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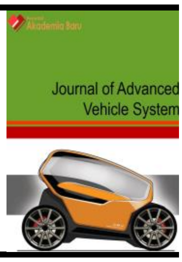

A Study of Driver Behavioral Adaptation to Advanced Driver Assistance System (adas) in Malaysia

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ABSTRACT

The advanced driver-assistance system (ADAS) is an intelligent transport technology to aid drivers in handling their vehicle. Equipped with onboard sensors and cameras to detect obstacles ahead as well as driver errors, the system can provide warning sound and visual display to prevent road traffic crashes. Several studies have been conducted to evaluate the effectiveness of such onboard safety technologies among drivers. Researchers found that there was a reduction in risky driving habits as a result of the use of the systems. However, some researchers are of the view that drivers need more time to develop a substantial understanding or mental model regarding the functions of ADAS. Although ADAS promises benefits to drivers by offering relief from numerous control tasks, very few studies have been conducted in Malaysia to determine the change in behavior among drivers when prompted by the warning sound and visual display that come with ADAS. Therefore, the current study has been conducted to achieve such a goal. Overall, 20 drivers who agreed to have their ADAS-compatible private cars installed with the In-vehicle Monitoring System (IVMS) participated in the study. Blind testing was employed to assess the effects of ADAS on driver behavior. Based on the results, the study found that the use of ADAS is able to improve driver behavior while on the road as a whole. With ADAS fully activated, the technology is able to provide warnings and prompt the driver whenever a violation is committed. In addition, the technology is also effective in reducing the number of driving violations. Hence. the relevant parties must explore the possibility of making ADAS affordable for every car owner.

Keywords:
ADAS, intelligent transport system, driver behavior, behavioral adaptation

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1. Introduction

The advanced driver-assistance system (ADAS) is an intelligent transport technology to aid drivers in handling their vehicles. Equipped with onboard sensors and cameras to detect obstacles ahead as well as driver errors, the system can provide immediate responses to prevent road traffic crashes. Through human-machine interaction, this technology is believed to be able to improve the safety of road users.

The use of ADAS has been well-received by the industry players and it is now installed on private and commercial vehicles. In Southeast Asia, ASEAN NCAP which provides safety ratings for new cars

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entering the regional market also emphasizes the use of advanced vehicle safety technologies including ADAS in its Roadmap 2021-2025 [1].

According to Li [8], among the examples of ADAS fitted on vehicles are:

i. Adaptive Cruise Control (ACC) which is equipped with automotive features to allow a vehicle to automatically adjust its speed to keep a safe distance with the vehicle in front.

ii. Lane Departure Warning (LDW) which is a mechanism to warn a driver if the vehicle exits its lane through a visual, audible, and vibrating alarm system.

iii. Forward Collision Warning (FCW) which is designed to alert the driver of the risk of a collision when an obstacle is detected.

For commercial drivers, ADAS is installed on logistics company vehicles to track the location of these vehicles. In addition, a driver's habits can also be monitored through the information obtained from various sensors on the vehicle to appraise the driver's performance. Such information can then be used to formulate ways to reduce the risk of company vehicles being involved in road crashes.

Several studies have been conducted in the US including by Horrey, Lesch, Dainoff, Robertson, and Noy [5] to evaluate the effectiveness of these advanced safety technologies among fleet drivers. The researchers found that there was a reduction in risky driving habits as a result of the use of a seat belt reminder system, which is part of the onboard safety system. In addition, Brookhuis and Brown [2] suggested that an approach using engineering features to change human behavior be implemented to improve the quality of road safety, transport efficiency, and environment.

In Malaysia, accident data obtained from the Royal Malaysia Police (PDRM) showed that on average, 80 percent of road accidents were due to human errors while 13 percent were due to environmental factors and the remaining 7 percent were due to automotive defects. With the use of intelligent transport system technology such as ADAS, road crashes resulting from human errors can be avoided as this technology can facilitate and assist drivers during the driving process [10]. However, Sullivan et al [13] are of the view that drivers need more time to develop a substantial understanding or mental model regarding the functions of ADAS.

Although the technology promises benefits to drivers by offering relief from numerous control tasks, very few studies have been conducted in Malaysia to determine the change in behavior among drivers when using the warning sound and visual display that come with ADAS. Therefore, the current study has been conducted to achieve such a goal.

2. Study Objective

Because researchers are divided on the effectiveness of ADAS in improving driver performance, this study has been conducted to evaluate driver behavioral change in response to the technology in Malaysia. To date, very few studies on ADAS have been conducted by researchers in the country due to the high cost in the installation of ADAS on private vehicles. In addition, drivers may also be resistant to the warning provided by ADAS after using it for long periods, hence reverting to their initial driving behavior.

Therefore, the study seeks to achieve the following objective:

i. To determine driver behavioral adaptation to the advanced driver-assistance system (ADAS) in Malaysia.

3. Literature Review

ADAS is an intelligent transport system installed on a vehicle to aid the driver through various means. The system is used to provide important information related to traffic, closure and blockage of roads, congestion levels, etc [7]. In addition, certain ADAS technologies are also able to assess the level of fatigue and distraction experienced by drivers, thus, providing feedback or evaluation of the driving performance. The system also uses long- and medium-range radar to inform drivers of the obstacles ahead as well as a collision-warning system to assist vehicle control and braking [4].

According to Brookhius, de Waard and Janssen [3], with the use of ADAS, driver errors can be reduced and even eliminated to improve road and transportation safety. The researchers are of the view that road accidents are mainly due to human failure resulting from tiredness, inattention as well as drowsiness. Shinar [12] also supported this statement by stating that driver factors require more attention compared to environmental and vehicle factors to lower the rate of road traffic crashes.

In Europe, the USA and Japan, ergonomic and engineering approaches have been combined to improve driver performance as well as hazard prediction. Car manufacturers, therefore, have emphasized driver comfort through the use of various electronic aids such as route guidance systems and advanced cruise control systems. The use of ADAS encompasses these systems and subsystems [3]. Additionally, the ADAS concept also includes blind spot detectors, adaptive cruise control, autonomous and intelligent cruise control.

Nevertheless, the main function of ADAS is to facilitate the driver's task by providing real-time advice, instruction and warnings. Researchers, however, argue that these driver support systems have different effects on driving tasks. For example, Zwahlen, Adams and DeBald [15] posited that ADAS had a negative impact on driver habits. This was due to the focus of drivers being distracted from the traffic as well as the attitude of some drivers who were too dependent on ADAS to fail to notice a sudden hazard, thus were slow to register a response.

Through their study, Jensen, Wagner and Alexander [6] have produced an analysis of driver behavior data on ADAS, particularly the in-vehicle driver behavior. The researchers then proposed a system for driver classification based on the in-vehicle behavior data that have been generated. Figure 1 below shows the six different driver categories ranging from ‘timid’ to ‘aggressive’ drivers as presented by the researchers.

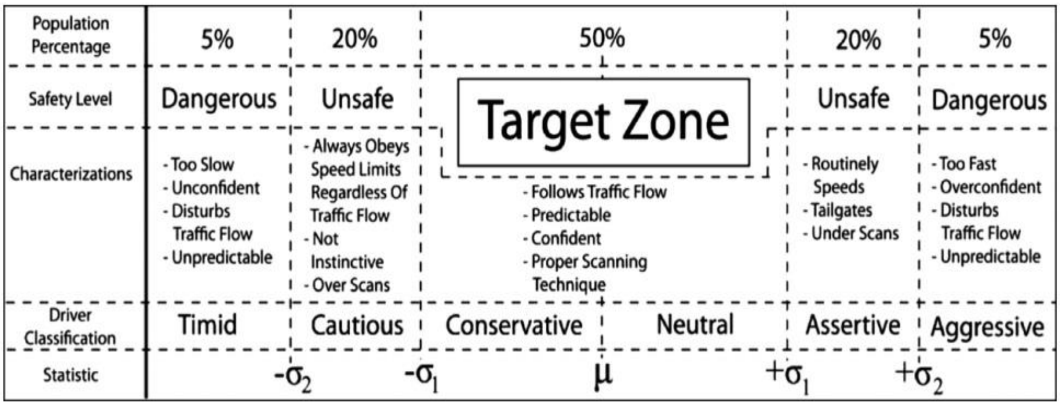

Fig. 1. Six different driver classifications

Further, Toledo, Musicant and Lotan [14] also focused on in-vehicle data recorders in their study for monitoring and generating feedback in respect to driver habits. Their study used the calculation of Individual Risk Index for the purpose of data analysis whereby based on the index, drivers were categorized according to different color codes, namely Green (for drivers with moderate behavior), Yellow (intermediate behavior) and Red (risky behavior). The main reason behind this classification was to produce a simpler system of risk reporting indexes that could be understood by everyone. Additionally, the researchers also applied the blind experiment as part of the research methodology.

Additionally, Pradhan, Lin, Wege, and Babel [9] conducted a study on the effects of behavior-based driver feedback systems on commercial long-haul operator safety to compare the driving behavior among commercial vehicle drivers who received feedback from their safety managers as compared to drivers who did not receive any feedback. Their study also applied the blind testing method where both drivers and their managers did not receive any feedback although data were recorded, followed by a period where the system was activated, and ended with an extended time frame of the blind phase. The researchers found a drop in the rate of risky events among drivers who received supervisor feedback and a significant improvement in their driving behavior compared to the drivers who did not receive any feedback.

Similar to the aforementioned research, this study shall also adopt the blind testing to achieve its objective. Therefore, the participants involved shall be prevented from accessing certain information (e.g. ADAS only records the driving events without providing warning display or sound) that can lead to bias in their response, hence, causing the results to be invalidated. Whereas in the the "unblind phase", the information (ADAS warning sound and display are activated) is revealed to the participants. The blind experiment is acknowledged as an important scientific method in the fields of psychology and social sciences.

4. Methodology

The methodology of this study includes sampling, installation of the devices and the “blind-unblind-reblind” testing as well as analysis of data.

4.1 Sampling

The sampling method used in this study was purposive sampling as the study aimed to ascertain driver behavioral adaptation to the warning sound and display of the Connected-ADAS (C-ADAS). Since not all cars were compatible with the device specifications, only drivers who were willing to have their ADAS-compatible private cars installed with the In-vehicle Monitoring System (IVMS) could participate in the study. Taking all the limitations into consideration, only 20 participants were involved in the experimental component of this study. All in all, the selection of participants included:

i. Their vehicle compatibility with the devices
ii. Their consent to install the devices

4.2 Installation of the Devices

Altogether, 20 vehicles were installed with the advanced driver-assistance system (ADAS) and onboard diagnostics device (OBD). These devices would capture data for the indicators shown below in Table 1.

ADAS was designed to produce beeping sounds as well as visual display on the vehicle dashboard to warn the driver in the event that an indicator was triggered. Among the indicators that were scrutinized in this study included the Forward Collision Warning (to detect high risk collision and determine the time of collision), Speed Limit Warning (to identify speed limit on signboard and alert over speeding), Lane Departure Warning (to detect unintended lane departure to encourage use of signalling) and Headway Monitoring and Warning (to warn drivers of the impending vehicle ahead). The device was installed by Atilze Digital Sdn Bhd, the distributor of C-ADAS in Malaysia. A summary of the device installation is shown in the figure below (Figure 2).

Table 1
Driving Indicators Detected by Each Device

Indicators	OBD	ADAS
Speeding	/	/
Harsh braking	/	
Harsh cornering	/	
Harsh acceleration	/	
Forward collision warning		/
Lane departure warning		/
Pedestrian warning		/
Headway monitoring		/
Travel duration	/	/
Time of travel	/	/
Distance travelled	/	/

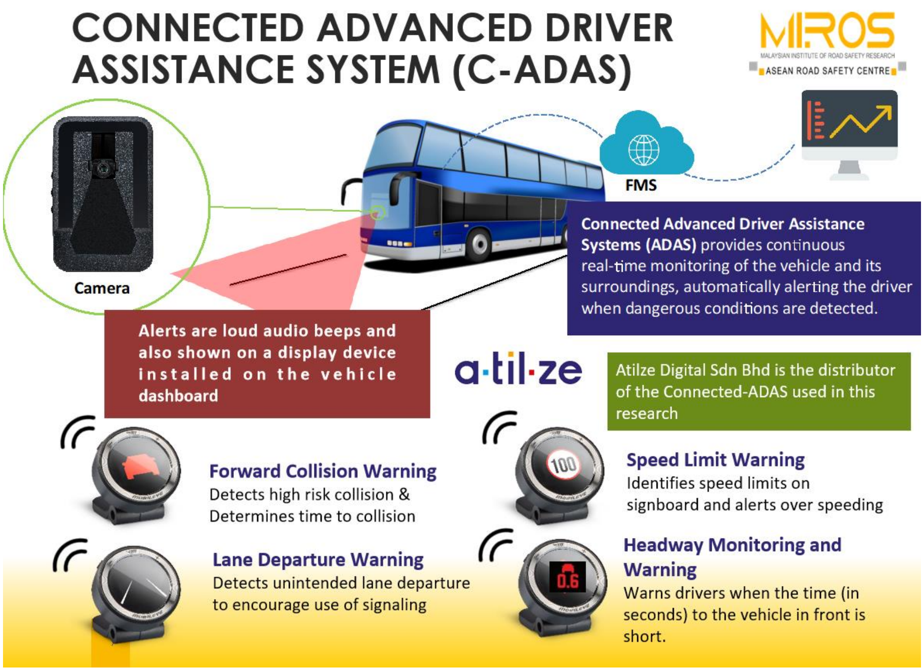

Fig. 2. Installation of ADAS

4.3 The Blind Testing

The duration for the blind, unblind and reblind test phases was fixed at 27 days respectively. The experimental study was conducted from 30 March 2018 to 31 July 2018. During the blind phase, ADAS only recorded the driving events without producing the warning sound or the visual display. In the next phase (the unblind phase), aside from recording the driving events, both warning sound and visual display were activated. In the final phase of the study (the reblind phase), the warning sound and visual display were again turned off while ADAS continued to record the driving events. The aim of the reblind phase was to assess the lasting effects of ADAS on the driver behavior after the unblind phase, independent of the visual and audible alerts. The phases of the study are summarized in the figure below (Figure 3).

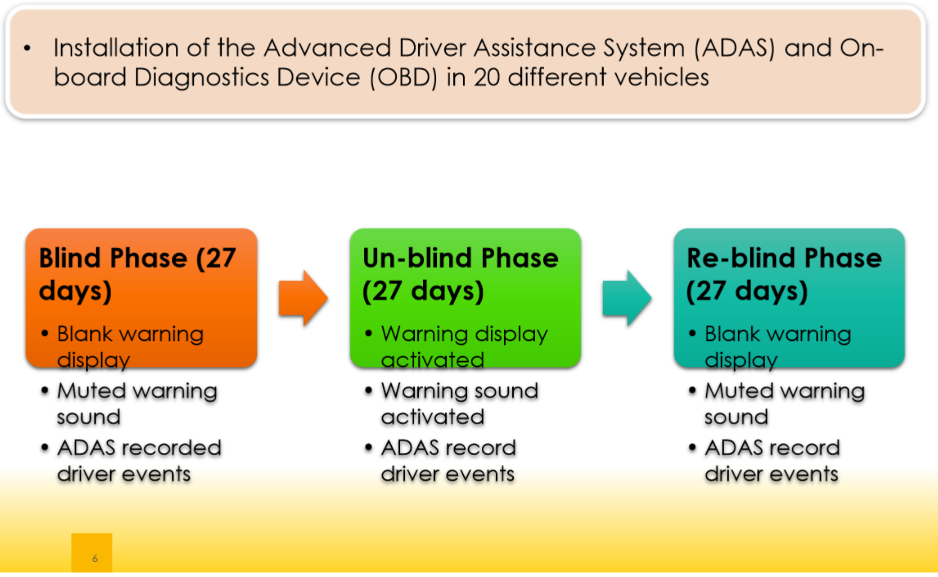

Fig. 3. Blind, Unblind and Reblind Phases

Based on the results, the study will be able to determine whether ADAS can lead to a change in the participants' driving behavior.

4.4 Data Analysis

The data collected were cleaned and analysed using Microsoft Excel due to their inconsistent nature.

5. Results and Discussion

This section will reveal the results of the study, namely the drivers' demographic, and the influence of in-vehicle monitoring system warning sound and visual display on the participants' driving behavior with regard to speeding, forward collision warning, headway monitoring warning and lane departure warning.

5.1 Participants' Demographic

From a total of 20 participants in the study, 9 were male whereas another 11 were female. In terms of age, 15 of the participants were below the age of 40 while another 5 were 40 years and above. As for their vehicle engine capacity, 16 participants drove vehicles above 1.4cc while the other 4 participants drove vehicles below 1.4cc. The table (Table 2) below illustrates the demographic of participants in the study.

5.2 Violations by Drivers

Throughout the study period, it was found that male participants committed more violations on average with 12,750 cases compared to female participants (7,810 cases). In terms of participants' age, the result showed that those above 40 years committed 14,302 violations on average compared to 8,609 by those aged below 40. Finally, with regard to engine capacity, the results showed that participants who drove vehicles below 1.4cc recorded 12,800 violations whereas those with vehicles above 1.4cc committed 9,341 cases of violation on average. Table 3 below summarizes the average number of violations committed by the study participants.

Table 2
Participants' Demographic Information

Demographic Variable	Category	No
Gender	Male	9
	Female	11
Age	Below 40 years old	15
	Above 40 years old	5
Engine Capacity	Below 1.4cc	4
	Above 1.4cc	16

Table 3
Violations Committed by the Drivers

Demographic Variable	Category	Average Number of Violations
Gender	Male	12,750
	Female	7,810
Age	Below 40 years old	8,609
	Above 40 years old	14,302
Engine Capacity	Below 1.4cc	12,800
	Above 1.4cc	9,341

Study period of 30 March 2018 – 31 July 2018

5.3 Overall Violations

Assuming the participants covered the same distance during both blind and unblind phases, a decrease of 20% in overall violations during the unblind period was observed as shown in Figure 4 below. After the ADAS was muted again for the reblind phase, the overall violations increased by 26%. Compared to the initial blind mode, the number of violations increased by 1%. This suggests that the presence of IVMS helped to change driver behavior and ensured favorable driving habits among the study participants. As mentioned by Qureshi and Abdullah (2013), intelligent transport system technology does help to reduce human errors while driving.

5.4 Violations by Type

In terms of violation types, the results showed that the biggest reduction was registered for Lane Departure Warning from the blind to the unblind phase with 49% (down from 16,382 cases to 8,307 cases). In contrast, the smallest reduction from the blind to the unblind phase was registered for Forward Collision Warning with 9% (from 1,992 cases to 1,819 cases). The results for the unblind and reblind phases, on the other hand, indicated that the biggest increase was for Lane Departure Warning at 82% (up from 8,307 to 15,131 cases). In addition, there was a reduction for Forward Collision Warning from the unblind to the reblind phase by 5.6% (from 1,819 to 1,718 cases). Figure 5 below illustrates the number of violation types throughout the three phases of the study.

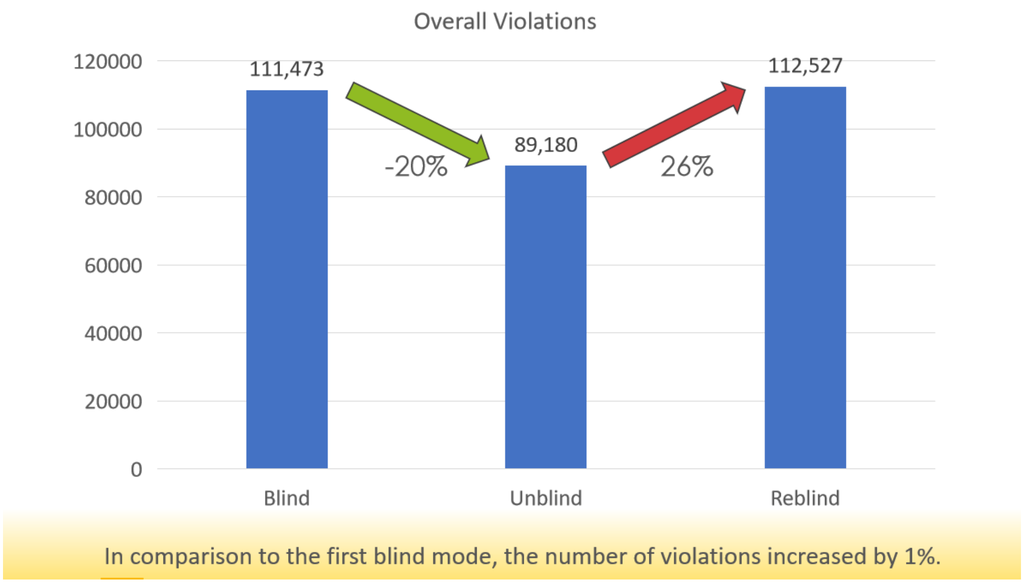

Fig. 4 Overall Violations during the Study

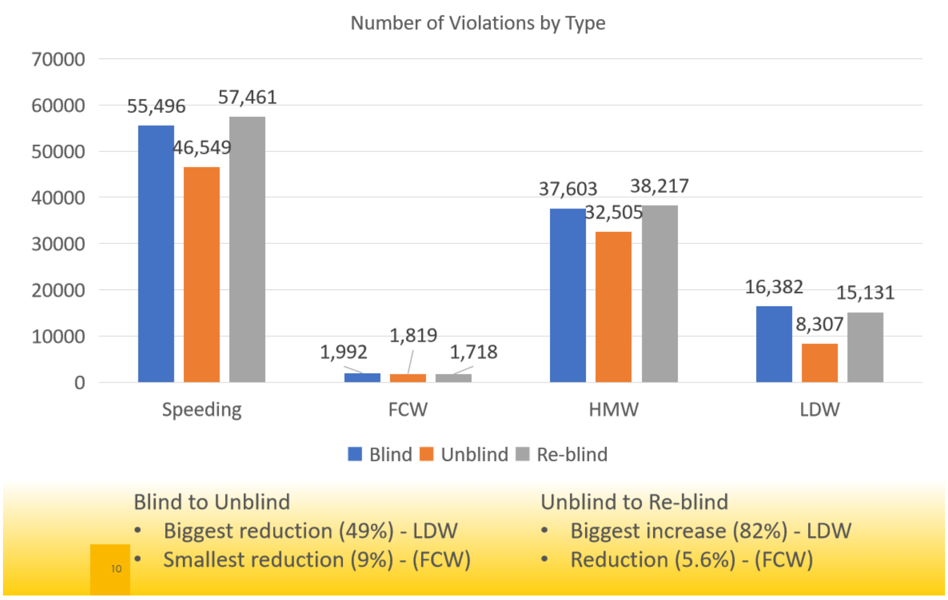

Fig. 5 Number of Violations by Type

5.5 Speeding

In respect to speeding violations, the study findings for the blind and unblind phases showed that on average, there was a reduction of 16% in the cases of speeding among the participants. As for the transition from the unblind to the reblind phase, there was an average increase of 3.5% in the speeding cases among the participants. Looking randomly at some of the participants, Driver 14 recorded a steady decrease in speeding throughout the three phases. Driver 11, on the other hand, registered a slight dip in speeding violations from the blind to the unblind phase before recording a significant increase in the reblind phase. Driver 5, in addition, displayed a steady increase in speeding violations throughout the three study phases. Figure 6 below illustrates the participants' speeding violations in the study.

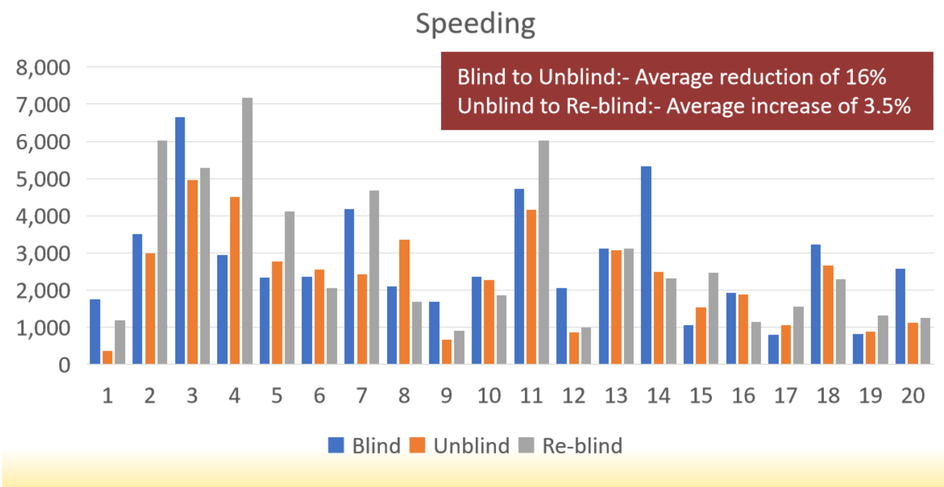

Fig. 6. Speeding

5.6 Forward Collision Warning

As for the forward collision warning provided by ADAS, the study findings indicated that more than half of the participants registered a drop of 9% in the number of violations during the unblind phase as the warning sound and visual display on the dashboard were activated. This trend of reduction continued into the reblind phase whereby the number of violations further dipped by 5.6%. For example, Driver 14 registered a steady downtrend throughout the three study phases. Driver 5, however, recorded a decrease in violations for the unblind phase before registering an increase during the reblind phase. Driver 11, in contrast, displayed an increasing violation pattern through the three phases. Figure 7 below summarizes the forward collision warning violations among the participants in the study.

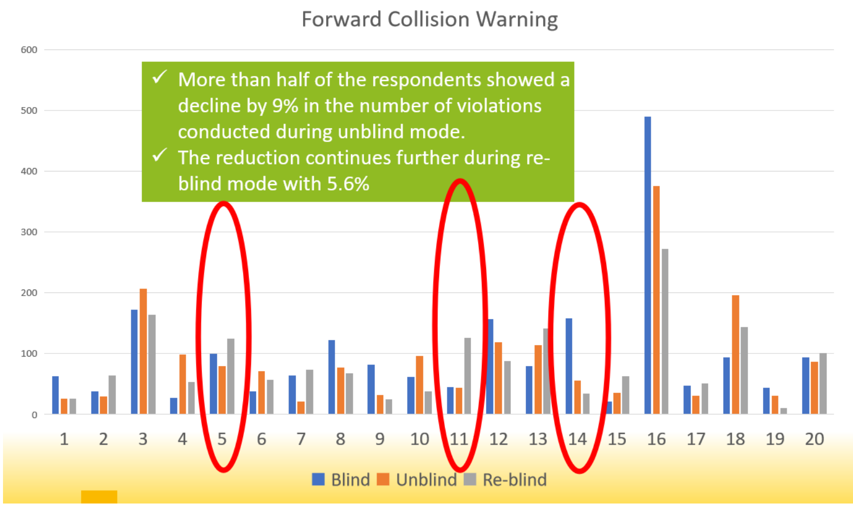

Fig. 7. Forward Collision Warning

5.7 Headway Monitoring Warning

ADAS also recorded the headway monitoring warning to the participants. On average, there was a reduction of 14% in the number of violations among the study participants from the blind to the unblind phase. For the transition from the unblind to the reblind phase, the findings indicated an average increase in violations of 17.6%. Driver 14, as an example, demonstrated a steady decrease in violations compared to Driver 5 who registered a steady climb in the number of headway monitoring warning. Driver 11, on the other hand, registered a downtrend in the unblind phase before recording a steep uptrend in the reblind phase. Figure 8 below depicts the headway monitoring warning as indicated in the study findings.

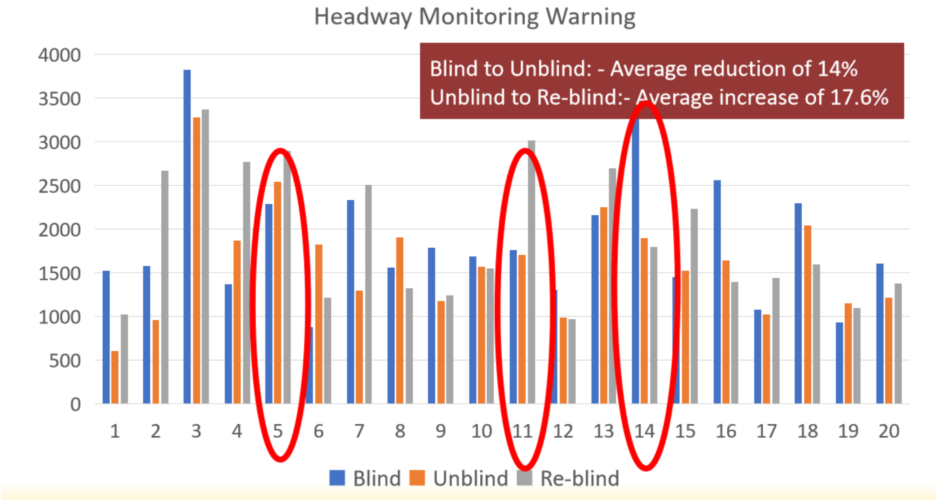

Fig. 8. Headway Monitoring Warning

5.8 Lane Departure Warning

Finally, the study also examined the lane departure warning violations among the participants. As illustrated in Figure 9, there was an average drop of 49% in the number of violations in the transition from the blind to the unblind phase. Nevertheless, a notable uptrend was registered from the unblind to the reblind phase where violations among the participants rose by 82.1%. Looking further at the trend in the blind and reblind phases, the results indicated that violations jumped by 7.6%. Using Drivers 5 and 11 as examples, there was a slight decrease in violations from the blind to the unblind phase before the cases climbed during the reblind phase. As for Driver 14, the transition from the blind to the unblind phase showed a significant decrease in violations before a marked increase was observed in the reblind phase. Hence, lane departure warning is something that needs to further explored in future studies.

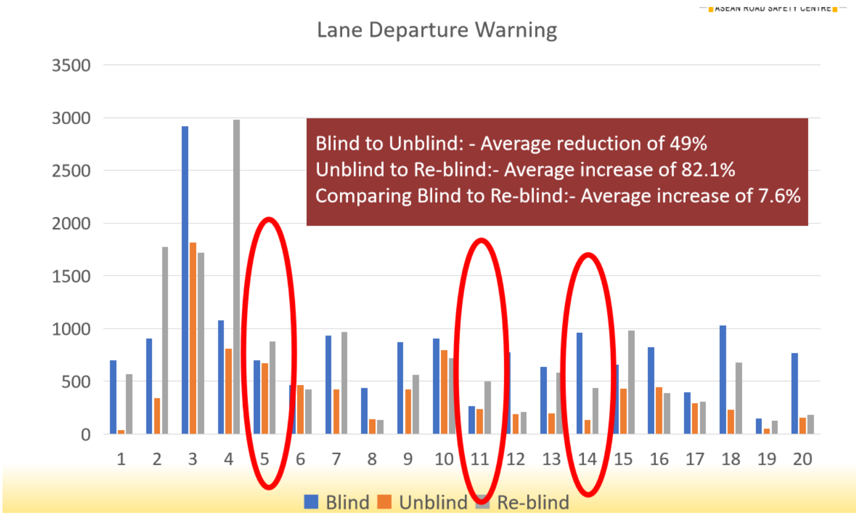

Fig. 9. Lane Departure Warning

6. Conclusions

To summarize, the study found that the use of ADAS was able to improve driver behavior while on the road as a whole. This is evident by the reduction in the number of violations among the study participants when the warning sound and visual display were activated during the unblind phase. In addition, the intelligent transport system was also able to promote safe driving habits among Malaysian drivers. With ADAS activated, the technology was able to provide warnings and prompt the driver whenever a violation was committed. In addition, the technology was also effective in reducing the number of violations. This is apparent by the reduction in the number of violations during the blind and reblind phases when the warning sound and visual display were purposely deactivated. It was therefore clear from the study findings that ADAS was able to bring about positive changes among the drivers. Hence. the relevant parties must explore the possibility of making ADAS affordable for every car owner.

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