INVESTIGATING THE RELATIONSHIP BETWEEN DRIVERS’ SPEED CHOICE AND THEIR USE OF A VOLUNTARY ISA SYSTEM

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SUMMARY

Intelligent Speed Adaptation (ISA) could be implemented in a number of ways. The technology exists to implement systems that are purely advisory, or ones that actually control the maximum speed allowed. A compromise would be to introduce a system that allows a driver to choose when to engage ISA, thus creating a “voluntary” system. Whilst on the surface this appears to be an appropriate solution in terms of driver acceptability, there are a number of issues that are of concern – the most obvious one being the likelihood that drivers will not engage such a system if they deem it unnecessary or they dislike it. This type of “selective recruitment” may seriously devalue the safety benefits of a voluntary ISA system. This paper will describe two studies that examined the relationship between drivers’ reported and actual speeding behaviour, their propensity to engage a voluntary ISA system and their attitudes towards such a system. These studies were carried out in a driving simulator and on-road and provide some interesting results of relevance to the implementation policy adopted for ISA.

BACKGROUND

Evaluations carried out on ISA have usually included some measure of acceptability and have attempted to study various aspects such as:

- Acceptability towards different types of ISA system (e.g. voluntary/advisory/mandatory).
- Examination of acceptability before and after use of an ISA system.
- Monitoring acceptability over an extended period to study long-term effects.

Studies have typically found that drivers are more accepting once they have had practical experience of ISA and that they generally prefer systems that allow them to override the speed control function if necessary (Várhelyi and Mäkinen, 2001; Comte, 2001).
In an analysis by Tate (1998), it was demonstrated how different types of ISA (e.g. advisory and mandatory) could affect the speed distribution in different ways. A mandatory system that enforces maximum speed would transform the distribution whereby the speed distribution is truncated, with no vehicles exceeding the speed limit. An advisory system on the other hand, which provides a warning only, could translate the speed distribution whereby the shape of the speed distribution remains the same, but is shifted downwards in terms of speed.

However there is little data that exists to establish the likelihood that drivers would use a voluntary ISA system, and therefore it has been impossible to calculate the accidents benefits that such a system could supply. Some accident modelling has shown that the benefits of voluntary ISA could be approximately half that of a mandatory system (Carsten and Tate, 2001).

The benefits of a voluntary ISA system could be compromised if those who choose to use it are relatively safe drivers in the first place. Such “selective recruitment” was termed by Evans (1985) in his analysis of seat belt and non-seatbelt wearing fatalities. Using U.S. crash statistics he was able to demonstrate that the probability that a driver was wearing a seat belt at the time of the crash declined as crash severity increased. In other words, drivers who would benefit most are those least likely to wear a seat-belt (Evans, 1996).

The studies reported here attempted to add to our knowledge of drivers’ propensity to use a voluntary ISA system. The aims were:

- To examine the propensity of drivers to use a voluntary ISA system
- To examine the mediating effects of acceptability on system use
- To establish the relationship between speed choice and system use

Simply asking drivers how inclined they would be to use ISA in any given situation is unlikely to provide an accurate answer. Actual interaction with the system is necessary, preferably over an extended period of time. Thus two studies were carried out that allowed drivers to use an ISA system in order to derive a direct measure of acceptability.

**METHOD**

Two studies were carried out, one on a driving simulator (Figure 1a), the other using an instrumented vehicle (Figure 1b). A total of 18 participants took part, balanced for age and gender.
Driving simulator

The Leeds Advanced Driving Simulator is fixed-base, and at the time of these studies, presented a 120º forward view and 50º rear view. The ISA systems were implemented by making alterations to the simulator’s vehicle dynamics model. The vehicle dynamics model replicates that of a Rover 216GTi, the vehicle on which the simulator is based. Using a logical road network, each individual section of road can be given a speed limit that the car will, if required, adhere to. If the participant is driving the simulator at or below the speed limit the ISA system is inactive. If the voluntary ISA system is engaged and the participant attempts to accelerate above the speed limit, the vehicle dynamics model automatically prevents any further increase in speed by closing the throttle and applying a small brake pressure to the hydraulic system. Therefore even if the driver depresses the accelerator to its full extent there results no increase in speed.

Instrumented vehicle

In order for the ISA system to function in the real world for the on-road trials, an instrumented vehicle was designed to receive information pertaining to the posted speed limit of the road on which it was travelling and where the changes in the speed limit occurred. A differential Global Positioning System (dGPS) gave a reliable accuracy of around 1m, with virtually instant update of position.

The position and value of every speed limit along the test route was stored in the laptop computer as a “virtual beacon”. This virtual beacon could be moved and its radius altered according to where the ISA system should operate. For example, if the speed limit changed from 60 mph to 30 mph, the beacon was positioned so that the ISA system would engage before the speed limit change. This ensured that the ISA system was able to decelerate the car sufficiently, such that the vehicle was travelling at the lower speed limit as it passed the speed limit sign.

The ISA software calculated the appropriate speed limit (as described above) and compared this with the car’s actual speed, determined from the ABS wheel speed sensors. If the car was travelling below the speed limit, it behaved as a normal car. However, if the voluntary ISA system is engaged, and the participant attempted to exceed the speed limit, a signal was sent to a pair of auxiliary Engine Control Units. These first reduced engine power by retarding the ignition for up to 30 seconds. In order to provide a longer and/or greater reduction in power, the amount of fuel injected into the engine was progressively cut. If the retardation and the fuel cut-off were insufficient, because the car was going down hill for example, the brakes were gently applied to decelerate the car to the speed limit. A laptop PC, installed in the boot of the car, not only ran the ISA software but also recorded the required data.

ISA System features

The voluntary system allowed the driver to decide whether to engage ISA or not. By providing drivers with an on/off switch, drivers were able to engage and disengage the system as required. In both the simulator and the on-road trials, an LCD was mounted on the dashboard to the left of the steering wheel. The HMI for both the trials was identical in order to increase comparability. In Figure 2(a) the display indicates to the driver that the speed limit of the road is 30 mph. In addition, the display shows the ISA system is engaged. In Figure 2(b) ISA has been disengaged, however the posted speed limit is still displayed.
Both objective and subjective measures were recorded in these studies.

Driver behaviour

The simulator study involved a route of approximately 22 miles comprising of urban, rural and motorway environments and provided a full range of speed limits between 30 and 70 mph. Similarly, the on-road study involved a route selected to include roads of varying speed limits and classes and was approximately 42 miles in length. Speed limits varied from 30 to 70 mph and was thought appropriate as the traffic was mostly free-flowing and there were opportunities for drivers to exceed the speed limit if they wished to do so.

Both the studies allowed the opportunity of collecting a wide range of driving variables, however, the variables of interest here were speed (mph) and system use (on or off). These were collected continuously throughout both the studies.

Driving Style

Participants completed the Driving Style Questionnaire (DSQ) before the experiment commenced. The DSQ contains 15 items based on behaviours that are associated with risky driving behaviour. The items relate to speed, traffic signal violation, headway, seatbelt use and gap acceptance. Self-reported speed as measured by the DSQ has been shown to correlate well with observed driving speed on a test route comprising motorway, rural and urban roads (West et al., 1992). The DSQ has been found to load onto six components namely: speed, calmness, social resistance, focus, planning and deviance. Whilst the DSQ only concentrates on breaking the speed limits (and thus does not address "appropriate speed"), there is evidence that violators of the speed limit have increased accident risk (Parker, Reason, Manstead and Stradling 1995). Only the items relating to speed were of interest in these studies. These items were:

- Do you exceed the 70 mph limit during a motorway journey?
- Do you exceed the limit in built-up areas?
- Do you drive fast?

The scores relating to the three items concerning speed were totalled. It was hypothesised that DSQ scores would correlate with system acceptability, such that those drivers who ordinarily choose to drive fast would exhibit lower scores on the acceptability questionnaire.
In addition it was hypothesised that the fast drivers would be more inclined to disengage the Driver Select system.

**Acceptability**

In order to measure acceptability, prior to drivers experiencing ISA, an acceptability questionnaire (Van der Laan et al., 1997) was administered. This questionnaire, developed specifically by researchers in the transport telematics field and allows participants to express a preference between the different systems in terms of “usefulness” and “satisfaction” using nine items. The concept of *usefulness* refers to how effective or supportive a system is, whilst *satisfying* refers to how pleasant it is to use. The authors predict that acceptability lies along a continuum according to the complexity of the system and the amount of control it exerts over driver behaviour. This questionnaire was also administered after subsequent drives, thus providing an indication of if and how acceptability changed after exposure to ISA.

**RESULTS**

For clarity, the results of the two studies will be described separately.

**Driving simulator study**

Each participant completed four drives using the same route. The system remained disengaged in the first drive for all participants, thus supplying baseline data on their normal driving behaviour. A total of 10 participants took part in this study. The participants for the study were drawn from an existing database and the sample was balanced for age and gender. All participants possessed a full, clean driving licence.

The following calculations were made:
- the propensity to engage the voluntary ISA system
- the average score across the three speed factors on the DSQ
- the average acceptability score.

In the simulator study, propensity to engage the system decreased as the speed limit increased (see Figure 3). In any case, average use was approximately 50% in areas with a speed limit higher than 30 mph.

Figure 3: Use of the voluntary ISA system (simulator study)
Correlation analyses were carried out on the variables outlined above; age was also included as a factor. It was hypothesised that lower acceptability scores would be associated with lower age, low system use and higher DSQ scores. Table 1 shows the correlation matrix obtained.

Table 1: Correlation analyses for DSQ

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Acceptability</th>
<th>System Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSQ</td>
<td>Pearson’s r 0.24</td>
<td>-0.14</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tail) 0.37</td>
<td>0.51</td>
<td>0.14</td>
</tr>
<tr>
<td>Age</td>
<td>Pearson’s r 0.25</td>
<td>0.36</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tail) 0.37</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Acceptability</td>
<td>Pearson’s r 0.35</td>
<td>0.15</td>
<td></td>
</tr>
</tbody>
</table>

It can be seen that no associations were found between acceptability, age and DSQ scores. This suggests that different driver types, as defined by their typical driving behaviour and age, did not hold different opinions about the utility or comfort of ISA, nor did these factors influence their use of the voluntary ISA system.

It was felt that this warranted further study, especially in the light of the fact that the simulator could not fully replicate the real-life experience of driving with ISA. For example, the driving simulator that was used was a fixed-base one, and thus no motional cues with regards to deceleration were available to the drivers. In addition, the acceptability scores may have been affected by the fact that other vehicles in the scene were travelling at or below the speed limit. The on-road study provided the ideal environment for further investigation.

**On-road study**

The experimental design was the same as used in the simulator study. However, due to time constraints, each participant only completed three drives using the same route. The system remained disengaged in the first drive for all participants, thus supplying baseline data on their normal driving behaviour.

The participants for the study were mostly drawn from an existing database. The sample was balanced for age and gender and participants were selected on the basis that they were regular drivers on all the road types incorporated in the test route.
The propensity to engage the system can be seen in Figure 4.

![Figure 4: Use of the voluntary ISA system (on-road study)](image)

The results of the study suggest that, as a rule of thumb, in urban environments drivers were willing to engage the ISA system for approximately 80% of time spent driving. The lower score in the on-road trials for one of the 30 mph areas is as a result of it being immediately after a 60 mph area. This inclined drivers to disengage the system due to pressure from following traffic. In most other areas, drivers were willing to use the system approximately 60% of the time.

A similar correlation analysis was undertaken and the results can be seen in Table 2.

**Table 2: Correlation analyses for DSQ**

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Acceptability</th>
<th>System use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DSQ</strong></td>
<td>Pearson’s $r$</td>
<td>-0.02</td>
<td>-0.11</td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tail)</td>
<td>0.48</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>Pearson’s $r$</td>
<td>0.75</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tail)</td>
<td>0.02</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>Acceptability</strong></td>
<td>Pearson’s $r$</td>
<td>0.39</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tail)</td>
<td>0.17</td>
<td></td>
</tr>
</tbody>
</table>

It can be seen from the results that this time there is a clear association between some of the variables.

Firstly, the correlation matrix indicates that acceptability scores increased as age increased. Therefore, although the acceptability scores were higher for the Driver Select group in general, only the older drivers were in favour of it.

There was found to be a negative correlation between system use and DSQ scores. Thus those drivers who admit to speeding, as measure by the DSQ, were less likely to engage the voluntary ISA system.
CONCLUSIONS

The propensity to use a voluntary ISA system was monitored to provide an estimate of the likely benefits of such a system. Obviously a voluntary system relies on the driver choosing to use it. The studies showed that, in general, drivers used the system for more than 50% of the time.

However, of major interest was discovering which drivers used it more than others, and whether these drivers held any views about speed and speeding that could mediate their use of the ISA system.

In the simulator study, no associations were found. However, in the on-road study, there was found to be a negative correlation between system use and DSQ scores. The interpretation here is that those drivers who admit to speeding were less likely to engage the Driver Select system. This is an important finding when considering the mechanisms for implementing ISA: those drivers who would benefit most would be less likely to use a voluntary system.

Estimation of compliance levels, however, may not be as simple as these studies imply. System use has been found to be dictated by the density and behaviour of the surrounding traffic (Comte, 2001) and undoubtedly by the degree of system penetration in the vehicle fleet. Research has found that drivers tend to influence one another’s speed (Åberg, Larsen, Glad and Beilinson, 1997) and that drivers choose their speed by comparing it to those of other drivers around them (Connolly and Åberg, 1993). Both the simulator study and the on-road trial indicated that drivers were willing to engage the system in low speed limit areas, where other speed-constraining factors existed. However, in both higher speed limit areas, particularly where traffic density was low, and in speed transition areas, drivers’ propensity to engage the system was considerably less. This introduces an “unknown” into the equation of system compliance in that drivers’ decisions are based on extraneous and changeable variables.

Whilst the sample sizes in these studies are relatively small, the results provide an indication that self-selection bias could be a problem in the take-up of a voluntary system. Furthermore, additional work needs to be undertaken to discover which driver types are more likely to use the system. The acceptability studies outlined here suggested that drivers who report higher preferred speeds also report lower acceptability scores. It is for these drivers that ISA would have the greatest benefits in terms of reduced mean speeds and it is particularly relevant for novice drivers.
References


