
Guo W, Blythe PT, Edwards SF, Pavkova K, Brennan D.

[Effect of Intelligent Speed Adaptation Technology on Older Drivers' Driving Performance.](#)

IET Intelligent Transport Systems 2015, 9(3), 343-350.

Copyright:

This is an open access article published by the IET under the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0/>)

Link to published article:

<http://dx.doi.org/10.1049/iet-its.2013.0136>

Date deposited:

09/10/2013



This work is licensed under a [Creative Commons Attribution 3.0 Unported License](http://creativecommons.org/licenses/by/3.0/)

Published in IET Intelligent Transport Systems
 Received on 31st July 2013
 Revised on 1st November 2013
 Accepted on 2nd November 2013
 doi: 10.1049/iet-its.2013.0136



ISSN 1751-956X

Effect of intelligent speed adaptation technology on older drivers' driving performance

Weihong Guo¹, Philip T. Blythe¹, Simon Edwards¹, Katerina Pavkova², Dan Brennan¹

¹TORG, School of Civil Engineering & Geosciences, Newcastle University, Cassie Building, Newcastle upon Tyne, NE1 7RU, UK

²Department of Civil Engineering, Institute of Transport Studies, Monash University, 3800 Victoria, Australia
 E-mail: weihong.guo@ncl.ac.uk

Abstract: Excess speeding on roads with a low-speed limit is a key error in drivers of all ages although the reasons for speeding can be significantly different. Drivers aged over 60 are generally more cautious, and take fewer risks than younger aged drivers. This study investigates whether Intelligent Speed Adaptation (ISA) technology can assist older drivers in maintaining vehicle speed. The technology can be employed in three ways: advisory (AISA), differential (DISA) and mandatory (MISA). Twenty-six drivers aged over 60 years old participated along with a comparison group of 16 experienced younger drivers aged under 60. All drivers completed four driving tasks in a driving simulator with and without ISA. Results show improvements in speed and lane-keeping performance vary depending on the type of ISA and driver age and training in effective use of ISA is needed for drivers of all ages. The study is one component of a wider research programme exploring how ITS could potentially help older people overcome some of the difficulties they experience with driving as they age and hopefully help them remain safe drivers for longer, a benefit both to the individual and society.

1 Introduction

Intelligent Speed Adaptation (ISA) is an in-vehicle system designed to promote compliance with speed limits by bringing the speed limit into the vehicle [1]. An ISA system can be configured to be 'advisory' or 'intervening' (overridable or non-overridable) [2, 3]. Extensive trials of both configurations have been carried out internationally, with UK trials in real-world driving conditions demonstrating that ISA can significantly reduce speeding and could in its non-overridable version deliver a 29% reduction in injury accidents [1, 3].

Overridable (voluntary) ISA solutions are likely to be less effective [4]. Drivers who enjoy and engage in speeding are less likely to use a system that would inhibit this. In other words, those drivers who would benefit most would be less likely to use it. A voluntary ISA system is also less likely to be utilised by drivers in areas with low-speed limits or low-traffic density, and in speed transition areas, where they do not perceive a need for it. The UK ISA trials (2004–2006) showed that ISA was overridden most often on 70 mph (112 kph) roads and in built up areas (20/30 mph zones) [3].

The reported studies did not focus specifically on drivers aged over 60 which is the approximate age where the decline of Killed and Serious Injured in reported road accidents stops and an increase begins [5]. For this age group, speeding is a key driver error but is usually not deliberate and is 'normal' behaviour rather than induced by cognitive impairment [6]. Moreover, research in the SiDE

(Social inclusion through the digital economy) project suggests that speeding on low-speed limit roads is a particular issue for this age group [5]. Eighty percent of participating drivers aged over 60 experienced difficulty in maintaining a relatively smooth speed under free-flow traffic conditions and exceeded the speed limit when driving on roads with a 30 mph (48 kph) speed limit [7]. Although older drivers are commonly known to avoid challenging situations they often drive in high risk urban environments where they are dependent on controlling and safely adjusting their speed and attention to other road users [5, 6, 8, 9]. Low-speed zones are often complex covering a variety of road layouts including residential streets and arterial roads (where roads are wider and often dual carriageways) [3]. They present multiple additional hazards such as schools, on street parking, varied signage and street furniture and the presence of vulnerable road users, which can provide cognitive challenges for older drivers. Some older drivers report difficulties in spotting speed limit signs leading to lack of awareness of the correct speed limit and unintentional speeding in free-flowing traffic conditions [10]. The same study found that older drivers have a propensity to cease driving when they receive a speed violation notification.

With the number of older drivers set to increase in line with population trends over the coming decades, and the adverse effect on both individual and society from loss of mobility caused by driver cessation, it is imperative to investigate ways to keep older drivers safely on the road for longer

[5, 10]. The focus of this paper is a study into the potential for ISA technology to improve the ability of older drivers aged over 60 to maintain speed when driving in a low-speed zone without compromising road safety. An experimental group comprising of 26 drivers aged over 60 and a comparison group of 16 drivers 60 and under were recruited. For the purposes of this paper, we refer to the group of drivers aged 60 and under as 'younger aged drivers' and those above 60 as 'older drivers'. As the study aimed to compare the older drivers with a group of experienced younger drivers, anyone with less than 10 years driving experience was not considered. Three versions of the ISA are presented: advisory, differential and mandatory. These were presented as scenarios under free-flowing traffic conditions on a driving simulator at Newcastle University. Driving performance was measured through speed and lateral lane-position data collected from the simulator.

2 ISA system

The ISA described in this study is a modified version of that used in the UK ISA trials [1, 3, 4, 11]. It is designed to assist older drivers in maintaining better and safer vehicle speed when driving on roads with a low-speed limit. The system constantly monitors vehicle speed and the local speed limit and prompts the driver to adjust the vehicle speed in relation to the local speed limit. The system can be employed in three ways based on personal preferences:

- The advisory ISA (AISA) reminds the driver of the local speed limit as well as forthcoming speed limit changes. The AISA underpins the following two options.
- The differential ISA (DISA) prompts the driver to slow down when the vehicle exceeds the speed limit.
- The mandatory ISA (MISA) activates the brake system automatically when the vehicle exceeds the speed limit.

These systems use information about the road on which the vehicle travels to make decisions about what the correct speed should be under free-flowing traffic conditions. This information can be obtained through the use of either a digital speed map which has accurate information about the physical location of the speed limit signs on the road network, including repeater signs, a camera to capture speed limit signs and feed into the ISA system, or a roadside beacon communicating with the vehicle. The systems are designed to be proactive to create extra time for the drivers to react to a new speed zone, to compensate for declined working memory by providing an always-on reminder of the speed limit, and to activate the autonomous braking function when required. This is particularly useful when older drivers are in unfamiliar areas or when they pass through areas where variable speed limits are used.

3 Experimental design

The study was performed on the SiDE driving simulator at Newcastle University by using four driving scenarios. The simulator provides a safe environment for introducing ISA systems to participants aged over 60. It is also more economical than real world trials which can be costly and take longer to implement. Driving performances were measured through speed and lateral lane-position data collected from the simulator. This section introduces the participants, design and process of the study.

3.1 Participants

3.1.1 Socio-demographic characteristics: To be eligible for the study, the participants were required to be experienced drivers, holding a license for at least 10 years. As this study was part of on-going research to explore technologies to support older drivers (aged over 60), 30 volunteers in this age group were recruited. A further 18 drivers aged 60 and under were also recruited with the aim to understand whether a system designed for older drivers would have an effect on drivers at younger ages. Out of the 48 participants, 6 did not complete all the required driving tasks because of simulator sickness and hence were excluded from the analysis. As a result, the sample used for the final analysis includes 26 drivers aged over 60 [16 male (62%) and 10 female (38%), average age = 70.5, SD = 7.25] and 16 drivers aged 60 and under [9 male (56%) and 7 female (44%), average age = 47.3, SD = 8.34]. Those aged over 60 formed an experimental group while those aged 60 and under formed a comparison group. Through comparison of the changes in driving performance between the two groups, the effect of the ISA systems on the older drivers could be determined.

According to the self-report, only one older participant remained in paid employment (self-employed) and only two participants aged 60 and under were not in employment. However, more than half of the retired older participants were still doing voluntary work with only 42% (11 out of 26) no longer working. Research into the wellbeing of older people suggests that volunteering benefits health and those who volunteer are generally of better health than those who do not [12, 13]. Hence, it can be assumed that the majority of the older participants were healthy and active.

Five mileage categories ranging from under 3000 miles to over 15 000 miles were listed for the participants to report which category they belonged to (see Table 1). The results indicate that the range of distances driven in a typical year is relatively evenly spread with typical annual mileages for over 88% (37) of the participants between 3000 and 15 000 miles, 5% (2) under 3000 miles and 7% (3) over 15 000 miles. A Mann-Whitney *U* test (MWT) was applied to examine whether the distribution of the younger aged drivers' annual mileage was the same as the over 60s'. Since the *p* value is 0.610 (>0.05), this shows that, although the younger aged drivers seem to travel more mileages in a typical year than those aged over 60, the distributions were not significantly different from each other. The same test was applied to examine whether the distribution of 'when they drove' and 'where they drove' were the same. The results again show no significant difference ($p_{\text{when}} = 0.632$ and $p_{\text{where}} = 0.648$). It suggests that this sample of older drivers has retained a generally similar driving pattern to their younger aged counterparts,

Table 1 Cross comparison of participants' age, gender and annual mileage ($n = 42$)

Annual mileage (0.000's)	60 and under ($n = 16$), %	Over 60 ($n = 26$), %
0-3	0	8
3-6	31	31
6-10	38	27
10-15	12	34
15+	19	0



Fig. 1 Recorded excess speed for each speeding offence reported by the participants ($n = 21$)

which could be seen as a sign of active living in this group of older participants.

3.1.2 Summary of the participants' speeding offences: In total, 58% (15) of older drivers and 38% (6) of younger aged drivers admitted that they had been convicted of speeding in the past decade (see Fig. 1). Among the 21 (=15+6) speeding offences, 7 were female with 2 aged under 60. It is possible that some of the participants chose not to divulge this information. All 15 older offenders committed the speeding violation when driving on a road with a 30 mph speed limit with an average excess speed of 5.2 mph ($SD = 1.97$), 17% higher than the actual speed limit. In contrast, only 13% (2) of the younger offenders were speeding on roads with a 30 mph limit, the other 25% (4) were on higher speed roads.

3.2 Driving simulator

The driving simulator used in this study consists of an aluminium cabin equipped with five 50 inch high-resolution LCD displays, all control actuators, dynamic force feedback steering wheel, clutch, brake and acceleration pedals, adjustable car seat and safety belt with a sensor. It also has three graphical channels and three simulated mirrors, that is, rear, left and right wing mirrors. The 5.1 sound system helps

create a real three-dimensional driving experience. Most of the participants stated that, compared with their own vehicle, the steering wheel was much lighter and the brake was more sensitive, however, it was regarded by all as 'good enough'.

3.3 Design of the driving scenarios

3.3.1 Simulated road map: For the experiment, a simulated circular road map with seven paths connected by seven nodes (see Fig. 2) was designed. The road layout was simple, comprising of a single carriageway with two lanes (one for each direction), no central reservation and several transitions from higher/lower speed limits – as the objective is to purely observe the speeding behaviour. The length and the speed limit of each path are listed in Fig. 2. Although the focus of the study was to test the ISA systems on low-speed limit zones only, various speed limits were included to create a closer-to-real-life driving experience.

3.3.2 Driving scenarios: Four driving scenarios were developed by using the simulated road map illustrated in Fig. 2. The scenarios generate random oncoming traffic, however, no vehicle was created in front of the drivers as this may influence their speed judgement and for the same reason no following vehicle was created. To make the

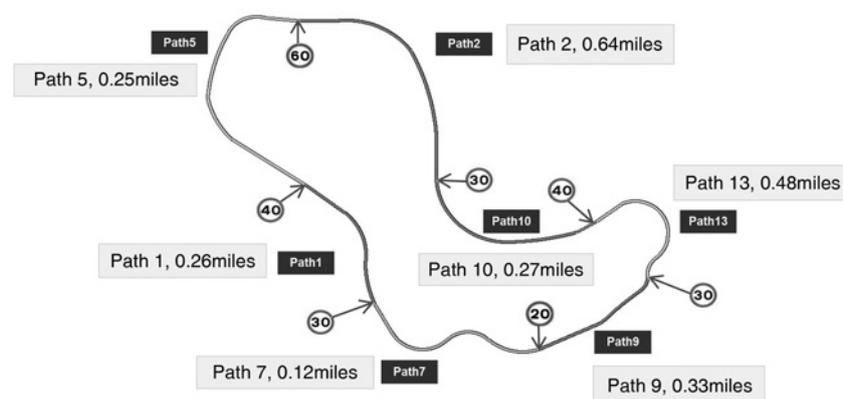


Fig. 2 Simulated road map

*The path numbers were generated during the map creating process and hence are not numbered consecutively

scenarios look different from each other, individual starting points were defined for each scenario and listed as follows:

- Scenario 1 – the ISA systems were not available, hence it was named as Scenario NISA. It began with Path 7.
- Scenario 2 – AISA system was available. It began with Path 10. A speed limit sign with a blue background colour in the left lower corner of the windscreen was used to remind the driver of the current speed limit. A 3-s long audible message would be triggered when driving towards a road with a different speed limit: ‘You are about to enter 20 miles per hour zone’. A 5-s gap was given between the trigger point and the entry of the new speed limit zone which provided the driver with a 2-s reaction time. This underpins Scenarios 3 and 4.
- Scenario 3 – DISA system was available. It began with Path 1. The background colour changes from blue to red if the driver exceeds the speed limit. An audible message is triggered at the same time when the colour changes: ‘Please slow down. You are over the 30 miles per hour speed limit’.
- Scenario 4 – MISA system was available. It began with Path 9. The automatic braking system is activated if the driver exceeds the speed limit and the steering wheel starts to vibrate. There will be no warning about speeding.

3.4 Data processing

The simulator was set up to collect data from the simulator every 0.1 s. The raw data from the simulator were in binary form and were converted into ASCII format, then were cleansed and organised in the MS Excel and R project software. SPSS software was used for descriptive statistics and further analysis. The values of the velocity were recalculated to mph (miles per hour) to comply with the UK Highway Code. Path numbers were used to divide the datasets into sections in relation to the speed limit and the position on the track. As there has never been an issue involving older drivers speeding on roads with a speed limit higher than 30 mph [7], driver performance on paths 2, 5 and 13 was not concerned in the context of implementing ISA systems in this study. Although path 7 had a speed limit of 20 mph, it was used as the starting point of Scenario 1 and hence was also excluded from the analyses.

However, if the path was defined as the starting path of one scenario but a middle path of another scenario, it would not be used to compare the participant’s speeding performance (e.g. Path 10 was not used to compare the speed performance between NISA and AISA). This is because the initial speeds of the starting path and of a middle path would always be significantly different from each other: one was always 0 mph and the other one was always much higher than 0 mph. Hence, two paths were defined to examine the driving performance of each scenario and are listed in Table 2.

3.5 Procedure of the study

Each participant was given considerable practice time to become comfortable with and competent at using the simulator prior to the data collection and to gain familiarity with the route. Scenario NISA was used for the practice and the data collected from the last 5-min practice were used as the baseline. Then, the participant was asked to complete three more driving tasks with one of the six pre-defined orders. This was to eliminate the effect of one particular order on the participants’ driving performance. The

Table 2 Paths used to examine the driving performance in each scenario

Path	Scenario NISA	Scenario AISA	Scenario DISA	Scenario MISA
1	no	yes	no	yes
9	yes	yes	yes	no
10	yes	no	yes	yes

participants were asked to obey the speed limit and drive along the road as they normally would in real life. A brief explanation of how each ISA system was implemented was given to the participant prior to the corresponding driving task. The participant would be informed to stop once he/she completed the whole circuit.

4 Results of the driving performance

Obedying the speed limit and maintaining stable steering and good lateral lane-keeping are fundamental to safe driving. In this experiment, the participants were asked to drive through a loop of road under free-flowing traffic condition with no junctions and with no overtaking activities. However, the participants could be distracted or experience cognitive overload from the ISA system and drift out of lane. Hence, both their lateral lane-keeping performance and their longitudinal vehicle speed performance were examined with and without the ISA systems by using the data collected from the driving simulator. The analyses were carried out on a scenario-by-scenario basis for each participant and then their performances were compared.

4.1 Lateral lane-keeping performance

Each participant had 12 lane-position datasets (= 3 paths × 4 scenarios). A ‘0’ value of the lane position represents the centre of the lane. A negative/positive value indicates that the car was on the left/right side of the central line, respectively. The lane width was 3 m and the vehicle width was 1.6 m. Hence, any value larger than 0.7 (1.5–0.8) or smaller than –0.7 (–1.5+0.8) means that the vehicle was either over the lane or on the pavement.

To translate the lane-position data into lane-keeping performance, two systems were adopted: a binary rating system (BRS) and the three-point ranking system (PRS). The BRS was used to indicate whether the vehicle had gone over to the pavement or to the other side of the road. This was done by identifying the minimum (Min.) and maximum (Max.) values and then giving a rating to the dataset a ‘0’ if not or ‘–1’ if yes. The PRS was applied to rank the lane-keeping performance based on the values of range (*R*), mean (*M*), standard deviation (*SD*) of each dataset by using a scale ranging from 1 (furthest from ‘0’) to 3 (closest to ‘0’). Furthermore, line charts were produced for each lane-position dataset to graphically demonstrate the lane-keeping performance to assist the rating and ranking (see Fig. 3). The sum of each scenario represents the participant’s lane-keeping performance where the larger value of the sum leads to a higher rank of the performance. A scale of 1–4 was applied for the ranking with ‘1’ being the poorest performance and ‘4’ being the best performance (see Tables 3 and 4).

The overview of the drivers’ lane-keeping rankings is illustrated in Fig. 4. It shows that, compared with driving

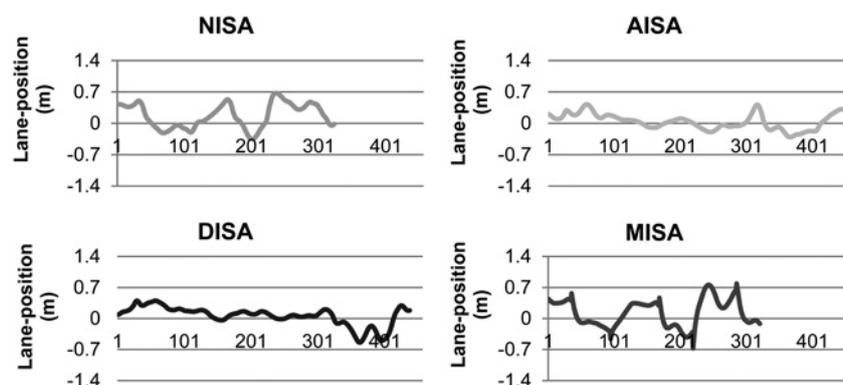


Fig. 3 Example of the graphic demonstration of the lateral lane-keeping performance

Table 3 Descriptive statistics of one participants lane-position data

Path	Scenario	Time	R	Min.	Max.	M	SD
1	2 (AISA)	33.2	1.1154	-0.2950	0.8204	0.184298	0.2552039
	4 (MISA)	32.5	1.0352	-0.2872	0.7480	0.207208	0.2597715
9	1 (NISA)	66.6	1.9721	-1.5175	0.4546	-0.366603	0.5936414
	2 (AISA)	46.0	0.6728	-0.3221	0.3507	0.054961	0.1679863
10	3 (DISA)	45.2	0.8173	-0.2427	0.5746	0.203642	0.1820054
	1 (NISA)	34.1	1.4546	-0.1593	1.2953	0.598858	0.4054190
	3 (DISA)	36.9	1.3184	-0.1673	1.1511	0.367614	0.2934673
	4 (MISA)	32.3	2.5846	-1.3027	1.2819	0.389786	0.3284136

Table 4 Example of the ranking exercises according to the data shown in Table 3

Scenario	BRS	Path 1 ratings			Path 9 ratings			Path 10 ratings			Sum	Rank
		Range	M	SD	Range	M	SD	Range	M	SD		
1 (NISA)	-2	(1)	(1)	(1)	1	1	1	2	1	1	5	1
2 (AISA)	-1	2	3	3	3	3	3	—	—	—	16	4
3 (DISA)	-1	—	—	—	2	2	2	3	3	3	14	3
4 (MISA)	-3	3	2	2	—	—	—	1	2	2	9	2

without any ISA system, the majority of the older drivers performed best when driving with the AISA system (over 65% of drivers rated 4) while over half of the drivers aged 31–60 performed the best when driving with the DISA system. The results of the Kruskal–Wallis test (KWT) confirm that the distribution of the older participants across the four scenarios is significantly different but that of their younger counterparts is not (see the p values in Table 5). This suggests that the older participants' lane-keeping performance were likely to be affected by the ISA systems but not those aged 60 and under. The AISA system has the

potential to improve the lane-keeping performance of the older drivers while the DISA and MISA systems are unlikely to do so.

Table 5 also shows that although only one mean value of the older participants' lane position (-0.018) is closer to '0' than that of the younger participants (-0.05), the differences of each paired mean values are very small ranging from -0.063 to 0.104 m. The results of the MWT demonstrate that the distribution of the younger and the older participants' lane-keeping performances was not statistically significantly different ($p = 0.385$). This indicates

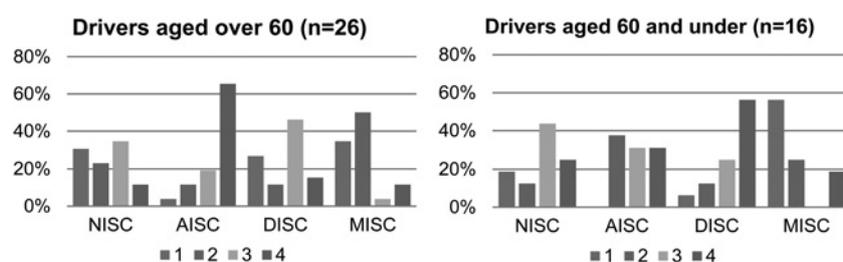


Fig. 4 Summary of the drivers' lane-keeping rankings

(note: 1 = 'poorest performance', 4 = 'best performance')

Table 5 Descriptive statistics of the participants' lane-position values (left) and the *p* values of the KWT (right)

Driver group	Path	The mean lane-position values of the participants				MWT <i>p</i> values ^a
		NISA	AISA	DISA	MISA	
older (<i>n</i> = 26)	1	—	-0.018	—	0.07	0.001 ^b
	9	0.144	0.121	0.135	—	0.001 ^b
	10	0.213	—	0.218	0.26	0.022 ^b
younger (<i>n</i> = 16)	1	—	-0.05	—	-0.034	0.770
	9	0.072	0.065	0.057	—	0.728
	10	0.149	—	0.173	0.2	0.342

^aNull hypothesis – the distribution of the lane-keeping performance is the same across the four scenarios (rejected)
^bThe difference is significant at the 1% level

that the participants aged over 60 were still able to maintain lane-position nearly as well as their younger counterparts, either with or without the ISA systems.

Both the groups had the worst performance when using MISA where over 80% of the participants' lane-keeping performances were rated either 1 or 2. When observing steering behaviour, it reveals that these participants were surprised when the autonomous braking function was activated and failed to hold the vibrating steering wheel tight enough. It seems to suggest that they did not know what the right action should be when control of the vehicle's speed was taken away from them. Since being able to maintain good lateral lane position is extremely important for road safety, this issue needs to be addressed for the technology to be used properly and safely.

MWT and KWT were also applied to examine the distributions of the lane-keeping performances across the age and gender categories within the younger and the older groups, respectively. The results show that gender had a statistically significant effect on the older participants' lane-keeping performance ($P_{Older-Gender-P1} = 0.000$, $P_{Older-Gender-P9} = 0.031$, $P_{Older-Gender-P10} = 0.007$) but age did not ($P_{Older-Age-P1} = 0.343$, $P_{Older-Age-P9} = 0.588$, $P_{Older-Age-P10} = 0.429$). Since the mean values of female older participants' lane-position (-0.0214 on path 1, 0.0491 on path 9 and 0.138 on path 10) are smaller than those of the males (0.104 on path 1, 0.125 on path 9 and 0.242 on path 10), it can be concluded that the females lane-keeping performance is better than the males. However, neither gender nor age had an effect on the younger participants' lane-keeping performance.

4.2 Speed performance

Twelve datasets of speed were produced for each participant (= 3 paths × 4 scenarios). To translate the speed data into performance, the same rating and ranking methods were applied. The BRS was used to indicate whether there was any speeding behaviour in a dataset. As the speed limits of the chosen paths were all 30 mph, any dataset with speed data 10% higher than the speed limit (i.e. 33 mph/53 kph) would be rated as '-1', otherwise, '0'. This was done by examining the maximum values of the speed. The PRS was applied to rank the values of *R*, *M* and SD of each dataset by using a scale ranging from 1 (furthest from '0' for *R* and SD or '30' for *M*) to 3 (closest to '0' for *R* and SD or '30' for *M*). Furthermore, line charts were produced to graphically demonstrate the speed performance to assist the ranking exercises (see Fig. 5). The sum of each scenario represents the participant's speed performance where the larger value of the sum leads to a higher rank of the speed performance. A scale of 1–4 was adopted for ranking with '1' being the poorest performance and '4' being the best performance.

Only two older participants did not exceed the 30 mph speed limit. All the other participants did so at one time or another with younger aged drivers (on average, six times per person) exceeding more often than older drivers (on average, four times per person). This indicates that exceeding the 30 mph speed limit was a common error among all the participants. The overview of the older and younger participants' speed ranking is shown in Fig. 6. It seems that drivers aged over 60 performed better in the MISA system (58% of drivers rated 4) and the AISA system (38% rated 4) than in the NISA and the DISA systems (only 4% rated 4 in both). Although a similar trend is seen with the drivers aged 60 and under, the mean speed value of these participants is always closer to '30' than the corresponding mean speed value of the older participants (see Table 6). The results of the MWT reveal that the younger participants' speed performance was significantly better than the older ones (see *p* values in Table 6).

The MWT was applied to the two age groups independently, indicating that gender did not have a significant effect on the participants' speed performance at the 5% level. However, the ISA systems had a significant effect on the older participants' speed performance ($P_{Older-P1} = 0.000$, $P_{Older-P9} = 0.001$ and $P_{Older-P10} = 0.000$) but not on the younger participants' ($P_{Younger-P1} = 0.063$, $P_{Younger-P9} = 0.301$ and $P_{Younger-P10} = 0.064$). The AISA and the MISA systems have the potential to improve the

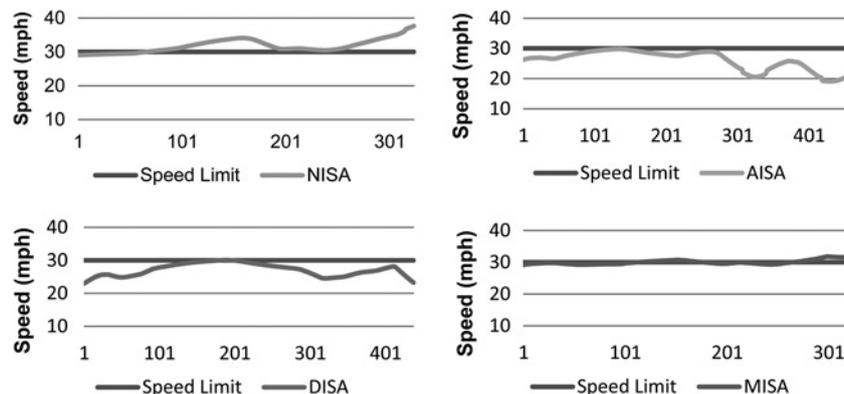


Fig. 5 Example of the graphic demonstration of the speed performance

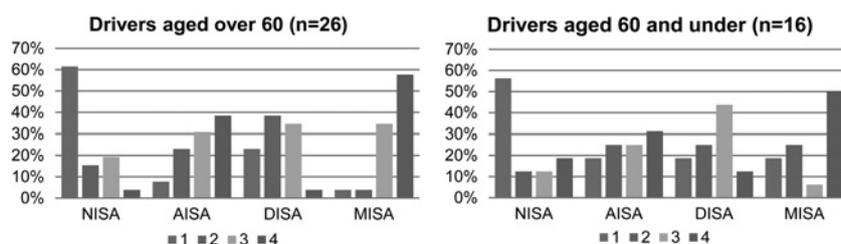


Fig. 6 Summary of the drivers' speed rankings

(note: 1 = 'poorest performance', 4 = 'best performance')

Table 6 P values of the MWT and the descriptive statistics of the participants' speed performance

Scenario	The mean speed values								
	MWT p values ^a			Older (n = 26)			Younger (n = 16)		
	Path 1	Path 9	Path 10	Path 1	Path 9	Path 10	Path 1	Path 9	Path 10
NISA	—	0.002 ^b	0.001 ^b	—	23	29	—	28	29
AISA	0.006 ^b	0.001 ^b	—	28	27	—	30	29	—
DISA	—	0.005 ^b	0.005 ^b	—	27	29	—	30	30
MISA	0.021 ^a	—	0.000 ^a	29	—	29	30	—	30

^aNull hypothesis – the distribution of the speed performance is the same between the younger and the older participants

^bThe difference is significant at the 5% level

performance of the older drivers but the DISA system has negligible effect.

5 Discussion

Research suggests that older drivers experience difficulty in maintaining a smooth speed under free-flow traffic conditions in built-up areas with low-road speed limits. Where speeding occurs it is rarely deliberate but is often associated with cognitive overload because of the complexity of the driving environment. Excess speed can lead to fixed penalty notices (which can result in driver cessation) or increased risk of involvement in road traffic accidents [10].

Underpinning the research presented in this paper is the theory that the ISA can play a role in helping older drivers stay safely on the road for longer. Driving simulator-based experiments are described by examining three versions of ISA technology: Advisory, differential and mandatory. Forty-two volunteers participated, with those aged 60 and under forming a comparison group. The simulator experiments focused on comparing the differences in driving performance in terms of speeding and lateral lane-keeping with and without the three ISA systems. Any conclusions on driving performance are not directly related to participants' everyday driving.

Through examination of the lane-keeping performance and speed performance, it seems that older drivers are more likely to be affected by the ISA systems than the younger aged participants when driving on a road with a speed limit of 30 mph.

Older drivers kept lane-position significantly better with the AISA system which has the least amount of interventions than with the DISA or the MISA. The younger aged drivers kept lane-position better with the DISA system which provides the highest frequency of information. This finding implies that older drivers tend to

perform better with technology which has less information, thus reducing cognitive load. However, the younger participants' lane-keeping performance is not significantly different from the older ones, either with the system or without. This suggests that the older drivers are as capable as their younger counterparts in terms of keeping safe lane-position.

Both the younger aged and the older drivers' lane-keeping performance deteriorated with the MISA. This was because of lack of experience with the autonomous braking system. A close observation of the drivers' steering performance revealed that those who performed badly with the system were taken by surprise when braking control was taken away from them. A training programme in how to use the system may enhance the effect of the MISA system in terms of lane-keeping performance.

Regarding vehicle speed, the younger aged drivers performed significantly better than the older participants with a mean value closer to the speed limit, but also exceeded the speed limit more often than the older drivers. Both the groups performed better with the MISA systems and the AISA system than without the ISA or with the DISA.

The results from this study suggest that the ISA should be designed differently for younger and older people. Training in how to use the system could enhance its potential for drivers of all ages.

Some form of the ISA would be accepted by a significant proportion of the drivers in the study. User perceptions and design issues of the ISA systems were measured during the study. The results will be reported in a future paper.

Furthermore, in discussion with industry partners the authors are exploring whether the ISA systems could be integrated with a new generation of In Vehicle Navigation Systems (IVNS) or even as part of an advanced insurance 'black-box' which monitors driving performance. Research in Denmark has shown that speeding can be reduced by an ISA system combining information about speeding and associated penalties, along with the incentive of reduced

insurance premiums [14]. This could benefit older drivers, who, like young drivers, tend to pay higher premiums for insurance based purely on their age, rather than driving ability. Integration of the ISA with the IVNS could also enable investigation into the difference between excess speed and inappropriate speed (driving within the speed limit but too fast for the conditions at the time), and the potential for the ISA to become a co-operative system where it is integrated with network-wide traffic management [3].

5.1 Limitations of the study

The majority of older participants seem to be healthy and active. They may also be the early-adopters of in-vehicle systems designed to support older drivers (as they actively volunteered for the study) and may not necessarily represent the older driver population as a whole. However, from our experience in the familiarisation drives in the simulator before the ISA was introduced there was no discernable difference in driving performance between this group and other groups of older drivers that have used the same familiarisation drives in other studies we have conducted [10], so we are confident that this group's profile should not bias the results. We intend to investigate this further in an upcoming trial.

Owing to the nature of the datasets, non-parametric tests were applied. The results of the nonparametric tests are typically less powerful and less efficient than the parametric tests. A large sample size would enable more robust and detailed analysis.

The study is also limited in its application to real world driving because of the use of simulated driving tasks and environment, a common limitation associated with studies using driving simulators [15]. The participants did not behave exactly the same way as they drive in real-traffic. However, a driving simulator based study is a cost-effective and efficient way to prove the concept and inform the design of the ISA for older drivers. Similar trials in an instrumented car on the Nissan Test Track in Sunderland will be conducted in a further study.

6 Conclusions

The ISA can play a role in helping older drivers stay safely on the road for longer by assisting with lane-keeping and speed performance under free-flow traffic conditions in built-up areas with low road speed limits. Examination of the performance data suggests that older drivers would benefit most from a MISA system in terms of keeping to the speed limit, but may be at greater risk of lane deviation. Lane keeping benefits most from the AISA, which has least interventions. As the AISA is also seen to benefit speed maintenance, it is likely that this system is currently the most effective for wider deployment. Training is a prerequisite for deployment of any ISA system. The ISA

systems need to be tested and the findings verified through real on-road and on-test track driving tasks before they can be considered for commercial production and widespread adoption. Consideration is being made to how such a system could be integrated into an insurance black-box product or a bespoke in-vehicle navigation system described in [10].

7 Acknowledgment

The authors gratefully acknowledge support for this research by the SIDE Projects (Social Inclusion through the Digital Economy) which is funded by the Research Councils UK Digital Economy Programme with a value of £12M (\$18 m) to the Newcastle Research Hub and the EPSRC 'Telling Tales of Engagement' programme.

8 References

- 1 Carsten, O.: 'Is intelligent speed adaptation ready for deployment?', *Accident Anal. Prev.*, 2012, **48**, pp. 1–3
- 2 Carsten, O.: 'European research on ISA: where are we now and what remains to be done' (ICTCT, Nagoya, 2002)
- 3 Lai, F., Carsten, O.: 'What benefit does intelligent speed adaptation deliver: a close examination of its effect on vehicle speeds', *Accident Anal. Prev.*, 2012, **48**, pp. 4–9
- 4 Jamson, S.: 'Would those who need ISA, use it? Investigating the relationship between drivers' speed choice and their use of a voluntary ISA system', *Transp. Res. F, Traffic Psychol. Behav.*, 2006, **9**, (3), pp. 195–206
- 5 Guo, W., Brake, J., Edwards, S., Blythe, P.T., Fairchild, R.: 'The application of in-vehicle systems for elderly drivers', *Eur. Transp. Res. Rev.*, 2010, **2**, (3), pp. 165–174
- 6 Selander, H., Lee, H.C., Johansson, K., Falkmer, T.: 'Older drivers: on-road and off-road test results', *Accident Anal. Prev.*, 2011, **43**, (4), pp. 1348–1354
- 7 Guo, W., Brennan, D., Blythe, P.T.: 'Detecting older drivers' stress level during real-world driving tasks'. Int. Conf. on Applied Psychology and Behavioral Sciences, Paris, June 2013, #307
- 8 Charlton, J.L., Oxley, J., Fildes, B., *et al.*: 'Characteristics of older drivers who adopt self-regulatory driving behaviours', *Transp. Res. F, Traffic Psychol. Behav.*, 2006, **9**, (5), pp. 363–373
- 9 Meng, A., Siren, A.: 'Cognitive problems, self-rated changes in driving skills, driving-related discomfort and self-regulation of driving in old drivers', *Accident Anal. Prev.*, 2012, **49**, pp. 322–329
- 10 Emmerson, C., Guo, W., Blythe, P.T., Namdeo, A., Edwards, S.: 'Folk in the road: In-vehicle navigation systems and older drivers', *Transp. Res. F, Traffic Psychol. Behav.*, 2013, **21**, pp. 173–180
- 11 Carsten, O., Fowkes, M.: 'External vehicle speed control – executive summary of projects results'. 2000, Institute for Transport Studies, MIRA, University of Leeds
- 12 Luoh, M.C., Herzog, A.R.: 'Individual consequences of volunteer and paid work in old age: health and mortality', *J. Health Social Behav.*, 2002, **43**, (4), pp. 490–509
- 13 Musick, M.A., Wilson, J.: 'Volunteering and depression: the role of the psychological and social resources in different age groups', *Social Sci. Med.*, 2003, **56**, (2), pp. 259–69
- 14 Agerholm, N., Waagepetersen, R., Tradisauskas, N., Harms, L., Lahrmann, H.: 'Preliminary results from the Danish Intelligent Speed Adaptation Project Pay as you Speed', *IET Intell. Transp. Syst.*, 2008, **2**, (2), pp. 143–153
- 15 Valero-Mora, P.M., Stevens, A.: 'Human-centred design and assessment of information technologies in traffic', *IET Intell. Transp. Syst.*, 2003, **7**, (2), pp. 171–73