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Effects on Driving Performance of In-Vehicle Intelligent Transport Systems: Final Results of the Australian TAC SafeCar Project

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Abstract

This paper reports the final outcomes of a large six-year collaborative research and development project undertaken by the Monash University Accident Research Centre, in conjunction with the Victorian Transport Accident Commission (TAC) and Ford Australia. The TAC SafeCar project, as it has become known internationally, was designed to evaluate, in an on-road trial, driver interaction with three in-vehicle Intelligent Transport Systems: Intelligent Speed Adaptation (ISA); Following Distance Warning (FDW); and the Seat Belt Reminder (SBR). The technical operation of the technologies, driver acceptance of them, and their effects on driving performance and safety were evaluated. These systems, along with a Reverse Collision Warning (RCW) system and Daytime Running Lights, were equipped to 15 Ford passenger cars sub-leased to several Government and private organisations in Melbourne, Australia. A total of 23 drivers drove a SafeCar for 16,500km. The study is the first to have examined the interactive effects of ISA and FDW systems, and the first to have examined long-term driver adaptation to FDW and SBR systems. In this paper, the overall effects of the systems on driving performance and safety are reported. In a companion paper, findings pertaining to driver acceptance of the systems are presented.

Introduction

Intelligent Transport Systems (ITS) have significant potential to enhance traffic safety [1,2]. The term ITS refers to integrated applications, employing combinations of information, communications, computing, sensor and control technologies, which aim to improve transport safety and mobility and reduce vehicle emissions. Many such technologies have been developed to enhance vehicle safety: to prevent crashes, reduce trauma during a crash or to reduce trauma following a crash (see [1] for a review). Currently, however, there is very little consumer demand for such systems. There are several reasons for this. First, most consumers are unaware that such technologies exist: if they do not know that they exist, they will not demand to have them. Second, at their present state of technical maturity and level of deployment, most are too expensive for purchase by the average consumer. Third, there will be no demand for in-vehicle ITS applications unless vehicle manufacturers and consumers judge them to be safe, reliable, useful, easy to use, and affordable. Unfortunately, the long-term safety benefits of most vehicle ITS applications are not well understood. The systems have not been deployed for long enough and in large enough numbers in traffic for crash numbers to be a reliable indicator of changes in safety [2].

Against this backdrop, the Transport Accident Commission (TAC) commissioned the Monash University Accident Research Centre (MUARC) in June 1999 to undertake what has become known internationally as the *TAC SafeCar* project. In addition to the key project partners – the TAC, MUARC and Ford Australia – more than a dozen other organisations provided technical input to the project. The aim of the project was to evaluate the technical operation of a small selection of ITS technologies with significant potential to enhance driver safety, to assess the acceptability of these to drivers, and to evaluate the impact of these technologies on driver performance and safety, both on the road and in an advanced driving simulator. The ultimate aim of the project was, through demonstration and quantification of the benefits deriving from the systems, to stimulate community demand for them in Victoria, and more broadly within Australia.

The TAC SafeCar project was conducted in four phases. Phase 1 culminated in the selection of several in-vehicle ITS technologies that were estimated to have the potential to significantly reduce road trauma in Victoria. Phase 2 involved the development of functional and Human-Machine Interface (HMI) specifications for these 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. In Phase 4, a field evaluation of all four technologies as well as a simulator evaluation of two variants of the ISA system were conducted. The purpose of the field evaluation was 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.

The TAC SafeCar study is unique. It is the first study, known to the authors, to have systematically examined the interactive effects on driving performance of ISA in conjunction with other ITS technologies. It is also the first study to have examined the effects on driving performance and behaviour of long-term exposure to Seatbelt Reminder and FDW systems. This paper reports the final outcomes of the Phase 4 field evaluation, which is the culmination of six years of collaborative research and development activity. A paper presented at this conference last year contained preliminary findings from the field trial for 8 Treatment drivers only. The present paper reports final results for all Treatment and Control drivers, a greater number of key performance measures and crash and trauma reduction estimates. A companion paper, that reports findings pertaining to driver acceptance of the technologies deployed in the field evaluation, can be found in the current conference proceedings [3].

Safecar Its Technologies

As noted above, fifteen Ford sedans and wagons, sub-leased by 9 government and private companies in Melbourne, Australia, were each fitted with the following ITS technologies: Intelligent Speed Adaptation; Following Distance Warning; a Seat Belt Reminder; and Reverse Collision Warning. These systems were designed to automatically issue warnings to the driver only if they violated certain road rules, undertook certain high-risk driving behaviours, or were in danger of colliding with an object or vehicle when reversing. Briefly, the ISA system was designed to warn the driver when he/she was travelling 2 km/h or more over the posted speed limit. A visual warning was issued via an ITS visual warning display mounted on the dashboard, and this was accompanied by a short duration auditory signal and continuous upward pressure on the accelerator pedal. The FDW system was designed to warn the driver if he/she was following too closely the vehicle immediately in front. There were six levels of visual warning, displayed on the ITS visual warning display, which increased in intensity as following distance decreased. The final visual warning was accompanied by a repetitive auditory warning. The SBR system issued visual warnings via the ITS visual warning display when it sensed that any vehicle occupant was unrestrained, and issued progressively more intense auditory warnings at speeds greater than

10 km/hr. Finally, the RCW system was a reversing aid that warned the driver if he/she was about to collide with an object to the rear of the vehicle. The repetition rate of the auditory warnings became more rapid as the distance between the vehicle's rear and the object decreased. The test vehicles were fitted with a number of additional systems to support the on-road study. These included: a System Override Button and a Data Logging System. For a more detailed description of these systems, the reader is referred to a paper by [4].

Study Design

Each of 23 drivers drove one of the SafeCar vehicles over a distance of 16,500 kilometres. Of these participants, 8 (7 males and 1 female) were assigned to a control group and 15 (14 males and 1 female) to a treatment group. Drivers were aged between 29 and 59 years, with a mean age of 43.4 years. Participants were recruited from Government and private companies in and around Melbourne.

For the purposes of the field trial, the four ITS technologies in the experimental vehicles were divided into two groups: “key” systems and “background” systems. The key systems, ISA and FDW, were the SafeCar ITS technologies that were of primary interest in the study. The background systems were SBR, and RCW. The Treatment participants were exposed to the key and background systems, while the Control participants were exposed to the background systems only.

The Treatment participants were not exposed to all four ITS technologies for the entire length of their trial. The ITS systems turned on and off at predetermined points in the trial, in order to assess the effects of each system on driving performance before, during and after exposure to them. The Treatment participants' trial was divided into a number of periods: the “Familiarisation”, “Before”, “During” and “After” periods, as depicted in Figure 1.

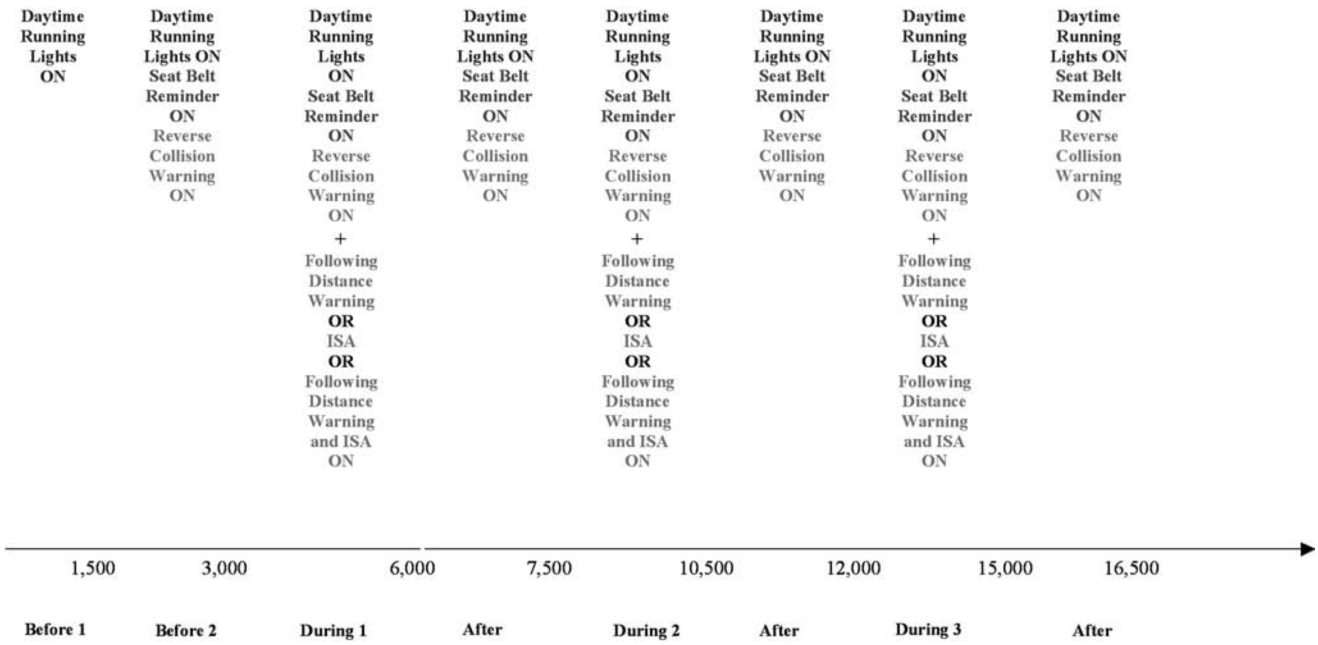

Figure 1: Treatment Group Design Sequence

The Familiarisation period lasted for 200 kilometers and provided drivers with the opportunity to familiarize themselves with the SafeCar before any ITS technologies were activated. Participants then completed the Before 1 period, which lasted for 1,500 kilometers. During this period, baseline performance data were collected and, hence, no ITS system warnings were issued. The data logger, which records a range of driving performance data, was first activated during this period and remained on for the rest of the trial. Next was the Before 2 period, which lasted for 1,500 kilometers. In the Before 2 period the RCW and SBR systems were activated and these systems remained on for the rest of the trial.

The During periods were designed to assess the effect on driving performance of the ISA and FDW technologies in the SafeCars. The During periods were divided into " During 1, 2 and 3" periods, and each lasted for 3,000 kilometers. The During 1 period occurred immediately after the Before 2 period. In addition to the RCW and SBR systems, in the During period drivers received warnings from the ISA, FDW system, or both systems concurrently. The system or system combination received in each During period was counterbalanced across drivers to control for order effects. Each During period was followed by a 1,500 kilometer " After" period in which the system(s) that was active in the previous During period was switched off.

The control participants' trial was divided into two periods: the Control 1 and the Control 2 periods. The Control 1 period was equivalent to the Before 1 period experienced by the treatment participants. During the Control 2 period, which lasted for the remainder of the trial (15,000 kilometers), the SBR and RCW systems were active.

Results

This paper presents the key findings that emerged from the field trial. The findings derive from analysis of the logged driving data only. The key findings deriving from the ISA, FDW and SBR systems are summarised below. The effect of the RCW on driving behaviour was not evaluated. Developed for commercial rather than research purposes, there were several vagaries in the data generated by the RCW. For this reason the data from the RCW system were not logged during the study.

The analyses were performed on data aggregated across the 15 treatment drivers and 8 control drivers. As each treatment driver received the ISA and FDW systems, separately and together - 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 in each of the three During periods. In each case, data is presented for the following periods: the Before 1 period; the ISA, FDW or ISA & FDW *'Before'* period, which corresponds to the period directly before drivers received a particular system(s); the ISA, FDW or ISA & FDW *'During'* period, which corresponds to the During period in which a particular system(s) was activated; and the ISA, FDW or ISA & FDW *'After'* period, in which the system(s) that was active in the previous During period was switched off.

Prior to conducting the analyses, the data were screened to ensure the assumptions of the analyses were met. Inspection of the ISA, FDW and SBR data revealed that the data were normally distributed and no extreme univariate outliers were present. Variables which contained missing values were excluded from the analyses.

Intelligent Speed Adaptation

A series of analyses (t-tests and ANOVAs) was conducted on the speed data to examine if use of the ISA system, alone and combined with FDW, influenced mean and 85th percentile speeds, standard deviation (SD) of speed, percentage of time spent above the speed limit and mean trip time. These analyses were performed separately for five speed zones (50, 60, 70, 80 and 100 km/h roads) and only data for " free" speeds (i.e., when the time headway between the SafeCar and a vehicle in front was 3 seconds or more) were examined. [Traditionally, it has been reported (e.g., [5]) that, at time headways of about 3 seconds or greater, the speed at which a driver chooses to travel is not influenced by the vehicle ahead, although some (e.g., [6]) have argued that the speeds of two vehicles are linearly dependent for time headways up to 6 seconds. In conducting these analyses in was noted that were no major differences in variability across the variables and conditions examined.

Both ISA alone and ISA and FDW were effective in reducing the treatment drivers' mean speed, with the combined systems leading to the greatest speed reductions. When ISA was active alone mean speeds reduced significantly (by up to 1.4 km/h) in the 60 and 100 km/h speed zones ($p < .05$). Mean speeds also reduced significantly (by up to 1.5 km/h) in all but the 100 km/h speed zones when both ISA and FDW were active ($p < .05$). When the ISA system was disengaged in the After period, however, mean speeds increased significantly again in most speed zones, implying that most of the speed reduction benefit from the ISA system was obtained only while the system was active. Use of the FDW system alone had little or no effect in reducing mean speed in the speed zones examined. Finally, comparable reductions in mean speeds across the control drivers' trial were not found, suggesting that the reductions in speed for the treatment drivers were due to the effect of the ITS systems and not to other, uncontrolled, variables.

Interestingly, the ISA system was more effective in reducing higher speeds, such as 85th percentile speed, than in reducing mean speed. Both ISA alone and ISA and FDW combined were effective in reducing the treatment drivers' 85th percentile of speed, with the combined systems again leading to the greatest reductions. When ISA alone was active, 85th percentile speed reduced significantly (by up to 2.7 km/h) in 50, 60, 70 and 100km/h zones ($p < .05$). When the ISA and FDW systems combined were active, 85th percentile speed reduced significantly (by up to 3.0 km/h) in 50, 60 and 70 km/h zones ($p < .05$). However, when the ISA system was deactivated in the After period, the 85th percentile of speed increased significantly again in most speed zones. As was the case with mean speed, no corresponding reduction in 85th percentile speed was evident across the control drivers' trial, indicating that the observed speed reductions were due to the effect of the SafeCar systems and not to other, uncontrolled variables.

ISA alone and ISA combined with FDW were very effective in reducing the proportion of time treatment drivers spent, relative to the control drivers, travelling at and above the speed limit in all speed zones examined. When the ISA system was active, the drivers spent 57 percent less time driving 10 km/h or more above the speed limit, compared to before the ISA system was active. When ISA and FDW combined were active, treatment drivers spent 65 percent less time driving 10 km/h or more above the speed limit.

For the treatment drivers, a significant reduction of up to 1.1 km/h in the standard deviation of speed was observed when the ISA system was active (alone and in combination with the FDW system) and this pattern was consistent across all speed zones examined ($p < .05$). The standard deviation of speed 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, mean travel time (in minutes) was examined in order to determine if the use of ISA increased the average time taken to complete commuter trips. A commuter trip was defined as any trip longer than 1 minute that was started and completed within the time period specified by each participant as the period in which they most often travel to and from work. Hence, mean travel times were based largely on common routes. ISA, by itself or in combination with FDW, did not significantly increase the treatment drivers' mean trip time. In fact there was a trend for mean trip time to decrease slightly when ISA alone and FDW alone were active. This is an encouraging finding, as it indicates that, although the treatment drivers' mean speeds were lower while the ISA system was active, these reductions in speed did not translate into an appreciable increase in trip time. Presumably, this is because there was less variability in their speeds during these periods. No corresponding decrease in speed variability was observed for the control drivers.

Following Distance Warning

A series of analyses (t-tests and ANOVAs) was conducted on the following distance data to examine if use of the FDW system, alone and combined with ISA, influenced mean time headway, the standard deviation of time headway and the percentage of time spent at time headways below 0.8 seconds. Time headway is defined as the distance in meters from a vehicle ahead divided by speed in meters per second. These analyses were performed separately for four speed zones (50, 60, 80 and 100 km/h zones). Examination of the underlying following distance distributions suggested that the change in performance was primarily reflected in a shift to longer following distances rather than a change in the shape of the distribution.

The FDW system, when active alone and when combined with ISA, was effective in increasing the treatment drivers' mean time headway. These increases occurred in all speed zones, but were significant only in 60, 80 and 100km/h zones. When

FDW alone was active, mean time headway increased significantly in 80 and 100 km/h speed zones (increases of 0.10, and 0.11 seconds, respectively), while for the combined FDW and ISA system, significant increases occurred in 60, 80 and 100km/h speed zones (increases of 0.09, 0.07 and 0.13 seconds, respectively) ($p < .05$). No corresponding increases in mean time headway were evident across the control drivers' trial. It is also interesting to note that, in contrast to the speed data, which found that ISA was more effective in reducing speeds when combined with the FDW system, the FDW system was no more effective at increasing following distance when it was combined with ISA, than when the FDW system alone was active.

The percentage of time treatment drivers spent driving in each of three time headway categories was examined immediately before, during and after exposure to the FDW system: 0 seconds to approximately 0.8 seconds; 0.8 to 1.6 seconds and 1.6 to 2.5 seconds. Investigating these three time headway categories allowed for the examination of the effect of the auditory and visual FDW warnings on following behaviour, as well as the identification of any negative adaptation to the system, whereby drivers spend less time at higher headways outside of the FDW warning range (above 1.6 seconds). When the FDW system was active, on its own or jointly with ISA, the treatment drivers tended to spend a smaller percentage of their driving time (a reduction of as much as 69% – from 6.1% to 1.2%) at headways below 0.8 secs, compared to the Before period. However, this effect was not significant in any of the speed zones examined due to large variability in the data ($p > .05$). The presence of the FDW system also did not significantly influence the percentage of time spent at time headways between 0.8 to 1.6and 1.6 to 2.5 seconds. Although not statistically significant, the effects of the FDW system on time headway were quite large in descriptive terms and, if reliable, could have a substantial impact on crashes.

When the FDW system on its own, or when combined with ISA, was activated, the standard deviation of time headway reduced significantly by 0.03 seconds, but only in 50 km/h speed zones ($p<.05$). However, no significant differences in the standard deviation of time headway were found for the other three speed zones examined.

Finally, although there was a trend for the minimum time headway reached per trip to increase in all speed zones when the FDW system (alone or combined with ISA) was active, these reductions were not significant in any speed zone.

Seatbelt Reminder Warning

A series of analyses (t-tests and ANOVAs) was conducted on the seatbelt data to examine if use of the SBR system influenced the percentage of trips driven where an occupant was unbelted for any part of the trip, in the percentage of total driving time spent unbelted, in the time taken to fasten a seat belt in response to the SBR warnings and the average speed reached before buckling up. The analyses were conducted on data collected in all speed zones, when the SafeCar was travelling at speeds of 10 km/h and more. The SBR analyses were conducted for the treatment and control drivers as a whole, given that both groups of drivers were exposed to the SBR system for the same number of kilometres (15,000 kms) and for the same driving periods. The SBR system used was unable to determine whether the changes in seat belt wearing behaviours described below pertain to the SafeCar drivers or to their passengers.

Prior to interacting with the SBR system, SafeCar occupants were unrestrained during any part of a trip on 32 percent of trips they undertook. In the Before 2 period, when the SBR system was activated, this percentage reduced to 16 percent, representing a 48 percent reduction, which was significant ($p < .05$). This reduction was maintained for the remainder of the trial, although there was a trend for the percentage of unbuckled trips to increase slightly again over the duration of the trial.

The percentage of travel time where an occupant was unrestrained also decreased significantly in the Before 2 period when the SBR system was first activated. Before the SBR system was active, about 5 percent of the distance travelled by SafeCars was undertaken with an occupant unrestrained. After activation of the system, this figure decreased significantly to 0.18 percent, a reduction of 96 percent ($p < .05$). This reduction was maintained for the remainder of the trial, although there was a trend for the percentage of driving distance spent unbuckled to slightly increase again over the duration of the trial, to about 0.31 percent by the end of the trial. Nonetheless, this percentage was still significantly lower than at the beginning of the trial, before the SBR system was activated.

Prior to activation of the warnings, it took unbelted occupants 30 seconds, on average, to buckle up. This reduced significantly to an average of 7 seconds in the Before 2 period when the SBR system was activated, which equated to a 77 percent reduction. This was maintained for the remainder of the trial and the time taken to buckle up was significantly lower at the end of the trial than at the beginning.

The peak speed reached when any of the vehicle occupants were unbuckled was also examined across the trial. Prior to activation of the SBR system, the peak speed reached before all vehicle occupants buckled up was 33.5 km/h. This reduced significantly to 26.9 km/h in the Before 2 period, when the system was activated, equating to a 20 percent reduction in peak speed ($p < .05$). This reduction was maintained for the remainder of the trial.

The proportion of time spent driving at " dangerous" speeds while a SafeCar occupant was unbuckled (defined as 40 km/h and over) was also examined across the trial periods. Whilst travelling unbuckled at any speed is considered dangerous, a threshold of 40 km/h was chosen as a " dangerous" forward moving speed to be travelling at while unbuckled because the risk to occupants of being fatally or seriously injured in a crash while driving unbuckled at this speed or higher is four times higher than the risk of a restrained occupant being killed or seriously injured at 40 km/h (Evans, 1996). Before activation of the SBR system, the percentage of driving time spent unbuckled while travelling at dangerous speeds was 6.72 percent. This reduced significantly to 0.05 percent in the Before 2 period, when the SBR system was activated, representing a 99.99 percent reduction in the percentage of time unbuckled ($p < .05$). This reduction was maintained for the remainder of the trial.

Crash and Trauma Reduction Estimates

Preliminary estimates of the benefits likely to be derived from wide-scale deployment of these systems have been derived. For the ISA system, the Power Model developed by Nilsson (2004) was employed to estimate the reductions expected in injury and fatal crashes based on the decreases in mean speed observed when the ISA system was active. Based on the observed reductions in mean speed, the ISA system on its own is estimated to reduce fatal and serious injury crashes by up to 9 and 7 percent, respectively. When operating in tandem with the FDW system, the benefits are greater. Further modelling, which takes account of the significant truncation by ISA of peak speeds, is likely to yield greater crash and trauma reduction benefits for this system. For the FDW system, the expected reductions in those driving instances during which a collision with the lead vehicle would occur if the lead vehicle suddenly braked (termed rear-end collision mode) were modelled based on the observed increases in time headway when the FDW system was active. Based on this model, the percentage of driving distance spent in rear-end collision mode (that is, where the vehicle would collide with the lead vehicle if it braked suddenly) is expected to reduce by up to 34 percent when the system is active and when the lead vehicle is braking at a moderate rate. Estimates of the cost savings expected from the use of the SafeCar SBR system were calculated by first determining the cost of unrestrained occupants in Australia and, second, the cost savings associated with seat belt use. Cost savings associated with seatbelt wearing were calculated by using HARM, which quantifies injury costs from road trauma. Use of the SBR system is expected to save the Australian community approximately $335 million per annum in injury costs.

Discussion and Conclusion

Overall, the ISA, FDW and SBR systems had a positive effect on safe driving performance. Interestingly, ISA was effective in reducing mean speeds, and even more so in reducing speeds at the higher end of the distribution, such as 85th percentile speeds. Statistically significant reductions in mean speeds deriving from use of the ISA system tended to be in the order of 1 to 2 km/h depending on the speed zone, which is lower than the 5 km/h reductions in mean speed found in previous ISA evaluations [7-10]. From an examination of the distributions, it appears that the use of ISA truncates both ends of the speed distribution, such that higher speeds are greatly reduced and lower speeds are slightly increased (e.g., drivers spend less time driving at speeds well below the speed limit), resulting in relatively small reductions in mean speed. This finding is supported by the speed variability data, which showed that speed was less variable when the ISA system was active. Another explanation why the mean speed reductions found in the current study were lower than that found in other studies is that during the trial a speed enforcement campaign was implemented in Victoria which led to population-wide reductions in mean speeds. These reduced mean speeds were, in fact, evident in the control drivers' speed data. It is possible that these overall reductions in speed, combined with a relatively conservative sample of drivers, attenuated the full potential effects of the ISA system. It is also possible that the definition of "free" speed adopted in this study (speed was defined as being free when the time headway between the SafeCar and a vehicle in front was 3 seconds or more) may have been too conservative. Re-analysis of the ISA data for free speeds that are defined as vehicle speeds at inter-vehicle time headways of 6 seconds or more [6] may yield even greater effects.

The ISA system appeared to be most effective in reducing speeding when combined with the FDW system. One reason that the combined systems had a greater effect on speed may be because the expected driver response to the FDW warnings is to slow down temporarily to increase the distance from the vehicle ahead, which would have further decreased mean speeds. Another explanation of why both systems combined had a greater effect on speed may simply be the result of the drivers receiving warnings from more than one system in a driving period, which provided them with extra incentive to drive in a safer manner.

The current study is the first to examine long-term adaptation (over 6000 km of driving) to a FDW system. Previously, adaptation to a laser-based headway detection device has been examined over relatively shorter distances (e.g., 110 km) [11]. Use of the FDW system significantly increased mean time headway and reduced time headway variability. In addition, although not statistically significant, there was a strong trend for the percentage of time spent at time headways at or below 0.8 seconds to decrease when the FDW system was active. Indeed, drivers spent up to 69 percent less time at headways at or below 0.8 seconds when the FDW system was active which, although not statistically significant, may have large crash reduction benefits. This finding is consistent with the Ben-Yaacov et al [11] study, in which it was found that the following distance warning system was effective in encouraging drivers to spend less time at shorter, unsafe, time headways. In contrast to the speed data, the FDW system, when combined with ISA, was as effective in increasing following distance as when the FDW system alone was active.

A consistent finding was that the positive effects on speeding and following behaviour induced by the ISA and FDW systems did not persist when the systems were deactivated in the After periods. Indeed, driving performance after system activation was similar to performance prior to system activation. Such evidence that safe driving behaviours are not sustained once the systems are switched off indicates the importance of drivers having permanent exposure to these safe driving technologies.

The current study is also the first to examine long-term adaptation to a SBR system; indeed, it is the only study known to the authors to have quantified the effects on seatbelt wearing performance of interaction with a SBR system. The findings revealed that driver interaction with the SBR system led to large decreases in the percentage of trips driven where an occupant was unbelted for any part of the trip, in the percentage of total driving time spent unbelted, in the time taken to fasten a seat belt in response to the SBR warnings and in the average speed reached before occupants buckled up. These results occurred even though the initial seatbelt wearing compliance rates, at least for drivers, were reportedly high, suggesting that the SBR system can be effective in further improving seatbelt compliance among occupants who already have high wearing rates.

Finally, over the course of the trial, there was very little evidence of " negative behavioural adaptation" to the systems, by either the treatment or control drivers. That is, drivers engaged very little, if any, in compensatory risk taking behaviours in response to the assistance provided by the SafeCar systems. There was one minor exception. As already noted, some treatment drivers tended to spend less time driving at speeds well below the speed limit, presumably as a result of driving to the ISA warnings; that is, increasing speed until warnings were issued.

The findings yielded in this study were very positive, especially when considering that the treatment drivers were generally conservative drivers and that they were constantly aware that their driving performance was being closely monitored. It is therefore probable that the positive results observed would be even greater in the general driving community under normal driving conditions. Furthermore, it is expected that the magnitude of the results would have been larger if the trial had taken place at a time when general speed levels in Victoria were not simultaneously decreasing.

Although the final outcomes from the SafeCar study are yet to be fully disseminated, the project has already had an impact, directly and indirectly, on ITS developments in Australia and overseas. Two ITS technologies, seatbelt reminder and reverse collision warning systems, are now fitted to Ford BA Falcons and Territory models in Australia. The project has attracted a large amount of publicity in Australia and overseas, raising community awareness of the safety potential of the SafeCar systems. Reference to the project is made in a number of Australian and overseas Government transport policy documents and the project has spawned a large and expanding ITS research program at MUARC. Learnings from the project have informed the design of international ergonomic standards for the design of vehicle cockpit systems. The project has provided local industry in Melbourne with expertise and knowledge in developing ITS related systems. Finally, at least one government authority in Victoria has installed on several of its fleet vehicles an ISA system functionally similar to that in the SafeCars.

On the basis of findings reported here, the authors believe a strong case can be made for the wide-scale deployment of ITS technologies, in-particular ISA and SBR systems. In the final report on the SafeCar project, many recommendations are made by the authors: for implementing wider-scale deployment of these systems; for the technical refinement of the systems; for dissemination of the findings from the study; for future research; and for further optimisation of the human-machine interfaces for the SafeCar systems.

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The Effect on Driver Workload, Attitudes and Acceptability of In-Vehicle Intelligent Transport Systems: Selected Final results from the TAC SafeCar project

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Abstract

As part of the Australian TAC SafeCar on-road study, 15 Ford vehicles were equipped with Intelligent Speed Adaptation (ISA), Following Distance Warning (FDW), Reverse Collision Warning (RCW), and Seat Belt Reminder (SBR) systems. The primary aim of the study was to assess whether long-term exposure to these systems leads to a change in measurable driving performance. As a supplement to the objective measurements of driving performance, a series of questionnaires was administered throughout the study to collect subjective data. These questionnaires were designed to evaluate:

1. changes in driver attitudes attributable to ITS exposure;
2. the effect of the ITS on the workload drivers experience while performing certain driving tasks; and
3. the acceptability of the ITS, in terms of usefulness, effectiveness, social acceptability, affordability and usability.

Twenty-three drivers were recruited to participate in the study and each drove one of the ITS equipped cars for 16,500km. The purpose of the current paper is to report a selection of the more interesting results from the subjective data collected in the TAC SafeCar on-road study. Potential barriers to uptake and acceptance of the various ITS are discussed. The final results pertaining to the effects of the SafeCar technologies on driving performance are reported in a companion paper presented at this conference.

Background

Many Intelligent Transport Systems (ITS) technologies are believed to have the potential to enhance road safety, and to reduce road trauma if implemented on a wide scale [1]. However, large-scale deployment of ITS is unlikely to be successful unless drivers are prepared to purchase and use the systems. Acceptability of the systems to drivers will be an important factor in this choice.

Based on the models of Davis [2] and Neilsen [3], the acceptability of a system can be broadly defined by five constructs: usefulness, effectiveness, social acceptability, affordability and usability. To be useful, participants must perceive the system to serve a purpose. To be effective, participants must believe the system does what it is designed to do. Social acceptability concerns the broader social issues that participants may consider when assessing the acceptability of ITS, such as the acceptable level of control, and the impact on privacy. Affordability relates to how much participants are willing to pay to purchase, install and maintain the system. To be usable, participants must find the system easy to learn how to use, easy to remember how to use, easy and efficient to use, and satisfying to use.

Acceptance of ITS technologies may also be affected by the perceived intrusion of the warning systems when driving. To minimise such intrusion, it has been advocated that ITS