving experience under keep-left traffic regulations and driving a simulator.

E. Data Acquisition and Analysis

The current study explores the differences in driving behaviour and performance between familiar and unfamiliar drivers in a keep-left traffic system. Driving behaviour and performance were assessed by exploring the driving mistakes that occurred prior to and while driving. Prior to the training session, when the window glass was uncovered, participants were observed fastening the seat belt by the researcher. It was easily observable that some participants entered the driving simulation from wrong side (i.e., passenger side not the driver side). Hence, mistakes related to getting inside the vehicle were also noted prior to starting the driving.

During the experimental session, mistakes related to driving at each intersection and roundabout were observed from log files. Driving mistakes included (1) using an improper approaching lane, (2) not signalling, (3) speeding, (4) driving against the traffic flow and (5) using an improper exiting lane. If no mistakes were made, 0 points were assigned to the driver, but if any of the above-mentioned mistakes were made, 1 point was assigned to the driver. All mistake scores were integrated into one file for data analysis.

Familiarity with driving under keep-left traffic regulations was a nominal independent variable with two groups: familiar and unfamiliar. The total number of mistakes on roundabouts and intersections and the total number of each type of driving mistake represented the dependent variables. Descriptive statistics were presented as mean, mean rank, minimum and maximum. To compare driving behaviour and performance between the familiarity groups, the Shapiro-Wilk test was conducted to determine normality for driving performance variables. None of driving performance variables were distributed normally ($p < .05$). Therefore, parametric tests (i.e., independent t-tests) could not be employed. Instead, the Mann-Whitney U test as a non-parametric test was applied [29].

IV. Results

A. Pre-Driving

Out of 34 unfamiliar participants, 26 participants (76.5%) did not get inside the simulated vehicle from the correct side, while none of familiar participants made the same mistake. Descriptive statistics indicate that the mean of getting inside the simulated vehicle from the wrong side was 0.77 for unfamiliar participants with a mean rank of 36.03, suggesting a strong tendency toward making such a mistake among unfamiliar participants (see Table I). None of familiar participants got inside the vehicle from the wrong side, resulting a mean of 0.00 and a lower mean rank of 15.00. That indicates a significant disparity between the two groups. The Mann-Whitney U test results indicated that the number of unfamiliar participants who did not fasten the seatbelt (mean = 0.59; mean rank = 36.03) was significantly greater than the number of familiar participants who made the same mistake (mean= 0.24; mean rank = 22.05), U = 232.00, p = 0.006 (see Table II).

B. While Driving

1) Section of road: The results of the Mann-Whitney U test showed there was a significant difference in the total number of driving mistakes on roundabouts between familiar (mean = 2.38; mean rank = 22.71) and unfamiliar (mean = 3.38; mean rank = 31.27) participants; U = 246.000, p = 0.026. On intersections, familiar participants made fewer driving mistakes with a mean of 2.48 and mean rank of 24.41 than unfamiliar participants (mean = 2.94; mean rank = 30.21). However, the difference was not statistically significant (U = 281.500, p = 0.092).

2) Type of mistake: Multiple Mann-Whitney U tests were conducted to compare driving mistakes in relation to their type between familiar and unfamiliar participants. For approaching the roundabouts/intersections from an improper lane, the U statistic was 337.000 (p = 0.361), and for not signalling, it was 349.000 (p = 0.446). Speeding yielded a U statistic of 344.000 (p = 0.40), while using improper exiting lane resulted in a U statistic of 301.000 (p = 0.16). These findings indicate no significant differences in driving mistakes between the groups, suggesting similar driving performance among participants.

Familiar participants did not drive against the traffic flow on roundabouts/intersections, while unfamiliar participants had a mean of this driving mistake of 0.80 (mean rank = 32.63). As such, a statistical comparison between the two groups was not performed, indicating a notable disparity in this mistake.

V. Discussion

The main objective of the study was to determine the effects of familiarity with traffic regulations on the driving

TABLE I. DESCRIPTIVE STATISTICS FOR DRIVING MISTAKES

Mistakes	Group	Minimum	Maximum	Mean	Mean Rank
Getting into the vehicle from the wrong side	Familiar	0	0	0.00	15.00
	Unfamiliar	0	1	0.77	36.03
Not fastening the seatbelt	Familiar	0	1	0.24	22.05
	Unfamiliar	0	1	0.59	31.68
Total number of mistakes on roundabouts	Familiar	0	5	2.38	22.71
	Unfamiliar	0	7	3.38	31.27
Total number of mistakes at intersections	Familiar	1	5	2.48	24.40
	Unfamiliar	0	5	2.94	30.22
Not using an improper approaching lane	Familiar	0	3	1.05	27.05
	Unfamiliar	0	2	1.09	28.59
Not signalling	Familiar	0	4	1.23	27.62
	Unfamiliar	0	4	1.29	28.23
Speeding	Familiar	0	2	0.43	27.38
	Unfamiliar	0	5	0.70	28.38
Driving against the traffic flow	Familiar	0	0	0.00	20.50
	Unfamiliar	0	4	0.79	32.63
Using an improper exiting lane	Familiar	0	5	2.14	25.33
	Unfamiliar	0	6	2.44	29.65

TABLE II. THE RESULTS OF MANN-WHITNEY U TESTS FOR A COMPARISON IN DRIVING MISTAKES BETWEEN FAMILIAR AND UNFAMILIAR PARTICIPANTS

Mistakes	U	p
Getting into the vehicle from the wrong side wrong side	NaN^a	
Not fastening the seatbelt	232.00	0.006
Total number of mistakes at roundabouts roundabouts	246.00	0.026
Total number of mistakes at intersections intersections	281.50	0.092
Not using the improper approaching lane lane	337.00	0.361
Not signalling	349.00	0.446
Speeding	344.00	0.397
Driving against the traffic flow	NaN^b	
Using an improper exiting lane	301.00	0.158

a The variance in getting into the vehicle from wrong side is equal to 0 after grouping on familiarity.
b The variance in driving against the traffic flow is equal to 0 after grouping on familiarity.

performance at roundabouts and intersections. An overall comparison between the driving performance prior to and while driving on roundabouts and intersections for familiar and unfamiliar drivers to a keep-left traffic regulation was addressed.

A. Pre-Driving

All familiar participants got into the vehicle from the correct side of the vehicle (i.e., the right side, which represents the driver side in a right-hand drive vehicle), while 76% of unfamiliar participants got inside the vehicle from the wrong side (i.e., the left side, which represents the passenger side in a right-hand drive vehicle). When the unfamiliar participants were asked about the reasons for making this mistake, they mentioned the unreality of the driving environment, hesitation concerning which is the correct side, and complete unawareness of the correct side. Statistical comparison using the Mann-Whitney U test was not feasible for not getting into the vehicle from the correct side due to the lack of collected data from familiar participants in relation to this mistake. Therefore, recruiting more familiar participants is required to better assess differences between the familiarity groups for this mistake. In general, although this mistake does not affect road safety, making such a mistake might be an annoying or embarrassing experience for the driver.

The results of this study indicate the number of unfamiliar participants who did not fasten their seatbelt was significantly greater than familiar participants. According to the post-simulation questionnaire, all familiar participants and the three unfamiliar participants who did not make this mistake thought it was not important to fasten their seatbelt as the driving session was not real but they did it anyway. For the unfamiliar drivers, there were additional reasons for not fastening the seatbelt. Some participants were unfamiliar with configurations of right-hand drive vehicles, while others forgot to fasten the seatbelt as they did not usually fasten it back in their home country or they did not realise that there was a seatbelt. Although this violation was observed prior to the driving tasks, fastening the seatbelt is very important factor in road safety. It reduces fatal injuries by between 45% and 60% [30]. Regarding this factor, a strategic awareness campaign intended to educate countries with less awareness of the importance of fastening the seatbelt is proposed by [31]. Changing behaviour towards fastening seatbelts through serious games is introduced by [32]. Another possible solution is to employ tactical feedback to remind the driver to fasten their seatbelt [33]. When conducting driving simulation experiments, it is important to emphasise the importance of fastening the seatbelt prior the observation process even though the experiment environment is simulated.

B. While Driving

1) Section of road: The results show a significant difference in the total number of driving mistakes on roundabouts between familiar and unfamiliar participants. On intersections, although unfamiliar participants performed more traffic violations compared to unfamiliar participants, this difference is not statistically significant. It might be that the intersections need fewer steering-related activities than roundabouts and therefore the drivers need to be more aware of the required activities in relation to the section of road at roundabouts in comparison to intersections. Drivers' awareness is higher when driving under familiar conditions than unfamiliar conditions [7]. More studies are required to explore why the performance on roundabouts is different than intersections, although a roundabout is a form of intersection.

2) Type of mistake: The results indicate an insignificant difference in speeding violations at roundabouts and intersections between familiar and unfamiliar drivers. The results conflict with those obtained in studies by [13], [14], who found that familiar drivers are more likely to perform speed violations and by [21], who found that unfamiliar drivers are more likely to ignore road signs and information when driving under unfamiliar traffic regulations. The reasons speed violations were committed by both groups in this study might be driving in unfamiliar routes for familiar group of participants [9] and the high cognitive load the unfamiliar drivers experienced when driving under unfamiliar traffic regulations [15]. More studies are required to explore the reasons behind the speeding violations by both the familiar and unfamiliar drivers.

Approaching and exiting roundabouts and intersections from the correct travelling lane can be related to steering skills and making correct decisions in accordance with the target turn. Despite the results of study conducted by [12], which found different steering activities between familiar and unfamiliar drivers, the results reveal that there was no significant difference in driving in an improper travelling lane when approaching and exiting roundabouts/intersections between familiar and unfamiliar drivers. Another reason for making such a mistake might be driving a simulator whose sensitivity might differ from a real vehicle. Further studies are required to understand the reasons behind this sort of mistakes for both groups of drivers. Signalling while turning or changing the lanes informs other users of road (e.g., other drivers on the road, pedestrians and motorcyclists) about the driver's near future turn or manoeuvre and gives time to others to plan or react accordingly. The reasons for not signalling could be driving habit, that it is unnecessary to give a signal (e.g., no traffic on the road), or misusing the control of direction indicator. These might explain why the results of this study did not show a significant difference in signalling when approaching roundabouts/intersections between familiar and unfamiliar drivers. The driving track of this study did not include any traffic. Additionally, some unfamiliar participants were confused about the correct location of direction indicator lever, as it is located to the right of the steering wheel, which may be an unfamiliar configuration.

The results of our study reveal that unfamiliar participants drove 27 times against the traffic flow when they entered the roundabouts/intersections, while none of the familiar participants made that mistake. This result does not allow us to perform a statistical comparison using the Mann-Whitney U test. Adding more familiar participants can provide extra data and thus better understanding for this situation. However, that might not guarantee that familiar drivers are going to drive against the traffic, as they are used to driving with the traffic flow, unlike the unfamiliar participants who made this mistake. In contrast to familiar drivers, unfamiliar drivers are required to distinguish the differences in traffic systems and rules between their home country and the host country. The unfamiliar drivers must adapt their knowledge and reactions to match the requirements of driving in the host country. Difficulties in adapting to keep-left traffic regulations might explain why unfamiliar participants drove against the traffic flow. Another reason for this behaviour might be that the unfamiliar drivers are more likely to ignore road signs [13], [14]. Despite presenting the required direction on the roundabout-ahead sign, unfamiliar participants might not pay attention to the sign or notice the difference in the information on the roundabout-ahead sign. Driving against the traffic flow results in failing the driving test in New South Wales, as well as in all states and territories, Australia [34] and increases the risk of serious and often fatal crashes (e.g., head-on collisions). Even though the familiar and unfamiliar drivers showed no significant difference in other driving mistakes, the risk at roundabouts and intersections was higher when unfamiliar drivers drove in unfamiliar traffic regulations in comparison to familiar drivers.

These results could be used to improve the few existing driving-assistance systems available for overseas drivers, particularly those who are driving under unfamiliar traffic regulations, as the improvement in such systems could improve the road safety. As automated car technology develops, it could be possible to customize the vehicle control automation level based on the driver's familiarity with the traffic regulations. In cases where the driver is not familiar with the local regulations, the system can fully or partially automate the vehicle when approaching complex roads, such as roundabouts and intersections. Other improvements include providing understandable and clear information to drivers based on their familiarity with the traffic regulations. However, this information must be easy to understand as providing complex information might increase the driver's cognitive load and lead to them ignoring the information.

Based on these results, suggested solutions include considering unfamiliarity with road regulations when designing an in-vehicle information system. Unlike familiar drivers, unfamiliar drivers need information regarding the correct direction of traffic when they reach roundabouts and intersections. Another solution is to modify the information that is provided to drivers via road signs to consider the issue of unfamiliarity with traffic regulation. The intersection-ahead sign, for instance, does not currently inform drivers about the direction of traffic flow. Presenting the direction of flow in perceivable locations as well as presenting the road structure might help unfamiliar drivers to correctly drive with the traffic flow when entering intersections (see Figure 3). Another designing suggestion is to use "do not enter" signs as part of the image of intersection to describe the traffic flow situation at upcoming intersections. Presenting the

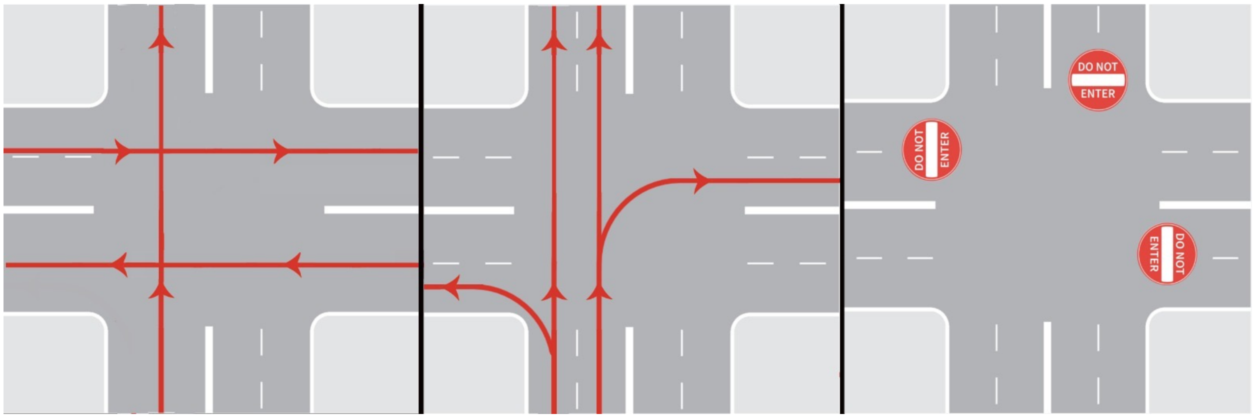

Fig. 3. Three possible alternative designs for intersection-ahead sign to facilitate driving in intersections.

road signs to the driver via an in-vehicle information system is better than the traditional road signs in terms of the proper driver's response to changes in the road environment [35].

Other solutions are suggested in the study conducted by [36], such as providing different navigation information (e.g., turn instructions), vehicle status information (e.g., seatbelt status), and driving assistance information (e.g., direction visualisation) based on the driver's familiarity with the soundings. However, in such systems, the information should be carefully designed. The study [37] recommends that an international and ergonomic standards should be considered when designing the road signs. Gamification and serious games also can provide suitable learning platform for drivers to adapt their behaviour and performance to safely drive under unfamiliar traffic regulations [38], [39].

C. Limitations and Future Work

The present study had some limitations in the driving tasks and the driving scenario. Future developments could include adding further driving tasks, such as overtaking. While the driver overtakes a vehicle from the right in a keep-left traffic regulation, the driver in a keep-right traffic regulation overtakes a vehicle from the left. Testing this driving task should be conducted on at least a three-lane road to make it possible for the driver to overtake from the right or the left. Testing familiar and unfamiliar drivers together in the same driving scenario can extend the knowledge about real interactions and behaviours when both groups of drivers drive together on the same road.

VI. Conclusion

In this paper, the differences in driving mistakes between familiar and unfamiliar drivers in a keep-left traffic regulation system were explored. Using a driving simulator, two pre-driving mistakes and five while-driving mistakes were calculated. The pre-driving mistakes were getting inside the vehicle from incorrect side of the vehicle and not fastening the seatbelt. The while-driving mistakes were using an improper approaching lane, not signalling, speeding, driving against the traffic flow, and using an improper exiting lane. Fifty-five right-handed male drivers participated in the study and were grouped into two groups (21 familiar drivers with a keep-left traffic regulation and 34 unfamiliar drivers with a keep-left traffic regulation). The results of this study confirm the first hypothesis (H1) that unfamiliar drivers will commit more traffic violations compared to familiar drivers, as the unfamiliar drivers performed significantly more mistakes than the familiar drivers did on roundabouts and insignificantly more mistakes on intersections. The results also demonstrate that the risk in traffic systems is higher when drivers drive under unfamiliar traffic regulations (H2, the second hypothesis), as the unfamiliar drivers might enter the roundabouts and intersections from the opposite traffic direction to which they are accustomed. Therefore, familiarity with traffic regulations should be considered when designing the driving-assistant systems, in-vehicles information systems, gamification and serious games, and other educational programs. That would help improving road safety, particularly in countries that have many unfamiliar drivers.

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