

# **Driver Adaptation to In-vehicle Intelligent Transport Systems: Preliminary Findings from the TAC SafeCar Project**

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## **ABSTRACT**

The Australian TAC SafeCar project is one of a growing number of on-road trials examining the effects on driver performance and safety in-vehicle intelligent transport systems (ITS). The aim of the project is to evaluate the potential road safety benefits of three in-vehicle ITS: Intelligent Speed Adaptation; Following Distance Warning; and Seat Belt Reminder. These systems, along with a Reverse Collision Warning system and Daytime Running Lights, have been equipped to 15 Ford passenger cars leased by several Government and commercial organisations in Melbourne. A total of 23 drivers will drive a SafeCar for approximately 17,000km. The project aims to examine behavioural adaptation to, and acceptance of, the technologies, separately and in combination, over time. The technical reliability of the systems is also being assessed. This paper presents some preliminary findings on the effects on driving performance of exposure to the Intelligent Speed Adaptation, Following Distance Warning and Seat Belt Reminder systems.

## **INTRODUCTION**

It is well recognised in Australia and overseas that in-vehicle Intelligent Transport Systems (ITS) have great potential to enhance road safety (1). In 1999, the Transport Accident Commission of Victoria (TAC) commissioned the Monash University Accident Research Centre (MUARC) to undertake what has become known internationally as the "TAC SafeCar" project. The ultimate aim of the project is to stimulate demand, initially by Victorian corporate fleet car owners and, in the longer term, by car drivers in the general community, for in-vehicle ITS technologies that are estimated to have high safety potential.

The project is a four-phase collaborative research project involving, as key partners, the TAC, MUARC, and the Ford Motor Company of Australia (Ford). Phase 1 of the project culminated in the selection of several in-vehicle ITS technologies that are estimated to have the potential to significantly reduce road trauma in Victoria, and

elsewhere in Australia. Phase 2 involved the development of functional and Human-Machine Interface (HMI) specifications for these ITS systems, the purchase and/or development of them, the fitment of them to two Ford demonstration vehicles, and testing of the technologies for usability and reliability. In Phase 3, 15 Ford passenger cars were equipped with four ITS technologies: Intelligent Speed Adaptation (ISA); Following Distance Warning (FDW); Seat Belt Reminder (SBR); and Reverse Collision Warning (RCW). During this Phase, the systems were also tested for acceptance against the original specifications (2). Phase 4, due for completion in late 2004, has involved a field evaluation of the four technologies as well as a simulator evaluation of two variants of ISA. The purpose of the field evaluation is to assess the technical operation of the ITS technologies, evaluate driver acceptance of them, and investigate the separate and combined effects of the technologies on driving performance and safety (3).

## **ITS TECHNOLOGIES**

Detailed descriptions of the four ITS technologies equipped to the TAC SafeCars have been provided elsewhere (3). Briefly, the ISA system is designed to warn the driver when he/she is travelling 2 km/h or more over the posted speed limit. When this occurs, the driver hears a momentary auditory “bong” and sees, on a 9.7 cm visual warning display mounted on the dashboard, a miniature speed sign showing the prevailing limit. Upward pressure on the accelerator pedal is felt if these stage 1 warnings are ignored for 2 seconds or more. The FDW system is designed to warn the driver if he/she is following the vehicle immediately ahead too closely. There are six levels of visual warning (displayed on the visual warning display), which increase in intensity as following distance decreases. The final visual warning is accompanied by an auditory warning. Visual warnings occur at time headways below 2 seconds, and the auditory warning occurs when time headways are less than 1.1 seconds. The SBR system issues a visual warning when any vehicle occupant is unrestrained and the vehicle speed is less than 10 km/hr. Auditory warnings are issued at progressively higher intensities at speeds above 10 km/hr. Finally, the RCW system is a reversing aid that warns the driver, via auditory warnings, if he/she is about to collide with an object to the rear of the vehicle. The repetition rate of the auditory warnings increases as the distance between the vehicle’s rear and the object decreases. The test vehicles have been fitted with a number of additional on-board systems to support the on-road study, including a System Override Button and a Data Logging System.

## **PHASE 4 STUDY DESIGN**

The field trial will involve 23 participants, each of whom will drive one of the 15 SafeCars for at least 16,500 kilometers. Participants have been recruited from Government and private companies in and around Melbourne. Of the 23 participants, 15 comprise the treatment group and 8 comprise the control group.

For the purposes of the study, the four ITS technologies in the SafeCars are divided into “key” systems and “background” systems. The key systems are the ISA and FDW systems, and the background systems are the SBR and RCW systems. The

treatment participants are exposed to both the key and background systems, while the control participants are exposed to the background systems only.

The treatment participants are not exposed to all four ITS technologies for the entire length of their trial. The ITS systems turn on and off at predetermined points in the trial, in order to assess the effects of these systems on driving performance before, during and after exposure. The trial for the treatment participants is divided into several discrete periods: the Familiarisation, Before, During and After periods. The Familiarisation period lasts for 200 kilometers and provides drivers with the opportunity to get used to driving the SafeCar before any ITS technologies are engaged and driving data are logged. Next is the Before 1 period, lasting for 1,500 kilometers. During this period, the data logger, which records a range of driving performance data, is activated and baseline performance data are collected. No ITS warnings are issued in this period. Next is the Before 2 period, which lasts for 1,500 kilometers. In the Before 2 period the RCW and SBR systems are active and these systems remain on for the rest of the trial.

The purpose of the During periods is to assess the effect on driving performance of the ISA and FDW technologies in the SafeCars. There are three During periods, each lasting 3,000 kilometers. The During 1 period occurs immediately after the Before 2 period. In addition to the RCW and SBR systems, the driver receives warnings from the ISA, FDW system, or both systems concurrently. The system or system combination received in each During period is counterbalanced across drivers to control for any order effects. Each During period is followed by a 1,500 kilometer "After" period in which the system(s) that was active in the previous During period is disengaged. Several participants also experience an 'After Trial' period, in which all SafeCar systems are turned off.

The trial for the control participants is divided into two periods: the Control 1 and Control 2 periods. The Control 1 period is equivalent to the Before 1 period experienced by the treatment participants. During the Control 2 period, the SBR and RCW systems are engaged. This period lasts for the remainder of the trial (15,000 kilometers). Several of the control participants also experience an After Trial period, in which all SafeCar systems are turned off.

## **PRELIMINARY FINDINGS**

At the time this paper was written, all 23 SafeCar participants had commenced the on-road study. Fifteen of these participants have been assigned to the treatment group and eight to the control group. Of these participants, thirteen (nine treatment and four control) had completed their trial. Preliminary results on the effects of the ISA, FDW and SBR systems on drivers' driving behaviour during the trial are presented here for *eight* of the treatment drivers who have completed their trial and for which full data sets are available. All of these eight treatment participants are male and range in age from 33 to 59 years. All data are aggregated across the eight treatment participants. Data are not provided for the control drivers, as only a partial data set was available for one control driver at the time of writing this paper. Unless

otherwise indicated, the analyses reported are descriptive only, as the small number of participants, in most cases, does not warrant the use of any inferential statistics at this point in time.

In order to examine changes in driving behaviour *across* and *within* the individual trial periods, each period has been broken down into 750 km intervals. In addition, as the analyses have been aggregated across the eight treatment drivers and each treatment driver received the ISA and FDW systems in different orders, it was necessary to present the data separately for the ISA, FDW, and ISA and FDW combined driving periods to avoid inferring that all drivers received the same system order across the During periods. In each case, data is presented for the:

- Before 1 period; the ISA, FDW and ISA & FDW *'Before'* period, which corresponds to the period directly before drivers received a particular system(s);
- ISA, FDW and ISA & FDW *'During'* period, which corresponds to the During period in which a particular system(s) was activated; and
- ISA, FDW and ISA & FDW *'After'* period, which corresponds to the period directly following the During period in which each driver received a particular system(s).

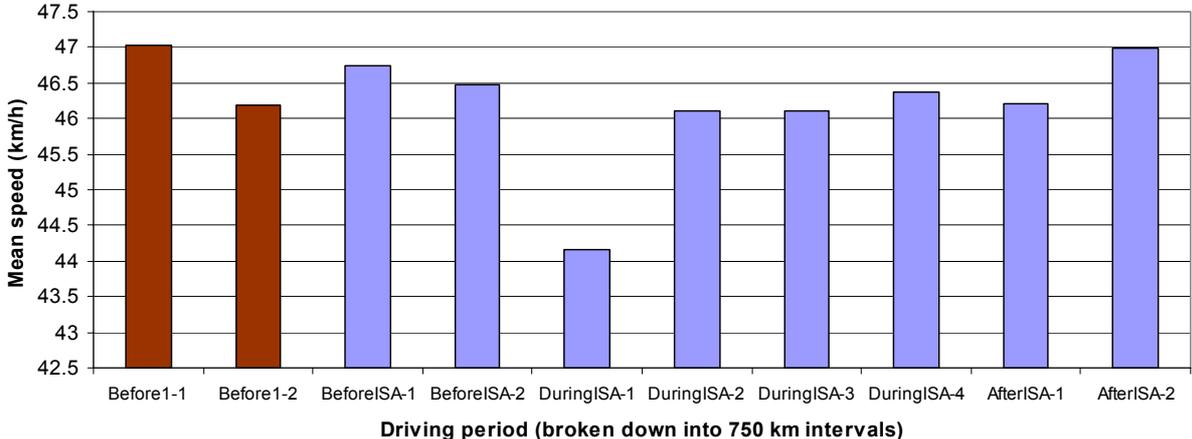
## INTELLIGENT SPEED ADAPTATION

Several speed-related driving performance variables have been analysed for the eight treatment drivers, including mean and peak speeds, speed variability (standard deviation), and mean trip time. These analyses were calculated separately for speed data collected in five speed zones (50, 60, 70, 80 and 100 km/h roads). Figures 1 to 3 present example mean speed profiles on 50 km/h roads for the ISA, ISA & FDW combined and FDW driving periods (each sub-divided into 750 km intervals) respectively.

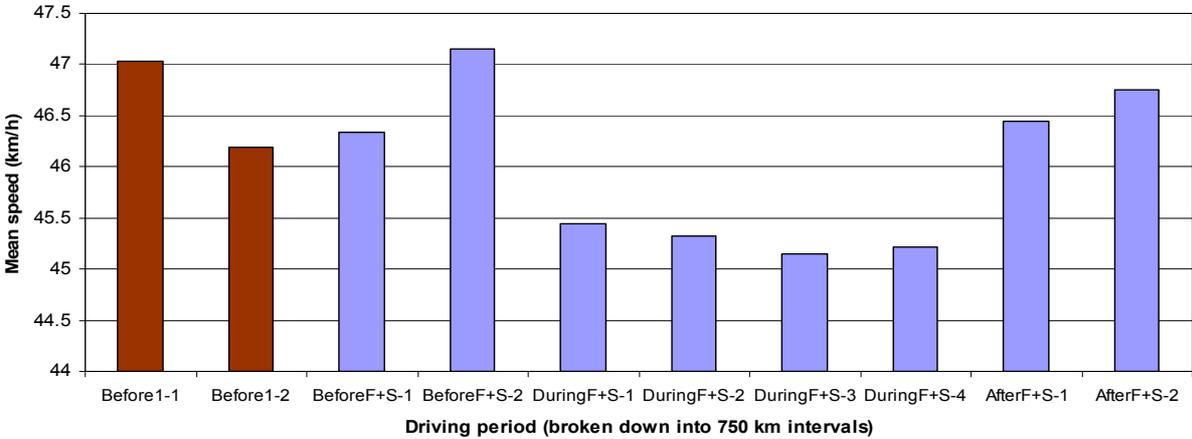
The treatment drivers' mean driving speeds, averaged across the five speed zones, reduced by up to 3 km/h when the ISA system was active. In addition, the treatment drivers spent 2% *more* of their driving time at or below the speed limit and 1% *less* time driving above the speed limit when the ISA system was active. Interestingly, the reductions in speed were more pronounced when the ISA and FDW systems were both active. Mean speeds after the ISA system was turned off were only slightly lower than those recorded *before* the system was switched on, implying that most of the speed reduction benefit from the ISA system was obtained only while the system was active.

A reduction of up to 1.5 km/h in speed variability was also found when the ISA system was active (either alone or in combination with the FDW system) and this pattern was consistent across all speed zones. Speed variability after the ISA system was switched off was only slightly lower than that recorded before the system was activated; again implying that most of the benefit from the ISA system was obtained while the system was active.

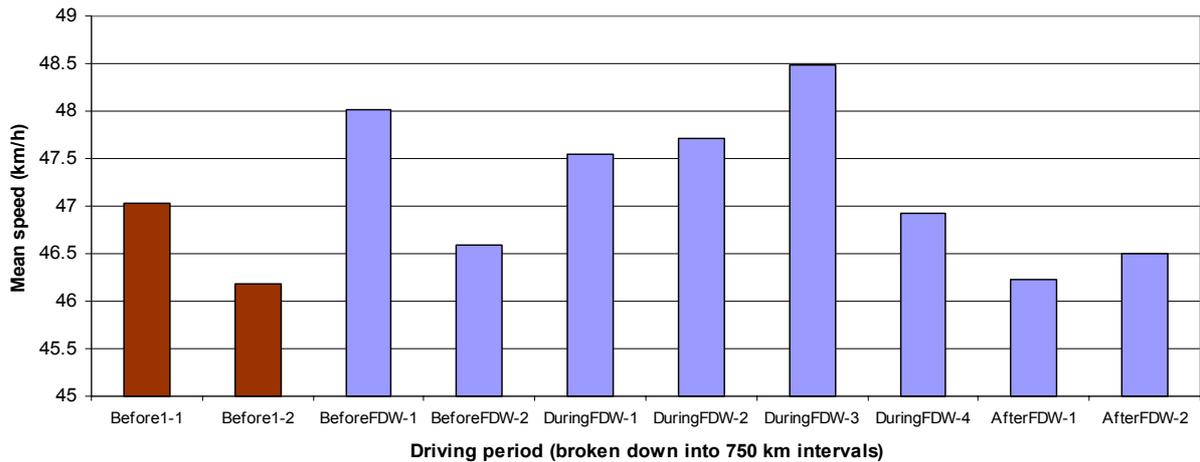
Finally, there was little preliminary evidence that the treatment drivers' trip times increased substantially with the use of ISA, with mean trip times increasing by up to only 1 minute when this system was active. This is a positive finding, as it suggests that, while drivers' mean and peak speeds were lower when the ISA system was active, this reduction in mean speed did not translate into an appreciable increase in trip time, presumably due to the reduction in speed variability during these periods.



**Figure 1.** Mean speed profile in 50 km/h zones across the ISA periods for the treatment drivers



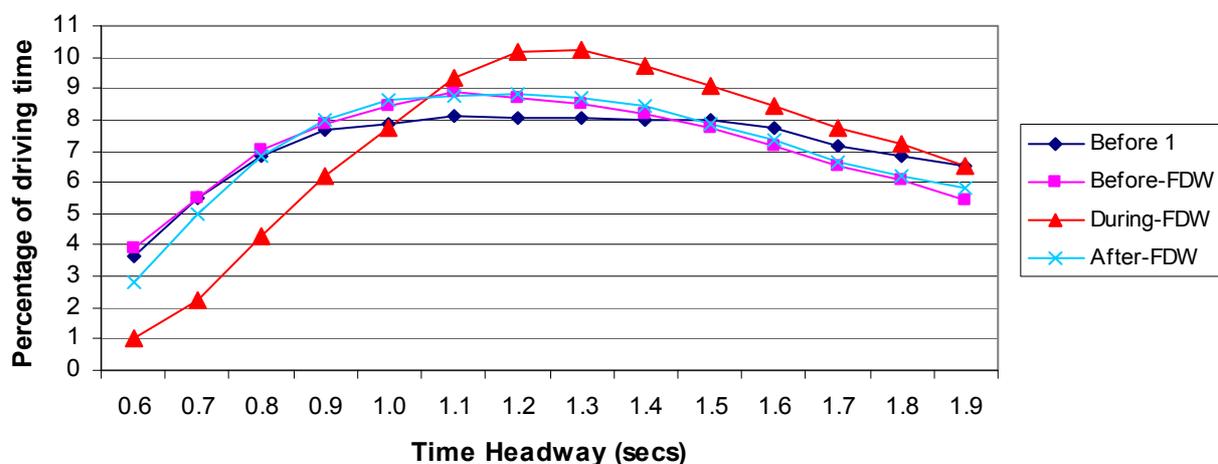
**Figure 2.** Mean speed profile in 50 km/h zones across the ISA & FDW periods for the treatment drivers



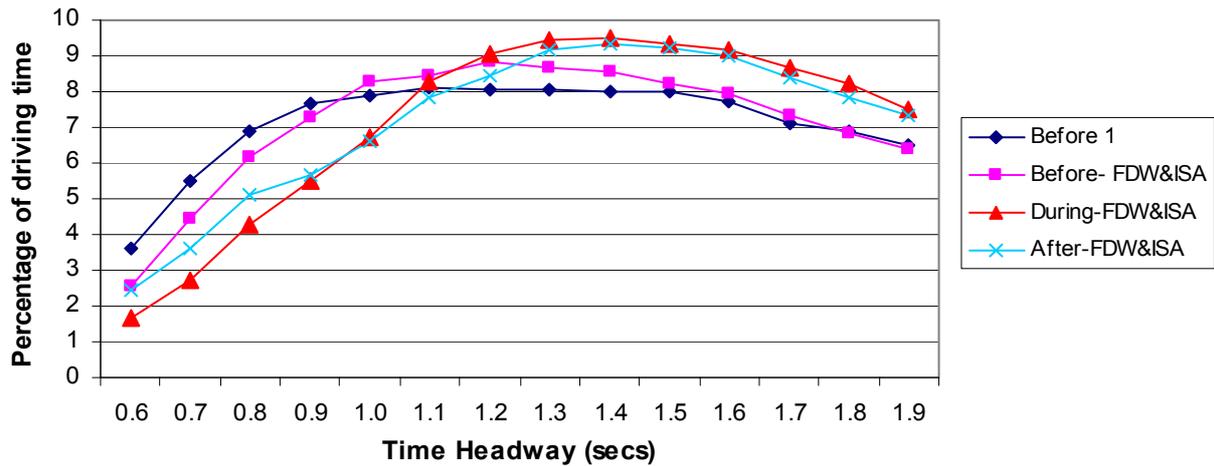
**Figure 3.** Mean speed profile in 50 km/h zones across the FDW periods for the treatment drivers

### FOLLOWING DISTANCE WARNING

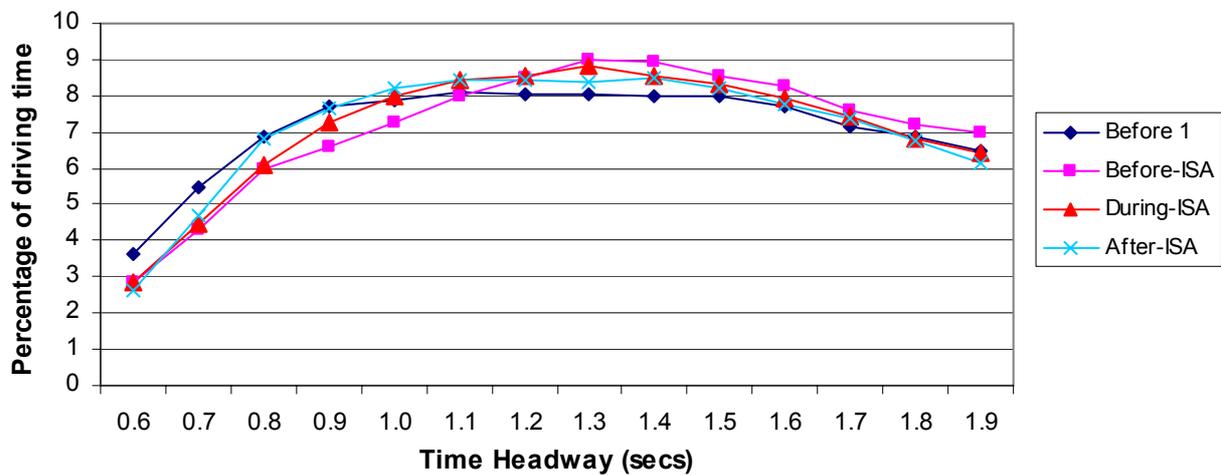
The percentage of driving time spent at each time headway from 0.6 to 1.9 seconds in each driving period was calculated for the eight treatment drivers. This was calculated for following distance data collected over five speed zones (50, 60, 70, 80 & 100 km/h roads) combined. Figures 4 to 6 display the percentage of time spent at each time headway for the FDW, FDW & ISA combined, and ISA driving periods, respectively, for the treatment drivers. As illustrated, when the FDW system was active (During period), either by itself or in combination with the ISA system, drivers spent up to 2.5 percent less time driving at headways less than 1.0 seconds and up to 1 percent more driving time at headways above 1.0 seconds, compared to the Before FDW period. This finding was statistically significant. This trend appears strongest when the FDW system alone was active. Interestingly, when operating on its own, the ISA system also encourages drivers to adopt longer following distances; although this effect is not as pronounced as when the FDW system operates alone or in conjunction with the ISA system.



**Figure 4.** Percentage of time spent at different time headways across the FDW periods for the treatment drivers



**Figure 5.** Percentage of time spent at different time headways across the FDW & ISA periods for the treatment drivers



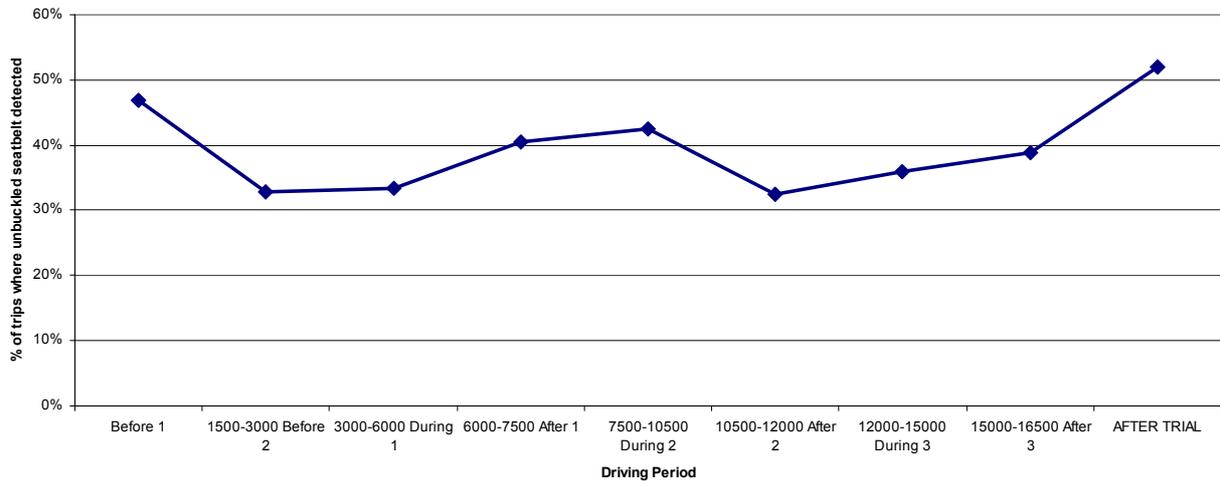
**Figure 6.** Percentage of time spent at different time headways across the ISA periods for the treatment drivers

## SEAT BELT REMINDER WARNING

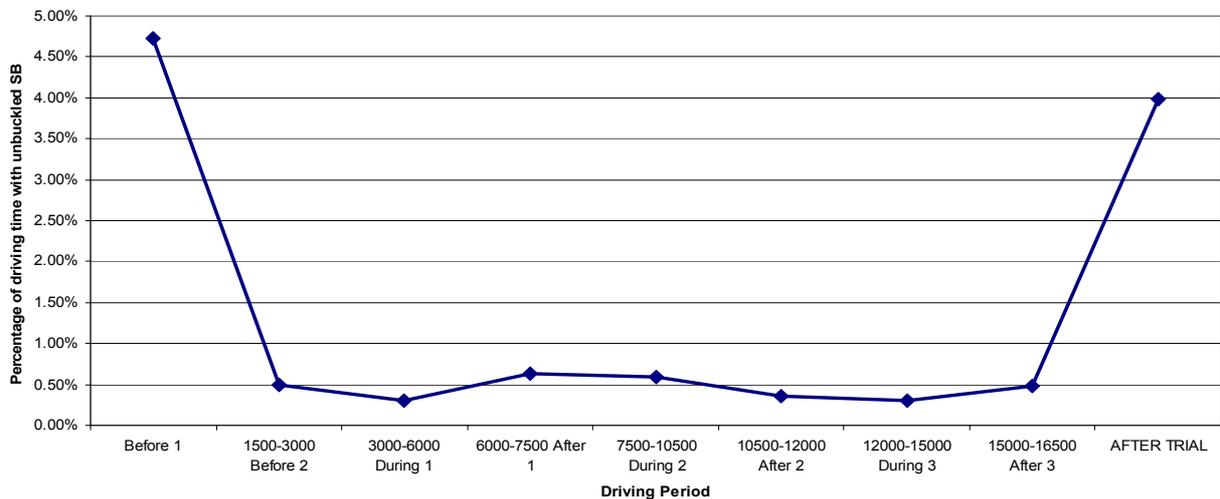
The percentage of trips and total driving time in which a SafeCar occupant was unbuckled, and the mean time taken to buckle up from the onset of the warnings, was calculated for each driving period. The SBR data were aggregated across the eight treatment drivers. The data obtained for the SBR system were analysed for all roads travelled on (averaged across speed zones). Figures 7 to 9 display the percentage of trips and percentage of total driving time in which a SafeCar occupant was unbuckled, and the mean time taken to buckle up from the onset of the warnings, respectively.

The percentage of trips undertaken whilst unbuckled and the percentage of travel time where a seatbelt was unbuckled both decreased substantially (by an average of 30% and 90%, respectively) in the Before 2 period when the SBR system was first activated. The average time taken to buckle up from the onset of the warnings also

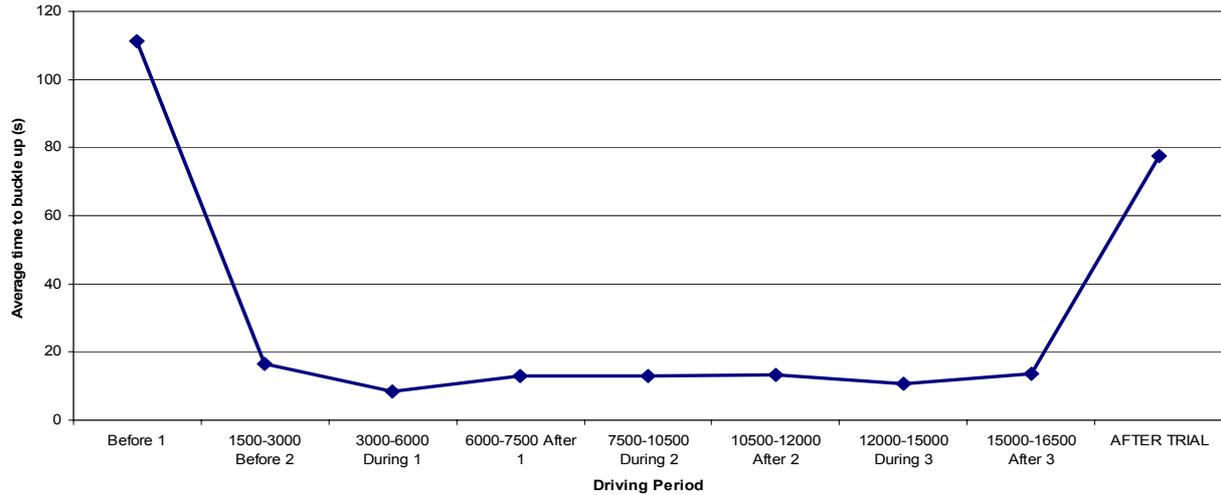
decreased from 130 seconds to 7 seconds when the SBR system was first activated. There was, however, a tendency for the percentage of trips and travel time spent unbuckled, and the average time to buckle, to increase slightly over the remainder of the trial, implying that the treatment drivers became more tolerant of the system warnings over time. Nevertheless, at the end of the trial, the percentage of trips and travel time spent unbuckled and the average time to buckle were well below Before 1 levels (approximately 17%, 90% and 120 seconds below, respectively).



**Figure 7.** Percentage of trips with seatbelt unbuckled for the treatment drivers.



**Figure 8.** Percentage of driving time with seatbelt unbuckled for the treatment drivers.



**Figure 9.** Mean time taken to buckle seatbelt for the treatment drivers.

## DISCUSSION AND CONCLUSION

The data reported in this paper, although mainly descriptive, suggest that all three SafeCar systems have a positive effect on the driving behaviour of treatment drivers. The ISA system installed in the SafeCars is functionally similar to the Active Accelerator Pedal system trialed in the Swedish city of Lund during 2000 and 2001 as part of a large-scale ISA evaluation study (4). The findings from the SafeCar study reported here, although preliminary and pertaining to only a sub-set of the speed zones being examined (i.e., 50 km/hr speed zones), are generally consistent with those found in urban areas in the Lund study: namely, a reduction in average speeds, less speed variation, and little or no increase in trip times. The TAC SafeCar study is the first study known to the authors, however, to examine the combined effect of ISA and FDW on driving performance. The preliminary findings reported here suggest that the speed reduction effects of ISA may be more pronounced when used in conjunction with the FDW system.

The SafeCar study is also the first to examine long-term exposure (over 6000 km of driving) to a FDW system, although exposure to a laser-based FDW device over a relatively shorter distance (about 110 km) on a six-lane divided highway has been examined previously (5). The preliminary findings from the present study, like those of Ben-Yaacov et al. (5), suggest that following distance warning systems are effective in making drivers spend less time at shorter time headways. Moreover, the preliminary findings reported here suggest that the use of ISA alone can also encourage drivers to adopt longer headways, although this effect is not as pronounced as when the FDW system is operational.

Finally, the SafeCar study is the first to examine long-term adaptation to a Seat Belt Reminder system. The preliminary findings from this study suggest that driver interaction with this system can lead to large decreases in the percentage of trips driven with an occupant unbelted, in the percentage of total driving time spent unbelted, and in the time taken to fasten a seat belt after the vehicle is started. These

findings provide empirical evidence for the potential safety gains estimated to be derived from use of SBR systems (6).

The TAC SafeCar project has yielded a massive amount of data, both logged and self-reported, relating to the technical operation of the ITS technologies, driver acceptance of them, and their effects, separately and in combination, on driving performance and behaviour over time. Of itself, the data from the Before period (i.e. baseline period) provides, for the first time in Australia, valuable data on drivers' naturalistic driving behaviours in a wide range of traffic conditions. A recently completed simulator experiment, undertaken as part of the project, has investigated additional issues not able to be examined in the field trial. These include the extent to which the design of the HMI for ISA systems affects short-term adaptation to them (specifically whether tactile warning systems are more effective than non-tactile systems), and the effectiveness of ISA systems for young novice drivers versus more experienced drivers. The results of more formal statistical analyses of the data reported here will be presented at this conference.

The authors are aware of an ISA system, available as a low-cost aftermarket product, that is likely to enter the Australian market early in 2005. The findings from the TAC SafeCar project will provide, among other things, timely data to support the early deployment in Australia of this technology.

## ACKNOWLEDGEMENTS

The authors acknowledge the support of the following organisations: Autoliv; Barker Technics Pty Ltd; Bosch; Digital Device Development Group Pty Ltd; Intelematics; OzTrak; PC Host; Royal Automobile Club of Victoria; VicRoads; Victoria Police; and Wiltronics Research Pty Ltd.

## REFERENCES

1. Regan, M., Oxley, J., Godley, S. and Tingvall, C. (2001). *Intelligent Transport Systems: Safety and Human Factors Issues*. Royal Automobile Club of Victoria Literature Report No. 01/01. Melbourne, Australia: RACV Ltd.
2. Regan, M.A., Mitsopoulos, E., Triggs, T.J., & Tingvall, C. (2002). The Australian TAC SafeCar project: On-road evaluation of multiple in-car ITS. *Proceedings of the 9th World Congress on Intelligent Transport Systems* (CD-ROM). Chicago, USA.
3. Regan, M.A., Mitsopoulos, E., Triggs, T.J., Tomasevic, N., Healy, D., Tierney, P., & Connelly, K. (2003). Multiple in-vehicle intelligent transport systems: Update on the TAC SafeCar project. *Proceedings of the 10th World Congress on Intelligent Transport Systems* (CD-ROM). Madrid, Spain.
4. Varhelyi, A., Hjalmdahl, M., Hyden, C., and Draskoczy, M. (2004). Effects of an active accelerator pedal on driver behaviour and traffic safety after long-term use in urban areas. *Accident Analysis and Prevention, Vol 36*, 729-737.
5. Ben-Yaacov, A., Maltz, M., and Shinar, D. (2002). Effects of an in-vehicle collision avoidance warning system on short- and long-term driving performance. *Human Factors, Vol 44*, 335-342.
6. Fildes B.N., Fitzharris M., Koppel S. & Vulcan A.P. (2002). *Benefits of seat belt reminder systems*. Report CR 211a. Australian Transport Safety Bureau.