IN CITY TRAFFIC EVALUATION OF VARIOUS CRASH AVOIDANCE FEATURES WITH CHINESE DRIVERS

Bing Deng
Raymond Kiefer
Wende Zhang
General Motors Safety Electronics & Innovation
U.S.A.
Paper Number 13-0181

ABSTRACT

This in-traffic study examined the performance and driver acceptance of various Crash Avoidance (CA) features with Chinese drivers on Shanghai urban, city roads. The test vehicle was a production 2011 Cadillac DTS equipped with Forward Collision Alert (FCA), Lane Departure Warning (LDW), Side Blind Zone Alert (SBZA), Front Park Assist (FPA), and Rear Park Assist (RPA) features. In addition, an "add on" camera-based FCA feature was installed on this test vehicle. Participants experienced the FPA and RPA features in a parking lot while approaching traffic cones, and then commenced a 25 km drive during normal traffic hours on urban roads. This drive included a variety of arterial, minor arterial, and branch roads. After this test drive, participants completed a series of questionnaires corresponding to each of the features they experienced. Overall, the RPA feature received generally more favourable ratings relative to the other features under these testing conditions. Furthermore, although undesirable false alarm activations associated with these features were observed, results generally indicated that the CA features evaluated appear promising in the China market.

INTRODUCTION

Various CA features are emerging in production vehicles offered in China. Given the unique traffic conditions and driver behavior characteristics in China, research is needed to examine the extent to which production crash avoidance features offered in other countries/markets (e.g., the United States) are well-suited, or at least readily adaptable, to these unique conditions. This in-traffic study provided an initial evaluation of the acceptance and performance of various CA features with Chinese drivers (primarily GM China employees) on Shanghai urban roads. The study employed a production 2011 Cadillac DTS (imported from the United States) equipped with a high level of crash avoidance feature content. Test participants were asked to drive the test vehicle on Shanghai urban surface roads and then provide subjective ratings on the various features that they experienced. The results reported here are part of a broader multi-study effort to gather feature performance and driver behavior data with crash avoidance features with Chinese drivers on China roads.

METHODOLOGY

Test Vehicle and Features Evaluated

To support this testing, a 2011 Cadillac DTS Platinum was imported from North America (see Figure 1) that was equipped with production FCA, LDW, SBZA, FPA, and RPA features. In addition, an "add on" prototype camera-based FCA feature was also installed on this test vehicle. (The vehicle was also equipped with Adaptive Cruise Control; but this feature was not used by participants in the current effort.) The radar-based production FCA feature lets the driver know when the feature detects a vehicle ahead, and warns the driver when following a vehicle directly ahead much too closely or when the driver may be in imminent danger of crashing into the vehicle ahead (Figure 3). In the latter case, a series of high-pitched warning beeps are sounded out the front speakers. The feature operates above 20 mph or 32 kph. The camera-based prototype FCA feature used an "add on" forward-looking camera sensor located on the windshield ahead of the rear view mirror. The feature also operates above 20 mph or 32 kph. The "add on" FCA display was located on the top of the dashboard to the right of steering wheel (Figure 3). Similar to the production radar-based FCA feature, when a vehicle is detected ahead, a green vehicle ahead display is lit. Furthermore, when the feature determines the vehicle is following too closely to the vehicle ahead, this display turns amber. When the feature determines that you may be in imminent danger of crashing into the vehicle directly ahead, this display turns red and flashes and a series of high-pitched warning beeps are sounded from the front.

The LDW feature operates above 35 mph or 56 kph, and requires at least one visible lane marking to operate. The LDW display is located in the instrument panel. When lane markings are detected ahead, a green LDW symbol is lit (Figure 4). If the vehicle drifts out of the lane without the turn signal activated, this symbol will turn amber and flash,

and three low-toned beeps are sounded. These beeps are played out of left front or right front speaker, depending on the direction of the lane departure.

The SBZA feature operates at all speeds when moving forward. The SBZA warning symbol is located in both outside side mirrors. When a vehicle is detected in the left/right blind zone, this symbol is lit in the left/right mirror. If the turn signal is activated in the direction of a detected blind zone vehicle, the SBZA warning symbol flashes to give the driver extra warning not to change lanes (Figure 5).

The FPA feature assists the driver in avoiding objects directly ahead of the vehicle while moving forward during low speed parking (i.e., below 5 mph or 8 kph). The object distance display for this feature is located on the top of the dashboard to the right of steering wheel in the center of the vehicle. This display uses two amber indicators and one red distance indicator light to warn the driver (Figure 6). When the vehicle is within 0.3 meters of a detected object, all three lights will flash and repeating high-pitched beeps are played out of both front speakers.

Similarly, the RPA feature assists the driver in avoiding objects directly behind the vehicle while backing during low speed parking (i.e., below 5 mph or 8 kph). The object distance display this feature can be viewed in the rear of the vehicle as the driver looks over their right shoulder. This display may also be visible in the rear view mirror. This display uses two amber and one red distance indicator light to warn the driver (Figure 7). When the vehicle is within 0.3 meters of a detected object, all three lights will flash and repeating low-pitched beeps are played out of both rear speakers.

Figure 1. Production 2011 DTS test vehicle

Figure 2. Forward Collision Alert (FCA) display

Figure 3. Camera-Based Forward Collision Alert (FCA) display

Figure 4. Lane Departure Warning (LDW) display

Figure 5. Side Blind Zone Alert (SBZA) display

Figure 6. Front Park Assist (FPA) display

Figure 7. Rear Park Assist (RPA) display

Data Acquisition Systems

The vehicle operational data was logged through the CAN bus. The operational and alert data from the “add on” prototype camera-based FCA feature was recorded and synchronized with vehicle data.

Test Participants

Test participants included 17 males and 6 females between the ages of 25 and 43 years old, with a median age of 33 years old. Figure 8 provides an age breakdown of the test participants. 70% of the test participants were between 25 and 35 years old, which corresponds well to Shanghai statistics indicating that more than 75% of driver license holders are younger than 35 years old [1]. Twenty of the 23 test participants were GM China employees, who had between 1 and 13 years of driving experience (with a median value of 6 years of experience). The remaining three test participants were company drivers who had 8, 11, and 16 years of driving experience.

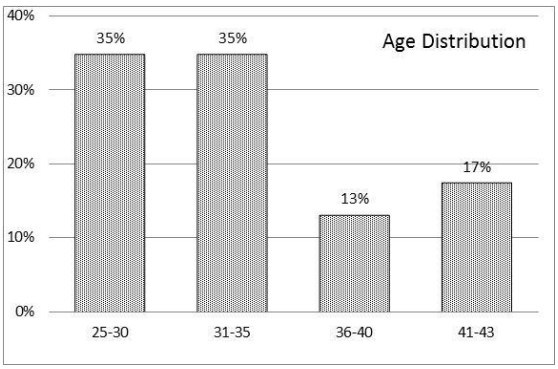

Figure 8. Age Breakdown of Test Participants

Test Procedure

A detailed PowerPoint and video description of each of the features evaluated (both available with Mandarin Chinese translation) was used for the initial training of all test participants. This training occurred as part of a "question and answer" workshop that occurred a few weeks before formal testing commenced.

On the day of a participant's test session, they were required to read and sign an Informed Consent Statement prior to participating in the study. Next, participants viewed the same feature-by-feature training video using in the previous workshop training. Participants then drove the test vehicle (accompanied by an experimenter), and initially were exposed to the FPA and RPA features in a parking lot while slowly approaching traffic cones.

Next, the test participants drove a 25 km (or 15 mile) test route between either between 9:30 and 11:30 am or between 2:00 and 4:00 pm. Participants drove on one of two urban surface road routes in Shanghai. These test routes included a variety of surface road types, including arterial, minor arterial, and branch roads.

It should be noted that on Shanghai arterial roads, 42% of traveling distance occurs at speeds of less than 40 kph (or 25 mph) [2]. Consistent with these traffic congestion-related findings, the 25 km (or 15 mile) test route took approximately 1-2 hours to complete (depending on traffic conditions). At the completion of the test drive, participants were asked to complete a series of 2-page questionnaires (translated into Mandarin Chinese) that addressed their perceptions and impressions of each of the features they experienced during testing. The questionnaires were designed, to the extent possible, to ask the participants the exact same set of questions for each feature. This questionnaire strategy was employed in order to enable direct comparisons across features, as well as shorten the time needed for the driver to complete the entire set of questionnaires.

RESULTS

The features evaluated were exposed to a rich set of "objects to be detected" (e.g., pedestrians, bicyclists, electric bicycles, motorcycles, and over-loaded carts) under driving conditions that are felt to be more dense, less orderly (with respect to drivers consistently following traffic rules), and more aggressive (e.g., frequent cut-ins and lane changes) than those typically found under United States (US) driving conditions. Figure 9 illustrates various aspects of the challenging China traffic environment, including unusual-looking vehicles, over-loaded vehicles, and complex busy intersections.

Figure 9. Challenging China traffic environment

All FCA questionnaire results reported below are associated with the FCA camera feature, since the logged vehicle operational data indicated no alerts were issued by the production radar-based FCA feature. The lack of FCA warnings observed from this FCA feature tentatively suggests that the associated production FCA timing approach would not be false alert prone under the test conditions evaluated.

Comparison among different systems was conducted using the eight rating dimensions listed below. Each dimension employed a 5-point rating scale with labeled points of 1= Disagree Strongly, 3=Neutral, and 5= Agree Strongly.
OVERALL: Overall, how would you rate your driving experience with the system?
PURCHASE INTEREST: I would like to have the system in my next vehicle
PLEASEABILTY: I was pleased with the system
HELPFULNESS: I think the system would help me in my everyday driving
SAFETY: I think the system would increase my driving safety
CRASH AVOIDANCE: I think the system would help me avoid relevant crash type
UNDERSTANDABILITY: The alerts came on, I understood why

ANNOYANCE: The alerts were annoying

The overall mean rating for each dimension is shown in Figure 10. The RPA feature received generally more favorable ratings relative to the other features evaluated under these testing conditions, suggesting that the RPA system (including the human machine-interface approach) evaluated appears well-suited for the China market. The remaining features evaluated yielded similar subjective ratings by the test participants, with overall mean ratings generally ranging between "3" (neutral) and "4" on the 5-point scale (where "5" corresponds to "strongly agree"). (Note, for the annoyance dimension, a lower number is a more favorable rating.) In addition, the ratings surrounding the "add on" prototype camera-based FCA system are promising.

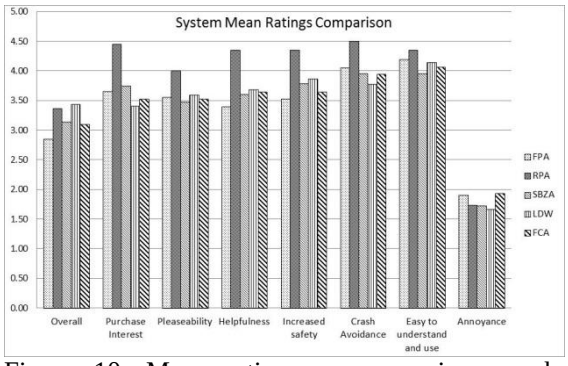

Figure 10. Mean ratings across various crash avoidance systems

When interpreting these results (in particular the SBZA and LDW findings), it is important to note that frequent lane change and prolonged "lane hovering" (i.e., driving on lane boundary for prolonged periods of time) are common strategies drivers use to gain a traffic queue advantage in China. In addition, as in other countries, some drivers may not use turn signals or scan their mirrors as part of their lane change behavior (note turn signal activations are used to suppress LDW alerts in the LDW system that was evaluated).

Another important caveat of these results is the relative low levels of driving experience test participants had with the features evaluated. Indeed, the relatively high RPA ratings could be attributed to driver's greater familiarity and experience with this particular feature. Hence, it should be noted that with increased exposure to CA features, the acceptance ratings of Chinese drivers could change (and hopefully become more positive).

Figure 11 provides results and the rating choices from the following alert timing question:
TIMING: Please rate the timing of when alerts came on.

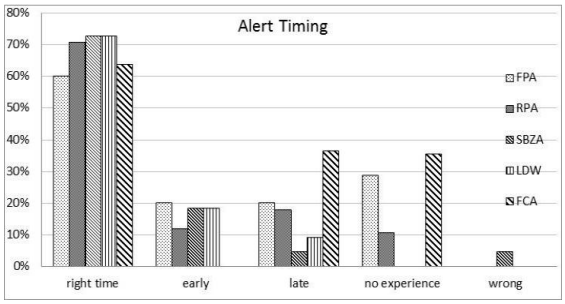

Figure 11. Alert timing ratings across systems

As shown on the right side of Figure 11 (under the "no experience" category), all drivers reported experiencing LDW and SBZA alerts, and the percentage of participants reporting no experience with the FPA, RPA, and (prototype camera-based) FCA alerts were 29%, 11%, and 35%, respectively. Even though all participants were given the opportunity to experience the FPA and RPA features in a parking lot while slowly approaching traffic cones, some did not provide the FPA and RPA alert timing ratings. These alert timing results indicate that the "right time" category received the highest percentage of ratings for each of the features evaluated, and that no "unacceptably late" ratings were observed. In addition, overall, the incidence of "unacceptably early" ratings was relatively low across features.

Figure 12 provides results from the following "anticipated system usage" question:
ON/OFF IN OWN VEHICLE: If I had the system I experienced on my own personal vehicle I would leave the system ON or OFF.

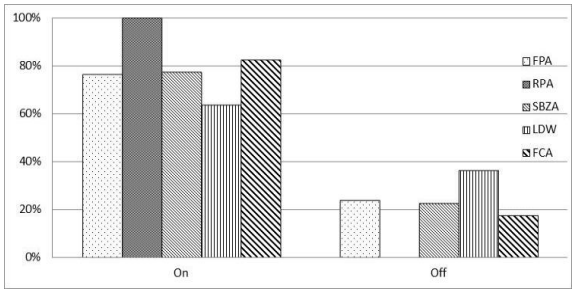

Figure 12. ON/OFF feature usage preferences across various crash avoidance features. (Note "ON" ratings combined results from the "ON all of the time" and "ON most of the time" categories, and "OFF" ratings combined results from the "OFF all of the time" and "OFF most of the time" categories.)

Results in Figure 12 indicate that that the percentage of drivers reporting they would leave these features ON (either all or most the time) ranged from a low of 64% for the LDW feature to a high of 100% for the RPA feature. This pattern of "anticipated system usage" findings is consistent

with the pattern of mean ratings of "purchase interest" shown in Figure 10.

Figure 13 provides results from the following two system-performance oriented questions:
FALSE ALARMS: Did you notice any instances when the system alerted when it should not have done so?
MISSES: Did you notice any instances when the system did not alert when it should have?

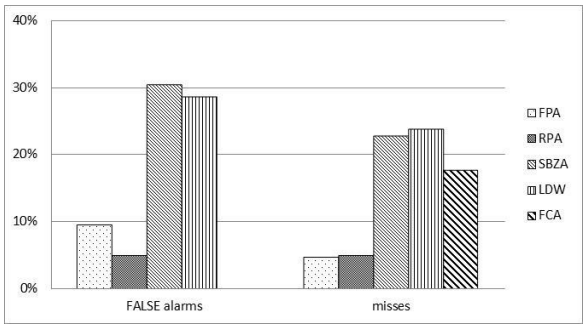

Figure 13. Reported false alarms and misses across various crash avoidance features

As shown in Figure 13, some test participants reported experiencing false alarms with the RPA, SBZA, and FPA features. In addition, some test participants reported experiencing misses with the LDW, SBZA, and (prototype camera-based) FCA features. It should be noted that these subjective data do not necessarily correspond to intended system performance, and that these subjective reports could be due to test participant's incorrect understanding of feature operation (particularly given their limited experience with these features under the current test conditions).

Given these important caveats on this subjective data, reported experiencing relatively higher levels of false alarms and misses with the LDW and SBZA features. Reported LDW false alarms tended to be associated with curves and freeway ramp scenarios, whereas reported misses for this feature tended to be associated with poor lane markings. Reported SBZA false alarms were associated with structures being very close to road edges (e.g. guardrails, barriers, trees), whereas miss issues were associated with the feature failing to detect other vehicles when stopped.

CONCLUSIONS

The results reported here are part of a multi-study effort to gather system performance and driver behavior data with crash avoidance features with Chinese drivers on China roads. Overall, the GM production and prototype "add on" crash avoidance features evaluated appear reasonably well-suited for the China market. It should be noted that the test participant's (aged 25 to 43) had extremely limited experience with these features relative to a feature owner (with the possible exception of the RPA feature). With respect to the relatively young age of the test participant's, the reader is reminded that 75% of driver license holders in Shanghai are less than 35 years old [1].

The RPA feature employed was particularly well-received by test participants, and appears well-suited for the China market. The preponderance of low speed travel on urban roads in China coupled with the close proximity and dense clusters of "objects of interest" (vehicles, pedestrians, and bicyclists) are consistent with the observed subjective ratings. In addition, the China driving environment and driving conditions more generally suggest that other "near field", low speed operation features (e.g., "distance to object" graphical displays, Rear Vision Camera, 360 degree camera-based surround-view feature, pedestrian/bicyclist detection) would similarly be well-received by Chinese drivers.

The LDW feature received the lowest anticipated driver usage ratings under these "limited experience" testing conditions, and the LDW and SBZA features had the highest levels of subjectively "reported" false alarms and misses. It is hypothesized that potentially the relatively high frequency of lane changes (and lane hovering), lower use of turn signals, and/or lower use of mirrors could have played a role in these subjective LDW and SBZA ratings. Hence, efforts should be pursued to attempt to better accommodate these features to the China market (which may benefit other markets as well), in order to help ensure drivers leave these features on.

Finally, multiple sensing and sensor fusion approaches (e.g., mono/stereo camera, radar, lidar, laser, and ultrasonic sensing) should be considered to improve feature performance under the challenging dense, dynamic, and generally less predictable vehicle, bicyclist, and pedestrian traffic conditions characteristic of urban China. These approaches may have particular importance for features that automatically control (e.g., brake and/or steer) the vehicle in order to avoid or mitigate the impact of potential crash.

REFERENCES

[1] Shanghai Statistics: http://www.stats-sh.gov.cn/ (2009 to 2011)
[2] Xuesong Wang, Haobing Liu, Xiaohong Chen, and Bing Deng, "Exploring Speeds on Urban Arterials using Floating Car Data: A Case Study in Shanghai", Journal of Transportation Engineering, 2012.