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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

By M Regan\*, K Stephan\*, E Mitsopoulos\*, K Young\*, T Triggs\*, N Tomasevic\*, P Tierney\*\* and D Healy\*\*

\*Monash University Accident Research Centre, Building 70, Monash University Victoria 3800, Australia

\*\*Victorian Transport Accident Commission

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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 Nielsen [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

technologies be designed such that drivers should be unaware they are driving a vehicle with ITS when they are driving safely [4]. This is important to ensure that the systems do not negatively impact on the workload drivers experience while driving. Indeed, a well-designed system might be expected to decrease driver workload.

Drivers' attitudes are also expected to play a role in public demand for ITS technologies. Attitudes to new technologies as a whole, and ITS specifically, will affect uptake of the systems. General road safety awareness and attitudes to unsafe driving behaviours will also be important predictors of public acceptance of the need for ITS.

The TAC SafeCar project commenced in June 1999. The on-road study was conducted between 2003 and 2005 to evaluate the potential safety benefits of several in-vehicle ITS, both alone and in combination with each other. The project was conducted as a collaborative research activity involving the Transport Accident Commission (TAC) of Victoria, the Ford Motor Company of Australia (Ford) and the Monash University Accident Research Centre (MUARC). The ultimate objective of the project is to stimulate demand for ITS systems in Victoria. As part of this study, the acceptability of ITS systems implemented in the SafeCar, the level of workload participants experienced while interacting with the systems, and attitudinal and other factors of interest were assessed. Selected final results pertaining to the acceptability of the SafeCar systems to drivers are reported in this paper. The final results pertaining to the effects of the SafeCar technologies on driving performance are reported in a companion paper presented at this conference [5].

## Method

Fifteen Ford vehicles were equipped with Intelligent Speed Adaptation (ISA), Following Distance Warning (FDW), Seat Belt Reminder (SBR) and Reverse Collision Warning (RCW) systems. Twenty-three drivers each drove one of the vehicles for approximately 16,500 km. All drivers were exposed to the background systems (SBR and RCW) for all but the first 1,500 km. Fifteen drivers (the treatment group) were also exposed to the key systems (ISA and FDW) in specified periods throughout the study. The remaining eight drivers comprised the control group, and received no exposure to the key systems.

### *Data collection*

Participants' driving behaviours, such as speed, following distance, and seat belt wearing were logged before, during and after exposure to the ITS systems to investigate the effects of the systems, both alone and in combination, on measurable driving performance. A series of questionnaires was also administered throughout the study, to collect subjective data relating to the acceptability of the systems, the level of workload drivers experienced while interacting with the systems, and attitudinal and other factors of interest.

### *Acceptability*

All participants answered questions about the usefulness, effectiveness, social acceptability and affordability of the ISA and FDW at baseline (after training and prior to experience of driving with the systems). The acceptability of ISA and FDW was re-assessed at the end of the study after the treatment group participants gained experience with the systems.

All participants rated the usefulness, effectiveness, social acceptability and affordability of the SBR and RCW systems at baseline, at the end of the project, and at two intervening time-points. Inferential analyses were performed to determine if there were differences between the treatment and control group in terms of system acceptability, and if there were any changes in the acceptability of the systems over time.

Data pertaining to the usability of the systems was collected once, in the period that the participants were first exposed to the system. Only participants in the treatment group rated the usability of ISA and FDW systems. All drivers rated the usability of the SBR and RCW. Descriptive results are reported for system usability.



Externally, the test cars looked like other Ford Falcons. The difference was in the dashboard presentation, as shown in this photo.

## Workload

Using the NASA raw task load index (NASA-tlx) questionnaire, participants were asked to rate the level of workload they experienced in several driving situations prior to the SafeCar systems becoming active, and then while the systems were issuing warnings. The NASA-tlx consists of six subscales (mental demand, physical demand, temporal demand, effort, performance and frustration level). Drivers rated their level of workload for each system on each subscale, from 0 to 100. An overall workload score was derived by averaging across the six workload dimensions.

## Attitudes and other factors

Questions relating to attitudes and other factors were included in the questionnaires administered at the beginning and end of the study. The modified Driver Behaviour Questionnaire [6] was used to collect information on driver behaviour. Information about awareness of road safety issues, attitudes to driving behaviours, and attitudes to ITS was also collected.

## Results

This paper presents a selection of the more interesting results from the questionnaires administered throughout the TAC SafeCar on-road study

### Self reported baseline driving behaviour

Prior to exposure to the SafeCar Systems, drivers were asked about their usual driving behaviours. Baseline driving behaviour is reported for all 23 participants.

*Speeding Behaviour:* A large number of participants reported sometimes (65.2%) or often (26.1%) exceeding the speed limit by 3km/h or more. In most cases (87.6%), excessive speeding was claimed to be inadvertent.

*Following Distance Behaviour:* Approximately half of the participants said they never (13.0%) or rarely (39.1%) followed at a distance of less than 2 seconds from the car in front. The other half reported sometimes (13.0%), often (30.4%) or always (4.3%) doing so. At least a third of the participants reported inadvertently following too close to the vehicle in front, while at least 10 percent reported intentionally following vehicles too closely.

*Seatbelt Wearing Behaviour:* Almost all of the participants (91.3%) reported always wearing seatbelts. Those who did not always wear seatbelts (8.7%) chose not to wear them only while reversing. A number of participants (39.1%) reported that they did not always check to see if their passengers were wearing seatbelts.

## Acceptability of the SafeCar Systems

Only data from participants who completed all of the acceptability questionnaires are included in the inferential analyses (11 treatment group participants and 8 control group participants).

### Usefulness

#### *General usefulness of the systems*

Participants felt that all of the systems would be more of use than not of use, both prior to, and after, experience with these systems. At the beginning of the study, the relative ranking of the four systems in terms of usefulness was, from most to least:

ISA, RCW, SBR (for passengers), FDW and SBR (for drivers). At the end of the study, the relative ranking in terms of usefulness, was: SBR (for passengers), RCW, SBR (for drivers), ISA and FDW.

#### *Usefulness in particular speed zones and traffic situations*

ISA was believed to be of use in 60km/h, 80km/h and 100km/h zones, on freeways, rural roads and when there is very little other traffic around. One notable exception was 50km/h zones, where participants did not feel that the ISA system was necessary.

The FDW system was rated as useful in various speed zones and traffic situations; for example, in 50km/h zones, rural roads, on freeways and for alerting tired drivers. After experience with the FDW system, over a third of the participants in the treatment group disagreed that the FDW system would be helpful on freeways, whereas none disagreed prior to using the system (this was not statistically significant).

The SBR was rated as useful, particularly for drivers who forget to put on their seatbelt, who do not wear seatbelts when travelling short distances, and for encouraging passengers to wear seatbelts. Participants recognised the need for the SBR system in various traffic situations, including where there was not much other traffic on the road. The SBR was less likely to be rated as useful when reversing.

### Effectiveness

The ISA, FDW and RCW systems were rated as effective in reducing the incidence and severity of crashes. After experience with the ISA system, most participants in the treatment group still perceived it to be effective in reducing crash incidence and severity, but the proportion that thought it would be ineffective was higher than at the beginning of the study.

The ISA and FDW systems were rated as effective in reducing the probability of being fined. Initially, most participants also felt the ISA system would be effective in decreasing fuel consumption, however by the end of the project almost half believed it would have no effect. Importantly, most participants did not think the ISA system would change travel times.

Participants did not believe that they would rely too strongly on the systems at the expense of their own judgement. Participants disagreed that receiving warnings from any of the systems could distract them while driving and potentially compromise their safety. Participants agreed they would lose trust in systems that issue false warnings or fail to warn when they should.

#### *Effectiveness in particular speed zones and traffic situations*

ISA: Over 80 percent of participants regarded the ISA system as effective in reducing speed in 50km/h, 60km/h, 80km/h and 100km/h zones, and residential areas. Most drivers also regarded it as effective for reducing speed on freeways, rural roads, where there is little traffic and when road conditions are poor.

FDW: Initially, approximately half of the drivers felt the FDW system would be effective in increasing following distance in 50, 60, 80 and 100 km/h zones. At the end of the study, the perceived effectiveness of the FDW in these speed zones increased, as it did in situations where there is little traffic, in heavy traffic and where it is difficult to see the road ahead.

SBR: The SBR system was rated as effective in increasing seat belt wearing for short trips, when traffic levels are low, and when travelling at all speeds. Approximately half of the participants thought the SBR was effective in increasing seatbelt wearing when reversing.

#### *Effectiveness of the systems for particular types of drivers*

Participants believed that the ISA, FDW and SBR systems would be effective for drivers who inadvertently practice unsafe driving behaviours. They also believed that these systems would be less effective for drivers who intentionally practice unsafe behaviours.

#### *Social Acceptability*

Participants felt that the systems in the TAC SafeCar did not take too much control away from the driver. They were consistent in their preference for not wanting a system with more control.

Drivers generally did not wish to be able to turn the ISA, RCW and SBR systems on or off. After being exposed to the FDW system however, a larger number of participants in the treatment group wanted to be able to turn the system on or off (this difference was not significant).

#### *Affordability*

The median of the amounts participants reported being willing to pay for purchase of the ITS for new and existing cars, installation into existing cars, and maintenance/service is described below.

ISA: Participants were willing to pay \$200 for purchase of the ISA for a new car and \$110 for an existing car, with an additional \$50 for installation.

FDW: Participants were willing to pay \$100 for purchase of the FDW for either a new or existing car, with an additional \$25 for installation into an existing car.

SBR: Participants were willing to pay \$100 for purchase of the SBR for either a new or existing car and \$22.50 for installation into an existing car.

RCW: There was a non-significant trend for participants in the control group to be willing to pay more for purchase of the RCW system for a new car (between \$200 and \$275 over time) compared to the treatment group (between \$50 to \$150 over time). The trend was also present for the amount participants were willing to pay for purchase of the system to retrofit to an existing car (\$225 for the control group and \$100 for the treatment group). Participants were willing to pay \$45 for installation into an existing car.

Participants were not willing to pay for yearly maintenance/service of any of the systems.

#### *Usability*

Usability data for the ISA and FDW systems is available for 12 participants, all of whom had experienced the ISA and FDW warnings by that time. Usability data for the SBR and RCW is available for 21 participants, because two participants had not yet experienced SBR or RCW warnings by the time they received the usability questionnaire.

Participants reported little difficulty judging what any of the warnings meant. Both visual and auditory warnings were effective and satisfactory. The only exception was the yellow bars of the FDW visual ladder, which were not reported to be easy to use or effective.

The position of the ITS display screen was problematic for a few drivers, who reported difficulty in seeing some warnings. Some participants reported a preference for a display located directly in front of the driver. There were also concerns raised about glare and reflection off the screen. Suggestions were made for improving the audio tones, such as using speech warnings and having an adjustable volume for each individual warning, rather than an overall volume control. Noteworthy is that all the system interfaces were designed in accordance with ergonomics best practice.

#### *Interest In Keeping The Systems*

Most participants expressed interest in keeping the ISA, SBR and RCW, prior to and after experience with the systems. However, while interest in keeping the FDW was high prior to use, interest decreased over time for participants who had experienced the FDW system.

Initially, the systems were ranked in the following order in terms interest in keeping them (from most interest to least interest): SBR, ISA, RCW and FDW. At the end of the study, the RCW had moved up to top spot in the relative rankings: RCW, SBR, ISA and FDW.

#### *Reasons for interest*

Participants wanted to keep ISA because it was useful when inadvertently speeding, to avoid speeding fines, and to save fuel. The participants who expressed interest in keeping the FDW believed it would enhance safety and remind drivers to keep at a reasonable following distance. Reasons for interest in keeping the SBR included the decreased risk of injury in a collision when occupants are restrained, and to alert drivers when occupants were not wearing seat belts. Participants were interested in keeping the RCW because of the increased awareness it provides and because reversing was easier, particularly when rear visibility was poor.

### *Reasons for disinterest*

Many of the reasons given for disinterest in keeping the ITS related specifically to the systems as implemented in the vehicle. The issue of false warnings was emphasised for the ISA system, particularly where the database was inaccurate.

Participants in the treatment group who did not want to keep the FDW system found it gave too many unnecessary warnings which could be distracting, particularly when other drivers cut in front of them.

## **Workload**

Participants were asked to rate the level of workload they experienced in several driving situations prior to the SafeCar systems becoming active, and then while the systems were issuing warnings. The data was derived from responses of drivers who returned the relevant questionnaire, and who reported experiencing ITS warnings. Hence the workload analyses are based on the responses of 10 drivers for ISA, 9 drivers for FDW and 21 drivers for SBR and RCW.

Participants reported significantly lower workload levels when reversing with the RCW system issuing warnings, compared to when they were reversing without the RCW. Participants in the treatment group rated their workload as significantly lower with SBR warnings than without, however there was no significant difference in the workload reported by the control group in this regard. Participants did not report any difference in the workload experienced while receiving warnings from the ISA or FDW systems, compared to when they were driving in the period prior to experiencing these warnings. However, participants did feel significantly more frustrated when receiving FDW warnings.

## **Attitudes and Other Factors**

### *Driver behaviour*

Conservative driving behaviours were reported, both before, and after, experience with the SafeCar systems. There was no difference between the reported behaviours of the treatment group and control group participants, nor was there any change after experience with ITS.

### *Awareness of road safety issues*

The FDW and SBR systems had a positive effect on road safety awareness. After using the SBR system, fewer of the participants thought it was legal not to wear a seatbelt when driving at less than 10 km/h. The proportion of treatment group participants who were aware of the recommended minimum following distance almost doubled, from 55% to 100%, after use of the FDW system.

### *Attitudes to driving behaviours*

The FDW system led to a change in attitude to driving behaviours; the treatment group drivers disagreed more strongly that it makes sense to tailgate if the driver in front is

too slow after they had experienced the FDW warnings. Experience with FDW also led to a decrease in the perceived likelihood of being caught by the police for tailgating.

### *Attitudes to ITS*

Participants agreed they would like a car that warns them in the following situations; exceeding the speed limit; tailgating; seatbelt non-compliance; impending collisions; driver blood alcohol concentration (BAC) over the legal limit; driver fatigue; and lane drifting. Participants did not want a car that prevents them exceeding the speed limit. At the beginning of the study, participants agreed they would like a car that stopped them tailgating, and a car that could not be started if someone was not wearing a seatbelt (interlock). However, they no longer wanted these intervening technologies at the end of the study, perhaps because they had experienced the more passive, warning systems. Participants agreed that they would like a car that prevented collisions and prevented drivers starting the car if their BAC was over 0.05, although the level of agreement decreased slightly over time.

## **Discussion**

### *Intelligent Speed Adaptation*

The large number of drivers that reported speeding inadvertently immediately highlights the potential benefit of the ISA system in reducing speed.

Although the drivers considered ISA to be necessary in most situations, they generally did not feel it would be necessary in 50km/h zones. It is unclear why. Considering the introduction of 50 km/h as the default speed limit in built-up areas in Victoria was quite recent, it may be expected that drivers would find the ISA system useful. However, this was not the case. Drivers may not believe they speed in 50km/h zones, although the logged driving data shows that ISA was effective in reducing speeding in 50 km/h zones. Perhaps drivers do not think it is likely they will be caught speeding in 50km/h zones, although penalties are not the only factor in speed choice. It is certainly not the case that drivers consider speeding in 50km/h zones to be safe; in fact, participants regarded exceeding the speed limit in 50km/h zones by 5km/h as dangerous, and by 10km/h as very dangerous.

There was a decrease over time in the extent to which the drivers perceived the ISA to be of use to them, and in how interested they were in keeping the ISA system. In contrast, the perceived usefulness of ISA in 60 km/h zones and 80km/h zones actually increased. It must be noted, however, that even with significant decreases in general usefulness and interest over time, the majority of drivers still rated the system highly, and most were still interested in keeping ISA.

### *Following Distance Warning*

Approximately half of the drivers said they never or rarely followed at a distance of less than 2 seconds from the car in front. The other half reported sometimes, often or always doing so. Determining whether following distance behaviour was inadvertent is difficult, however at least a third of the subjects reported inadvertently following too close, while at least 10% reported doing so intentionally.

The FDW system was rated as effective in increasing following distance, particularly at the end of the study. Despite this, fewer participants wanted to keep the FDW system after experiencing it. The FDW system's very effectiveness may contribute to this. While drivers are generally aware of the need to keep a following distance of two or more seconds from the car in front, it is possible that they may not be aware of what this actually looks like. If drivers do not keep appropriate following distances, then FDW system warnings will occur frequently. If drivers receive warnings when driving in a manner they consider to be safe, frustration could occur. Many of the reasons given for not wanting to keep the system were related to frustration, and the workload ratings revealed a significant increase in frustration level when receiving FDW warnings. Drivers also found it unacceptable that the FDW system gave warnings when another car cut in front of them. Although it is clear that the FDW system was operating as it was designed to in this situation, these warnings were regarded as false alarms. This will have to be addressed if drivers are to consider FDW systems acceptable. It should be noted that the FDW technology used in this study was limited in that it was adapted to function under different driving conditions than it was designed to. Therefore, it was anticipated that refinements would need to be made to any commercial product if this ITS technology was to prove acceptable to the end consumer.

The FDW system had a positive effect on road safety awareness and attitudes to relevant driving behaviours. Experience with the system led to a greater awareness of the recommended following distance and decreased acceptance of tailgating when the driver in front is driving slowly.

The ISA and FDW warnings had no effect on the overall workload level that drivers felt while driving which is a positive result. While it might be reasonable to expect that extra visual and auditory warnings could increase drivers' perception of workload whilst driving, the results from this study show that this was not the case.

### *Seat Belt Reminder*

Almost all drivers reported always wearing seatbelts. Those who didn't reportedly chose not to wear them only while reversing. The SBR system may, therefore, only be useful for drivers in limited situations. A number of drivers did not always check to see if their passengers were wearing seat belts and this identifies an important role for the SBR system.

It was encouraging that drivers found the SBR system useful, despite reporting rarely driving without a seatbelt. Drivers felt it would be particularly useful and effective for alerting them to unbelted passengers. The SBR system, as a device for warning the driver of unbelted passengers, was rated the most useful of all of the SafeCar systems, while for warning the driver that they were unbelted, it was ranked third most useful. Yet, drivers did not seem to think the SBR would be useful when reversing. This accords with the drivers' self-reports that reversing was the only situation in which they reported not wearing seat belts. Furthermore, although recommended to do so, it is currently legal for drivers not to wear a seatbelt while reversing a vehicle.

After using the SBR system, drivers were more likely to be aware of the requirement to wear a seatbelt when travelling slowly, which is a promising finding. Perhaps with more exposure to the SBR, there might also slowly develop an acceptance of the need for wearing seatbelts while reversing.

Drivers in the treatment group perceived their workload as significantly lower when receiving SBR warnings, compared to when they were driving prior to the SBR being operational. For drivers in the control group, however, there was a non-significant trend for the workload ratings to increase. 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.

### *Reverse Collision Warning*

Drivers liked the RCW system, and found it both useful and effective. The RCW was ranked first in terms of how interested the drivers were in keeping the TAC SafeCar systems. It also ranked second in terms of perceived usefulness. The RCW system was particularly effective in reducing driver workload.

## **Overall usability**

Overall, the systems were found to be usable, although some drivers felt the position of the visual warning display was not optimal. The drivers made several useful suggestions regarding how the usability of the system could be improved, both for the visual display and the auditory warnings.

Some drivers found the auditory warnings annoying. This is not surprising, since it is very difficult to ignore auditory warnings. The ability to attract a driver's attention regardless of the position of their head is one of the reasons that auditory signals are so effective as warning devices. However, auditory warnings should be used sparingly, for important messages, or else they can be annoying. It should be remembered that, in the TAC SafeCar, warnings were only issued when the driver was behaving in an illegal or unsafe manner, otherwise the systems remained silent.

## Barriers to acceptance

Barriers to driver acceptance of the systems were identified. Drivers will lose trust in systems that are unreliable. Based on the amount that drivers were willing to pay for the systems, cost may also be a barrier to acceptance, particularly maintenance and service costs. It is encouraging that several potential barriers to acceptance turned out not to be of concern. Drivers found the level of control of the systems acceptable, they did not feel that they would rely too strongly on the systems at the expense of their own judgement, and did not think the systems would distract them from their driving.

## General issues/limitations

The quality of self-reported behaviour data is always subject to the accuracy of self-report. Drivers may want to be regarded in a positive manner and thus report more acceptable behaviours. Drivers may also not be aware of how often they perform a specified behaviour. Self report data for any of the behaviours in this study could be subject to these problems.

The questionnaires that were used in this study were comprehensive. However, this meant they were also long and sometimes repetitive. Data quality can be affected if participants become bored and/or annoyed. The difficulty in designing questionnaires for this study was that previous research in this area had taken what the authors regarded as a piecemeal approach to subjective data collection. It was unclear what type of subjective data should be collected. Thus it was difficult to know how to reduce the questionnaire length while still retaining important concepts. Fortunately, the extensive subjective data collected during the TAC SafeCar study can now inform the design of subjective data collection instruments for future research of this sort.

## Conclusions

Overall, the TAC SafeCar systems were rated as being acceptable in terms of their usefulness, effectiveness, social acceptability and usability. That is, the systems were considered

to serve a purpose and to do what they are supposed to. Drivers were consistent in their belief that the TAC SafeCar systems would be effective for drivers who inadvertently practice unsafe driving behaviours and that the systems would be less effective for drivers who intentionally drive in an unsafe manner. None of the systems increased driver workload, and some positive changes to driver attitudes resulted from exposure to the ITS. Importantly, the two systems which were found to have the greatest effect in enhancing safe driving performances – the ISA and SBR systems – were also acceptable to drivers. On this basis, the authors recommend that these two systems be widely deployed on passenger vehicles in Victoria.

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# Reducing road accidents through fatigue detection and monitoring: A review.

By N. Wijesuriya

Department of Medical and Molecular Biosciences,  
University of Technology, Sydney.

PO Box. 123, Broadway, Sydney, NSW 2007, Australia.

## Abstract

Driver fatigue is recognised as a major risk for road safety. Fatigue reduces drivers' ability to react to road and traffic

conditions, resulting in potential serious injuries and fatalities. A method of reducing the risk of fatigue related accidents is through monitoring/detecting fatigue changes in drivers. Fatigue is shown to be associated with factors like psychological, physiological and performance based changes in drivers, and these could be used to indicate the occurrence of fatigue. This paper reviews the literature concerned with these measures, and discusses the implications of these measures for road safety as well as their limitations. Research suggests that these measures have the potential to be used in fatigue detection/warning systems. However, further research is needed before such devices could be implemented in vehicles as fatigue countermeasure devices.