EFFECTS ON DRIVING PERFORMANCE OF LONG-TERM EXPOSURE TO A SEATBELT REMINDER SYSTEM: FINDINGS FROM THE AUSTRALIAN TAC SAFECAR PROJECT

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ABSTRACT

The TAC SafeCar study evaluated the impact of three Intelligent Transport System technologies, alone and in combination, on driver performance: Intelligent Speed Adaptation, Following Distance Warning and a Seatbelt Reminder system for all seated occupants. The project had several aims: to evaluate the technical operation of these technologies; to assess the acceptability to drivers of them; and to evaluate, in an on-road setting, the impact of them, alone and in combination, on driver performance and safety. Twenty-three fleet car drivers (15 treatment and 8 control drivers) participated in the on-road study. Each participant drove a SafeCar for at least 16,500 kilometres. The SafeCar project was the first to evaluate the effects on driving performance of long-term exposure to a Seatbelt Reminder system. The results, reported in this paper, revealed that driver and passenger interaction with the Seatbelt Reminder system led to large and significant decreases in the percentage of trips where occupants were unbelted, in the percentage of total driving time spent unbelted, and in the time taken to fasten a seatbelt in response to the seatbelt warnings. The Seatbelt Reminder system was rated by drivers as being useful, effective and socially acceptable, and use of it led to a decrease in drivers' subjectively reported mental workload. Based on the results of the study, use of the Seatbelt Reminder system is estimated to save the Australian community approximately AUD $335 million per annum in reduced HARM costs. These findings were yielded even though initial seatbelt wearing compliance rates in the community were high, suggesting that Seatbelt Reminder systems can be effective in improving seatbelt compliance among occupants who already have high wearing rates.

INTRODUCTION

There is clear evidence that seatbelts are effective in reducing trauma to vehicle occupants in crashes, and in saving lives (Krafft et al., 2006; Glassbrenner, 2004; Eby et al., 2005). Consequently, new passenger vehicles are routinely fitted with them.

In many jurisdictions around the world there is legislation that mandates the use of seatbelts by all vehicle occupants. Despite the existence of this legislation, however, there are many occupants who choose not to wear seatbelts. Within the European Union (EU) Member States, for example, the average wearing rate for front seat occupants is 76 percent; for rear seat occupants, it is 46 percent (Krafft et al., 2006). In Australia, the comparable rates are 95 and 90 percent (Transport Accident Commission, 2007), respectively, even though the use of seatbelts by all seated occupants is actively enforced there by police. In the US, around 80 percent of front-outboard vehicle occupants use their seatbelt (Glassbrenner, 2004). Even though Australia has a relatively high rate of seatbelt use, around 33 percent of occupants killed each year in car crashes are unbelted (Fildes et al., 2002). In Sweden, the comparable figure is 40 percent (Krafft et al., 2006).

The reasons why vehicle occupants fail to wear seatbelts are many and varied. For some, it is a deliberate choice. For others, it is that they simply forget (see Harrison, Senserrick & Tingvall, 2000). In Australia, non-users appear mainly to be inconsistent users (rather than consistent non-users), who wear seatbelts in most day-to-day driving activity and tend not to only in slow or residential driving situations (Harrison, Senserrick & Tingvall, 2000).

For any countermeasure to be effective in promoting seatbelt use, it must target and address the underlying motivational and behavioural factors which contribute to non-seatbelt wearing. Clearly, given the less than 100 percent seatbelt wearing rates, legislation that is properly enforced and linked with public education has been only partially effective in doing so. Other countermeasures are needed. Over the years, various vehicle-based technologies have been developed for promoting seatbelt use. These include the early "mild" continuous buzzer-light seatbelt reminder (SBR), seatbelt ignition interlocks, and automatic belt systems (in which the shoulder belt automatically positions itself after the driver starts the vehicle; Krafft et al., 2006; Eby et al., 2005). These technologies, however, have not been very effective in increasing seatbelt wearing rates.

A more recent development is the "smart" SBR. These systems issue audible and/or visible signals to vehicle occupants when one or more occupants are unbelted, targeting people who appreciate the value of a seatbelt but are inconsistent users of the device. Typically, these systems issue mild warnings when the vehicle is stationary or slow moving, and more aggressive warnings at higher vehicle speeds. The first car with such a system was introduced in the US in 2000, and in Europe in 2002 (Krafft et al., 2006).

Smart SBRs have the potential to increase seatbelt usage by reminding people to belt up who habitually or occasionally forget to belt up, by alerting drivers and their passengers to the presence of unbelted occupants, and by obviating the need for the driver to reprimand occupants who fail to buckle up (which may be difficult in some situations). In 2002, EuroNCAP, the consumer crash protection program in Europe, introduced a protocol which rewards car manufacturers who produce vehicles equipped with smart SBRs for front- and rear-seated occupants.

Although smart SBRs are already on the market, relatively little research has been conducted to assess the effectiveness, acceptance and technical operation of them (Regan et al., 2006).

However, there has been some research on the effectiveness of SBR systems. In an early study, Bylund and Bjornstig (2001) examined the seatbelt usage rates of 477 vehicle occupants injured in motor vehicles crashes according to whether the vehicle they were driving was equipped with a SBR with a light and sound signal, a SBR with a light signal only, an "unknown" SBR, and no SBR. Twenty percent of drivers were found to be unbelted at the time of the crash. The seatbelt non-usage rate in vehicles with a SBR which issued light and sound signals (12%) was significantly lower than the non-usage rate in vehicles without a reminder system (23%). Also, the seatbelt non-usage rate was similar for those vehicles equipped with a SBR with a light signal only (22%) and those without a SBR (23%). Another interesting finding, given that the seatbelt non-users in the study were mainly young males who were driving at night, often under the influence of alcohol or drugs.

Preliminary survey research on the Ford BeltMinder, a SBR deployed in the United States, found a significant 7 percent increase in seatbelt use for drivers of vehicles equipped with the system compared with drivers of late-model Fords not equipped with the system (Williams et al, 2002). A later study found that, of the two-thirds of drivers who activated the reminder system, three-quarters reported belting up in response to the warnings and nearly half reported that their seatbelt use had increased because of their experience with the system (Williams and Wells, 2003).

Krafft et al (2006) observed, in 5 cities in Sweden, 3000 drivers of cars with a 'simple' (i.e., adaptive for driver only) seatbelt reminder (the cases) and without a seatbelt reminder (the controls). The case and control vehicles (but not drivers) were matched on all possible major variables except presence or absence of the SBR. In cars without a SBR, 82.3 percent of the drivers used the seatbelt; in those with the system, 98.9 percent of drivers used the seatbelt. The difference was statistically significant. The seatbelt usage rate for vehicles with a mild SBR was 93 percent. It was estimated that smart SBRs have the potential to save, per annum, 7,600 lives in Europe and 8,000 lives in the United States. Fildes et al (2002) determined whether SBRs would be cost beneficial for new vehicles sold in Australia. They calculated benefit-cost ratios ranging from 5.1:1 (for a simple SBR for the driver only) to 0.7:1 (for a simple device for all passengers).

There has been only limited research on the acceptability of SBR systems. Eby et al. (2005) conducted research to guide the development of an effective SBR. Research activities included a nationwide survey of part-time seatbelt users, development of design concepts, and a series of focus groups with part-time seatbelt wearers. They concluded that the most effective and acceptable SBR is one that is adaptive; which changes its signal type and presentation modality depending on seatbelt wearing behaviour over some time metric (e.g., time, distance or speed). Harrison et al (2000) used focus groups and questionnaires to gauge driver acceptance of SBRs. Although participants in the study did not interact with actual SBR systems,

they were generally positive about the likely introduction of the systems discussed. Turbell and Larsson (1998) reported similarly favourable attitudes towards SBRs among groups of Swedish road users.

In summary, there is evidence from observational studies that smart SBRs are generally effective in increasing seatbelt wearing rates, and appear to be acceptable to car drivers. No previous study, however, has examined and recorded the long-term impact of these systems on driver behaviour and performance over time.
In this paper we report the aims, methods and findings of an Australian study, known as the TAC SafeCar project, which assessed the effectiveness, acceptance to drivers and technical operation of a range of ITS systems, including a 'smart' (i.e., adaptive) SBR equipped to 15 Ford passenger cars ("SafeCars") driven by 23 drivers over a distance of at least 16,500 kilometres. This paper focuses on the impact on driving performance, mental workload and driver acceptability of the SBR system. The study provides, for the first time, detailed and long-term insights into the effectiveness of these systems in positively changing seatbelt wearing behaviour. The paper concludes with recommendations for further research and development activity.

METHOD

Participants

Twenty-three drivers drove a SafeCar vehicle over a distance of 16,500 kilometres. Eight participants (7 males and 1 female) were assigned to the control group and 15 (14 males and 1 female) to the treatment group. Participants were aged between 29 and 59 years (mean age = 43.4 years). Participants were recruited from Government and private companies in Melbourne, Australia, a large city with a population of approximately 4 million people.

SafeCar ITS Technologies

Fifteen Ford sedans and wagons, called 'SafeCars', were fitted with the following ITS technologies: Intelligent Speed Adaptation (ISA); Following Distance Warning (FDW); and SeatBelt Reminder (SBR). A Reverse Collision Warning system and Daytime Running Lights were also equipped to the SafeCars, but their effect on driving behaviour was not evaluated. 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.

The SBR system was a 'smart' or adaptive system that used seat buckle and weight sensors to detect when a vehicle occupant was unrestrained. The SBR system issued a two stage warning sequence. The Stage 1 warning was issued to the driver if vehicle speed was between 0 and 10 km/hr and an occupant was unrestrained. The Stage 1 warning consisted of a flashing visual icon and, below it, a static caption, "FASTEN SEATBELT", appeared on the visual warning display (see Figure 1). If vehicle speed exceeded 10 km/hr and an occupant was still unrestrained, the Stage 2 warning was issued. During Stage 2, the flashing visual icon and static caption were accompanied by a continuous auditory warning. The repetition rate of the auditory warning increased as the speed of the vehicle increased. Due to the design of the SBR system, it was not possible to determine if the seatbelt data deriving from the study related to drivers or to passengers.

Figure 1. Seatbelt Reminder System visual warning

The ISA system was designed to warn the driver when he/she was travelling 2 km/hr or more over the posted speed limit. Information regarding the location of the SafeCar and the local speed limit was determined by comparing the vehicle's location coordinates (obtained from GPS) with an on-board digital map database of the Melbourne metropolitan road network.

The ISA system had a two-stage warning sequence. The Stage 1 warning was initiated if the posted speed limit was exceeded by 2 km/hr or more. Here, a static visual icon denoting the posted speed limit appeared on the Visual Warning Display (see Figure 2). The visual icon was accompanied by a single short-duration auditory tone. If the first stage warning was ignored for two seconds or more the

Stage 2 warning was issued. During Stage 2, the visual icon flashed and was accompanied by strong upward pressure on the accelerator pedal. If necessary, the driver could override the upward pressure by pressing down hard on the accelerator pedal.

Figure 2. ISA visual warning icon

The FDW system was designed to warn the driver if he/she was following the vehicle immediately in front too closely. There were six levels of graded visual warnings, displayed on the visual warning display, which increased in intensity as following distance decreased. The FDW visual display resembled a ladder (see Figure 3). The six bars of the ladder display (i.e., gaps between the steps) represented the six levels of warning. When the time gap between the SafeCar and the vehicle in front was greater than 1.7 seconds, only a black outline of the ladder was visible. As time gap decreased, the bars of the ladder filled with colour. The first level of warning was issued when the time gap reached 1.7 seconds and the top bar filled with yellow. The bars of the ladder progressively filled with colour as the time gap decreased, as depicted in Figure 2. The sixth and final warning was issued when the time gap reduced below 0.8 seconds accompanied by a repetitive auditory warning. Here, the bottom bar of the ladder turned red, the ladder continued to flash and a continuous auditory warning was issued.

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 SafeCars were also fitted with a number of additional systems that supported the on-road data collection. These included: a System Override Button, a Data Logging System and a Master Pushbutton. The Data Logging system enabled automatic collection of a wide range of driver and vehicle performance data, such as vehicle speed and time headway. The data were recorded up to 5 times a second and stored on removable flash memory cards. The System Override Button temporarily disabled the SafeCar system warnings for approximately one minute. This button was located on the dashboard, to the left of the driver's seat. Finally, the Master Pushbutton allowed drivers other than participants to drive a SafeCar without being exposed to any system warnings or messages. Non-designated drivers were reminded with a voice prompt to press the flashing System Override Button when starting the car to disable all SafeCar systems. The Master Pushbutton ensured that the data collected for a SafeCar related to the designated driver's performance only.

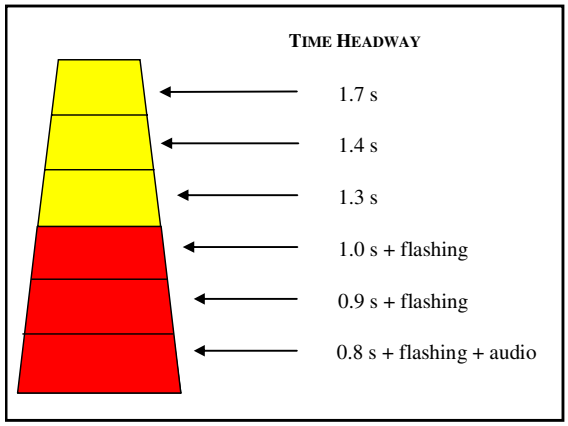

Figure 3. Following Distance Warning system graded warning ladder

Experimental Design

The ITS technologies in the experimental vehicles were divided into two groups: 'key' systems and 'background' systems. The key systems were the ISA and FDW systems and the background systems were the SBR and RCW systems. The treatment participants were exposed to both the key and background systems, while control participants were exposed only to the background systems.

Treatment Drivers The treatment participants were not exposed to all ITS technologies for their entire trial. The ISA and FDW systems turned on and off at predetermined times 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 4.

The Familiarisation period ran for 200 kilometres and provided drivers with the opportunity to familiarize themselves with the SafeCar prior to

any ITS technologies being activated. Participants then completed the Before 1 period, which lasted for 1,500 kilometres. During this period, baseline performance data were collected and, thus, no ITS system warnings were issued. The data logger, which recorded a range of driving performance data, was first activated during this period and recorded on for the remainder of the trial. Participants then entered the Before 2 period, which lasted for 1,500 kilometres. In the Before 2 period the RCW and SBR systems were first activated and these systems remained on for the rest of the trial.

The three 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 kilometres. 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 either the ISA system, 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 kilometre After period in which the system(s) that was active in the previous During period was switched off.

Control Drivers The control participants' trial was divided into two periods: the Control 1 and the Control 2 periods (see Figure 4). The Control 1 period was equivalent to the treatment participants' Before 1 period. The Control 2 period lasted for the remainder of the trial (15,000 kilometres), and during this period, only the SBR and RCW systems were active.

Data Collection

Both objective and subjective data were collected during the study. Objective measures of driving performance were derived from the data automatically recorded by the Data Logging system in each test vehicle. The data logging system was capable of recording data relating to the ISA, FDW and SBR systems only. Driving data relating to the use of the RCW system and DRLs were not recorded during the trial. Subjective measures of driver workload were obtained through a series of questionnaires administered to participants at a number of points throughout the trial. Only a small sub-set of the subjective data for the SBR system is reported. Further details can be found in Regan, Triggs et al. (2006).

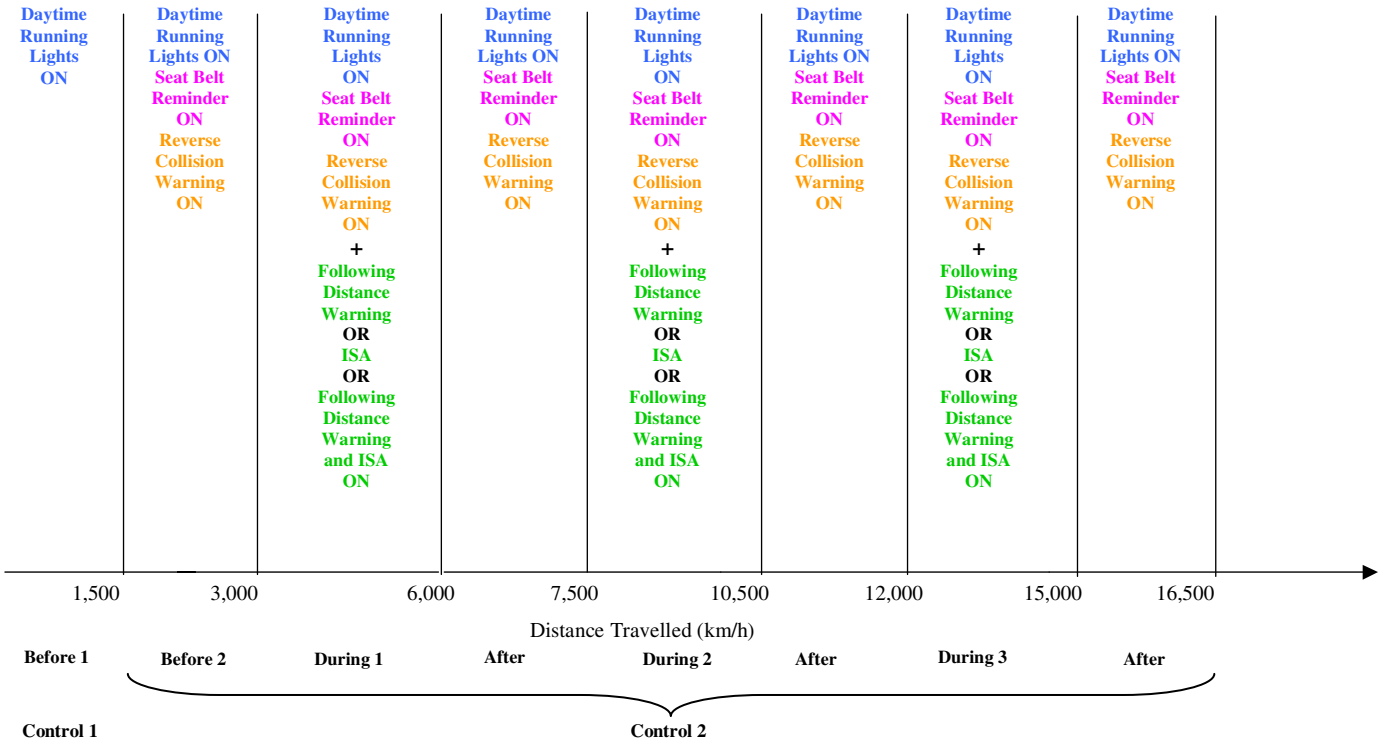

Figure 4: Treatment Group Design Sequence

RESULTS

Data Analysis

This paper focuses on the impact on driving performance, mental workload and driver acceptability of the SBR system. A series of t-tests and repeated-measures ANOVAs was conducted on the seatbelt data to examine if use of the SBR system influenced the percentage of trips and driving distance spent with an occupant unrestrained, the time taken to fasten a seatbelt in response to SBR warnings and the percentage of time spent travelling at dangerous speeds (>40km/hr) while unrestrained. The analyses were conducted on data collected in all speed zones, when the SafeCar was travelling at speeds of 10 km/hr 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 at the same point in the trial and for the same number of kilometres (15,000 kilometres following the Before/Control 1 period). Due to the configuration of the SBR system, it was not possible to determine if the data collected related to the driver or their passengers; thus, the interpretation of the seatbelt data in the following sections is limited to discussing the overall effects of the SBR system for drivers and passengers combined.

The SBR data is reported for 21 of the 23 SafeCar drivers. The data for two drivers, one treatment and one control, were excluded from all SBR analyses, as these two drivers experienced technical problems with their SBR system early in their trial, whereby the SBR system was constantly issuing warnings even when there was no weight on the seats.

Percentage of Trips Taken While Unrestrained

The percentage of trips that were undertaken where a seatbelt was unbuckled for any part of the trip was compared across the driving periods to examine if the use of the SBR system improved seatbelt-wearing habits. The percentage of trips undertaken while unrestrained for any part of the trip is displayed in the second column of Table 1.

Prior to exposure to 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 17 percent, representing a 47 percent reduction, which was statistically significant ($t(20) = 4.14$, $p = .001$). This reduction was maintained over the remainder of the trial (remaining driving periods combined) ($t(20) = 3.05$, $p = .006$); although there was a non-significant trend for the percentage of unrestrained trips to increase slightly again over the duration of the trial.

Table 1.
Percentage of trips and driving distance spent unbuckled and mean time taken to buckle for each driving period for all drivers (n=21)

Driving Period	% trips	% driving distance	Mean Time to Buckle (secs)
Before 1	31.88	4.98	29.71 (36.50)
Before 2	16.63	0.12	7.01 (3.55)
During 1	18.15	0.21	7.97 (8.37)
After 1	19.01	0.19	5.29 (3.28)
During 2	22.54	0.43	7.19 (4.35)
After 2	18.75	0.12	8.83 (8.55)
During 3	20.82	0.14	6.41 (3.48)
After 3	19.84	0.09	6.87 (4.42)

Note: Standard Deviation in parentheses.

Driving Distance Spent Unrestrained

The percentage of total driving distance that was driven while an occupant was unbuckled was also compared across the driving periods to examine if the use of the SBR system improved seatbelt-wearing habits. These data are displayed in the third column of Table 1.

The percentage of travel time where an occupant was unrestrained decreased significantly from pre-exposure levels in the Before 2 period when the SBR system was first activated. Before the SBR system was active, approximately 5 percent of the distance travelled by SafeCars was undertaken with an occupant unrestrained (see Table 1). After activation of the system, this figure decreased significantly to 0.18 percent, a reduction of 96 percent ($t(20) = 2.72$, $p = .013$). This reduction was maintained over the remainder of the trial (remaining driving periods combined) ($t(20) = 2.75$, $p = .012$), although there was a non-significant trend for the percentage of driving distance spent unrestrained to increase slightly again over the duration of the trial.

Mean Time to Buckle

The mean time (in seconds) taken for all occupants to fasten the seatbelt in response to the Stage 1 SBR warnings was examined over the trial to determine if the presence of the SBR system warnings decreased the time taken for drivers and occupants to buckle up.

Prior to activation of the warnings, it took unbelted occupants 30 seconds, on average, to buckle up in response to the SBR warnings (see fourth column of Table 1). This time to buckle up reduced significantly to an average of 7 seconds in the Before 2 period when the SBR system was activated, equating to a 77 percent reduction ($t(20) = 2.79$, $p = .011$). This reduction was maintained over the remainder of the trial, with the time taken to buckle up being significantly lower at the end of the trial than at the beginning ($t(20) = 2.77$, $p = .012$).

Time Spent Unrestrained When Travelling at Speeds Above 40 km/hr

The proportion of time spent driving at 'dangerous' speeds while a SafeCar occupant was unrestrained (defined as 40 km/hr and over) was also examined across the trial periods. While travelling unrestrained at any speed is considered dangerous, a threshold of 40 km/hr was chosen as a 'dangerous' forward moving speed to be travelling at while unbuckled because the risk to unrestrained occupants of being fatally or seriously injured in a crash at this speed or higher is four times higher than the risk to a restrained occupant (Evans, 1996).

The proportion of driving time spent unbuckled while travelling at dangerous speeds is displayed in Figure 5 for each driving period for all drivers. As illustrated, before activation of the SBR system, the percentage of driving time spent unrestrained 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 unrestrained ($t(20) = 2.30$, $p = .032$). This reduction was maintained for the remainder of the trial (remaining driving periods combined) ($t(20) = 2.29$, $p = .033$).

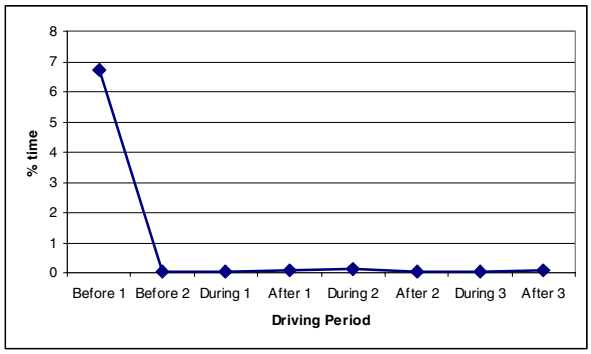

Figure 5. Percentage of driving time in each driving period spent unbuckled while travelling at dangerous speeds

Occupant Reponses to the Stage 1 and 2 SBR Warnings

The percentage of times the SafeCar occupants buckled up in response to the Stage 1 and Stage 2 SBR warnings was examined for each trip across the driving periods to determine if a) the presence of the SBR system increased the proportion of times occupants buckled up during the time the warnings were active and b) to examine if the occupants mostly buckled up during the Stage 1 warnings or waited for the Stage 2 auditory warning before buckling. The percentage of times the occupants did not buckle at all during a trip was also examined.

The SafeCar occupants responded to the Stage 1 warnings by buckling up on approximately 70 percent of occasions and responded to the Stage 2 warnings on approximately 20 to 24 percent of occasions. These figures suggests that, on the majority of occasions, the occupants buckled up in response to the Stage 1 visual warnings and did not wait until they received the auditory warning. The proportion of times that occupants did not buckle up at all in response to the SBR warnings decreased from almost 14 percent prior to the SBR system activation to around 8 percent in the periods when the SBR was active.

Driver Acceptance and Subjective Mental Workload

A number of questionnaires were administered to participants throughout the on-road trial that were designed to collect subjective data relating to participants baseline seatbelt wearing behaviour, the acceptability of the SafeCar ITS systems and the level of subjective mental workload participants experienced while interacting with the systems. It is important to note that the questionnaire data related to drivers only, not all vehicle occupants as the logged data did.

Reported Baseline Behaviour Prior to exposure to the SBR system, almost all of the participants (21; 91.3%) reported 'always' wearing a seatbelt when driving. The remaining participants reported 'often' doing so (2; 8.7%). The participants that reported not always wearing a seatbelt said they did not wear one when reversing from a driveway or car park.

Effectiveness of SBR The participants were asked what effect the SBR system would have on seatbelt wearing for most drivers in several driving situations. Overall, the majority of participants believed that the SBR system would increase seatbelt wearing when driving short distances

(90.5%), in low traffic density (78.7%), when travelling at speeds greater than 10km/hr (78.7%) and at speeds less than 10km/hr (70.7%). The remainder of the participants believed the system would induce 'no change' to seatbelt wearing in these situations.

The participants reported that the SBR system would be particularly effective for drivers who inadvertently practice unsafe seatbelt behaviours, but would not be very effective for drivers who intentionally do not wear their seatbelt.

Usefulness of SBR Participants rated the SBR system highly in terms of how useful it was in assisting them (the driver) to buckle up. Prior to using the system, 31.6 percent of participants rated the systems as 'always of use'. At the end of the trial, after all participants had experienced the system, the percentage of participants who rated the SBR system as 'always of use' rose to 42.1 percent. The system was rated particularly useful for drivers who forget to put on their seatbelt and for drivers who do not wear seatbelts when travelling short distances.

The participants also rated the SBR system highly in terms of its usefulness in letting drivers know that their passengers are not wearing seatbelts. The proportion of participants that rated the system as 'always of use' increased over time, from 47.4 percent at the beginning of the study to 68.4 percent at the end of the trial.

Subjective Mental Workload Subjective mental workload was measured using a standard workload questionnaire: the NASA-Raw Task Load Index (NASA-RTLX) (Byers, Bittner & Hill, 1989). Participants were asked to rate the level of workload they experienced in several driving situations prior to and during activation of the SBR system. The treatment participants rated their overall mental workload as significantly lower when the SBR warnings were active compared to when the system was not active. The control group, however, did not report any difference in mental workload when the SBR system was active versus inactive.

Estimated Injury Cost Savings

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 seatbelt use. The method used to calculate these cost savings was drawn from a report by Fildes, Fitzharris, Koppel and Vulcan (2002). Cost of injury to unrestrained occupants was determined by using cost and injury data from the Bureau of Transport and Regional Economics (BTRE; 2001). Cost savings associated with seatbelt wearing were calculated by using HARM, which quantifies injury costs from road trauma. These costs comprise not only medical and treatment data, but also allowance for loss of earnings, impairment and loss of quality of life; that is, they represent the societal cost of injury. For further detail regarding how HARM is calculated, the reader is referred to Chapter 3 of the report by Fildes et al. (2002).

The amount of injury costs saved each year depends on the effectiveness of the SBR device. In accordance with Fildes et al. (2002), the effectiveness of the SBR system was calculated by determining the percentage of SafeCar participants who demonstrated an improvement of greater than 90 percent in seatbelt use in the Before 2 period when the SBR system was active from Before 1 levels *and* spent less than 0.5 percent of driving distance in the Before 2 period unrestrained. Of the 21 SafeCar participants used in the calculations, 12 met this criterion and, hence, the effectiveness of the seatbelt reminder system was 57 percent. It is estimated that at 57 percent effectiveness, use of the SafeCar SBR system would save the Australian community approximately AUD$335 million per annum in injury costs (assumes 100 percent fitment to vehicle fleet).

DISCUSSION

The current study is the first to have examined long-term adaptation to an adaptive SBR system. However, due to the design of the SBR system, it was not possible to determine if the seatbelt data deriving from the study related to drivers or to their passengers. As a result, the interpretation of the seatbelt data is limited to discussing the overall effects of the SBR system for drivers and passengers combined.

Logged Driving Data

As expected, interaction with the SBR system led to large and significant decreases in the percentage of trips driven where an occupant was unrestrained for any part of the trip. Use of the SBR system leads to a 48 percent reduction in the proportion of trips taken in which an occupant was unrestrained. This reduction was maintained for the entire period in which the SBR system was active, although there was a suggestion in the data for the percentage of unbuckled trips to increase slightly over the duration of the trial. This finding is very positive as it occurred even though the initial seatbelt wearing compliance rate among occupants was high, suggesting that the SBR system can be effective even among occupants with high wearing rates. The finding that the improvement in seatbelt wearing

induced by the SBR system was maintained for the entire trial is also positive, as it suggests that occupants did not start to ignore or attempt to override the warnings after the system had been active for a period of time.

Although no other research has examined long-term adaptation to SBR systems, a number of studies have been conducted, which examined whether the presence of a SBR decreases the number of vehicle occupants not wearing their seatbelt (Bylund & Bjornstig, 2001; Williams, Wells & Farmer, 2002). These research studies found that seatbelt wearing rates were higher among the occupants of vehicles fitted with a SBR system than those not equipped with a SBR. Despite having higher initial seatbelt wearing compliance rates than in previous studies, the present study still found that the SBR system was effective in further increasing seatbelt wearing rates.

It was anticipated that use of the SBR system would reduce the percentage of driving distance driven with an occupant unbuckled. Before the SBR system was active, approximately 5 percent of the distance travelled was undertaken while an occupant was unrestrained. After activation of the system, however, this figure decreased significantly to 0.18 percent, a reduction of 96 percent. This reduction was maintained for the rest of the trial. It is encouraging to note that, even though occupants initially spent only a small proportion of their driving time unbuckled, the SBR system was effective in further decreasing the time spent unbuckled to almost zero.

Positive benefits of the SBR system were also found in terms of the mean time taken to buckle from the onset of the SBR warnings. Prior to activation of the warnings, it took unbelted occupants 30 seconds, on average, to buckle up from when the warnings would have commenced had the system been active (i.e., when the ignition was turned on). However, as expected, the mean time taken to buckle reduced significantly to an average of 7 seconds in the Before 2 period when the SBR system was activated, equating to a 23 second or 77 percent reduction. This reduction was maintained for the remainder of the trial, with the time taken to buckle up significantly lower at the end of the trial than at the beginning. It therefore appears that the SBR system is effective in getting those occupants who tend to put their seatbelt on after the car has started moving to buckle up earlier. Indeed, several of the drivers reported in the questionnaires that, prior to the SBR system being activated, they tended to drive out of their driveway and down the street before they buckled, but that the SBR system encouraged them to buckle up while the vehicle was still stationary.

The effectiveness of the SBR system in being able to reduce the proportion of time spent driving at dangerous speeds while an occupant was unbuckled (defined as 40 km/hr and over) was also demonstrated. Prior to activation of the SBR system, the percentage of driving time spent unbuckled while travelling at dangerous speeds was 6.72 percent. This reduced by 99.99 percent to 0.05 percent when the system was first activated and was maintained for the remainder of the trial. Reducing the amount of time occupants spend unrestrained at dangerous speeds is likely to reduce the severity of injuries sustained by vehicle occupants and the risk of being fatally injured in the event of a crash.

The percentage of times occupants buckled up during the Stage 1 and Stage 2 SBR warning periods was also examined. The analysis sought to examine the relative effectiveness of the Stage 1 and 2 seatbelt warnings; specifically, if occupants mainly buckled up during the Stage 1 warning period or waited for the Stage 2 auditory warnings. Occupants buckled up on approximately 70 percent of occasions during the Stage 1 warning period and approximately 22 percent of the time during the Stage 2 warning period. On the remainder of occasions (8 percent), occupants did not buckle up at all in response to the warnings. This suggests that, on the majority of occasions, the occupants buckled up in response to the Stage 1 visual warnings and did not wait until they received the auditory warning before buckling up. It does, however, highlight that occupants also relied on the auditory warnings on over 20 percent of occasions and, thus, in order to be maximally effective, SBR systems should contain both visual and auditory warnings.

Driver Acceptance and Subjective Workload Data

Almost all of the drivers reported always wearing seatbelts, and those who did not always wear seatbelts reportedly only did not to wear them while reversing. The SBR system may, therefore, mainly be useful for drivers in limited situations. However, the issue of passenger use of seatbelts is also important. A number of drivers reported that they did not always check to see if their passengers were wearing seatbelts and, as such, this identifies an important role for the SBR system. Indeed, drivers felt the SBR system would be particularly useful and effective for alerting them when their passengers are not wearing seatbelts.

It was encouraging that drivers also reported the SBR system to be personally useful, even though they initially reported rarely driving without a seatbelt on. However, drivers did not seem to think

the SBR would be particularly useful when reversing. This is in accordance with the drivers' self-reports that reversing was the only situation in which they reported not wearing seatbelts.

Finally, the drivers in the treatment group felt that their level of workload was significantly lower when receiving warnings from the SBR system, compared to when driving prior to the SBR warnings being operational. The drivers in the control group, however, did not rate their workload as lower when the SBR system was operational; in fact, there was a non-significant trend for the workload ratings to increase overtime. It is unclear why the SBR system had such a different effect on the perceived workload of the two groups, when all of the drivers had the same SBR system in their cars.

Conclusions

Overall, the SBR system was effective in promoting safer seatbelt wearing behaviour, despite the test participants having high initial (self-reported) seatbelt wearing rates. On the basis of findings reported here, the authors believe a strong case can be made for the wide-scale deployment of SBR systems. If implemented on a population basis, SBR systems would be expected to yield significant gains to the community in terms of injury reductions and cost savings.

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