INFORMATION SOCIETY TECHNOLOGIES (IST) PROGRAMME

AIDE

IST-1-507674-IP

Long-term phase test and results

Deliverable No.		**D1.2.4**	
SubProject No.	**SP1**	SubProject Title	**Behavioural Effects and Driver-Vehicle-Environment Modelling**
Workpackage No.	**WP1.1**	Workpackage Title	**DVE Modelling**
Activity No.	**A1.2.3**	Activity Title	**Assessment of variables: Integration (Long-Term Effects) phase**
Authors		**Evangelia Portouli, Vasilis Papakostopoulos (CERTH/HIT)** **Frank Lai & Kathryn Chorlton, ITS Leeds** **Magnus Hjälmdahl & Mats Wiklund, VTI** **Chin, E. (PSA), De Goede, R., Hoedemaeker, D.M., Brouwer, R.F.T. (TNO)** **Lheureux, F. (LPS-University of Provence), Saad, F. (INRETS), Pianelli, C. (INRETS & LPS-University of Provence), Abric, J-C. (LPS-University of Provence) and Roland, J. (RENAULT)**	
Status		**Submitted to EC**	
File Name:		**AIDE D1.2.4 v5 Submitted to EC.doc**	
Project start date and duration		**01 March 2004, 48 Months**	

History table

Version No.	Date (dd/mm/yy)	Details
1	13 October 2006	Sent to 1.2 partners for comments
2	19 October 2006	Sent for review
3	3 November 2006	Peer review results sent to the main authors
4	6 November 2006	Deliverable with Leeds and PSA corrections
5	11 November 2006	Deliverable finalised, according to peer review comments. Sent for submission

Table of Contents

LIST OF TABLES ..... **IV**

LIST OF FIGURES ..... **VI**

GLOSSARY OF ABBREVIATIONS ..... **VIII**

EXECUTIVE SUMMARY **1**

1 INTRODUCTION **2**

2 LONG TERM EFFECTS OF ISA **4**

2.1 INTRODUCTION 4
2.2 PROJECT OVERVIEW 5
2.2.1 The ISA-UK Project *5*
2.2.2 The Swedish Lund ISA-trial *5*
2.3 ANALYSIS OF VEHICLE DATA 7
2.3.1 UK data *7*
2.3.2 Swedish data *7*
2.4 RESULTS UK-TRIAL 12
2.4.1 Comparison between time and distance as measure of system exposure *12*
2.4.2 Distance based analysis *12*
2.4.3 Further consideration of distance as measure of system exposure *26*
2.5 RESULTS SWEDISH LUND ISA-TRIAL 29
2.5.1 The driver population *29*
2.5.2 Overall results *30*
2.5.3 Results on 70 km/h roads *31*
2.5.4 Results on 50 km/h roads *32*
2.5.5 Results on 30 km/h roads *33*
2.5.6 Change point estimation *33*
2.5.7 Further considerations of the data *35*
2.6 DISCUSSION 36

3 BEHAVIOURAL CHANGES DUE TO LONG TERM USE OF SPEED LIMITER AND CRUISE CONTROL **39**

3.1 INTRODUCTION 39
3.2 METHOD 39
3.2.1 Data collection *39*
3.2.2 Data analysis *40*
3.3 RESULTS 40
3.3.1 Characteristics of the respondents *40*
3.3.2 Overall description of the system's usage *42*
3.3.3 Motives for owning the systems and their links with the use made of them *44*
3.3.4 The reasons for not using the driving support systems *46*
3.3.5 Using the driver support systems *49*
3.3.6 Acceptance of the support systems in the next vehicle *61*
3.4 SUMMARY AND CONCLUSION 62
3.4.1 Use and non-use of the systems *62*
3.4.2 Familiarisation with and appropriation of support systems *63*
3.4.3 Frequency of use of support systems: the role of the situational context *63*
3.4.4 Perceived behavioural changes when using support systems *64*
3.4.5 Length of period of ownership of the system *64*

4 ON-ROAD STUDY ON LONG-TERM EFFECTS OF FCW+LDW ON DRIVING BEHAVIOUR 65

4.1 INTRODUCTION 65
4.2 METHOD 65
4.3 RESULTS 66
4.3.1 Speed *66*
4.3.2 Longitudinal behaviour *67*

4.3.3 Lateral Behaviour ... *70*
4.3.4 Subjective ratings ... *75*
4.4 OVERVIEW OF RESULTS ... 83
4.5 DISCUSSION ... 84

5 EFFECT OF LDWS ON DRIVING BEHAVIOUR ... 87

5.1 INTRODUCTION ... 87
5.2 EXPECTED LONG TERM EFFECTS OF LDWS ... 88
5.3 METHOD ... 88
5.3.1 Questionnaire ... *89*
5.3.2 Interview's guide content ... *89*
5.3.3 Participants ... *90*
5.3.4 Exposure Groups ... *91*
5.3.5 Age Groups ... *92*
5.4 RESULTS ... 92
5.4.1 Description of exposure groups ... *92*
5.4.2 Long-term effects ... *97*
FRENCH PARTICIPANTS ... 102
FRENCH PARTICIPANTS ... 103
DUTCH PARTICIPANTS ... 103
5.4.3 Results for DVE modelling ... *109*
5.5 DISCUSSION ... 119
5.5.1 Long term effect of LDWS ... *119*
5.6 CONCLUSION ... 120

6 DISCUSSION AND CONCLUSIONS ... 121

6.1 RESULTS FROM THE ISA STUDY ... 121
6.2 RESULTS FROM THE SL-CC STUDY ... 121
6.3 RESULTS FROM THE FCW/LDW STUDY ... 122
6.4 RESULTS FROM THE LDWS STUDY ... 123

7 CONTRIBUTION TO THE DVE MODEL ... 125

7.1 CONTRIBUTION FROM THE ISA STUDY ... 125
7.2 CONTRIBUTION FROM THE SL-CC STUDY ... 125
7.3 CONTRIBUTION FROM THE FCW/LDW STUDY ... 126
7.4 CONTRIBUTION FROM THE LDWS STUDY ... 126

8 GUIDELINES TO OTHER AIDE SPS ... 127

8.1 INPUT TO SP2 ... 127
8.1.1 Guidelines from the ISA study ... *127*
8.1.2 Guidelines from the SL-CC study ... *127*
8.1.3 Guidelines from the FCW/LDW study ... *127*
8.1.4 Guidelines from the LDWS study ... *127*
8.2 INPUT TO SP3 ... 127
8.2.1 Guidelines from the ISA study ... *127*
8.2.2 Guidelines from the SL-CC study ... *128*
8.2.3 Guidelines from the FCW/LDW study ... *128*
8.3 INPUT TO SP4 ... 128
8.3.1 Guidelines from the ISA study ... *128*

9 REFERENCES ... 129

ANNEX 1: THE ISA-UK PROJECT ... 132

A1.1 THE ISA SYSTEM ... 132
A1.1.1 Vehicles ... *132*
A1.1.2 Digital speed limit map ... *133*
A1.2 FIELD TRIAL METHODOLOGY ... 139
A1.2.1 Trial design ... *139*
A1.2.2 Recruitment ... *139*
A1.2.3 Participants ... *141*
A1.2.4 Data completeness ... *143*

A1.2.5 Data processing *143*
A1.2.6 Vehicle Kilometres *145*

ANNEX 2: INTERVIEW OF LDWS STUDY ON AFIL SYSTEM **146**

List of tables

TABLE 1: OVERVIEW OF SYSTEMS AND METHODOLOGIES PER STUDY 3
TABLE 2 THE DISTRIBUTION OF MEN AND WOMEN ACROSS THE SI-GROUPS 29
TABLE 3 ESTIMATED CHANGE POINTS (KM) 34
TABLE 4 ESTIMATED DIFFERENCES FOR CHANGE POINTS, ROW MINUS COLUMN 34
TABLE 5 ESTIMATED IMMEDIATE EFFECT, PERCENTAGE UNIT 34
TABLE 6 ESTIMATED DIFFERENCES FOR IMMEDIATE EFFECT, ROW MINUS COLUMN 34
TABLE 7 ESTIMATED LONG TERM EFFECT, PERCENTAGE UNIT 34
TABLE 8 ESTIMATED DIFFERENCES FOR LONG TERM EFFECT, ROW MINUS COLUMN 34
TABLE 9 ESTIMATED EFFECT, PERCENTAGE UNIT 35
TABLE 10 ESTIMATED DIFFERENCES FOR EFFECTS, ROW MINUS COLUMN 35
TABLE 11: CHARACTERISTICS OF THE SAMPLE ACCORDING TO GENDER, AGE AND PERIOD OF OWNERSHIP OF THE SYSTEMS. 41
TABLE 12: BREAKDOWN OF THE DIFFERENT USER PROFILES BY GENDER AND AGE 43
TABLE 13: FREQUENCY (%) WITH WHICH THE DIFFERENT MOTIVES FOR OWNING THE SYSTEMS WERE SELECTED 44
TABLE 14: FREQUENCY (%) WITH WHICH THE DIFFERENT REASONS WERE GIVEN FOR NOT USING THE SL, ACCORDING TO GENDER AND AGE 47
TABLE 15: FREQUENCY (%) WITH WHICH THE DIFFERENT REASONS WERE GIVEN FOR NOT USING THE CC, ACCORDING TO GENDER AND AGE 48
TABLE 16: FREQUENCY (%) WITH WHICH NON-USERS SELECT OR REJECT THE DIFFERENT CHARACTERISTICS PROPOSED 49
TABLE 17: FREQUENCY (%) WITH WHICH USERS SELECT OR REJECT THE DIFFERENT CHARACTERISTICS PROPOSED 50
TABLE 18: PERCEIVED EASE WITH WHICH SYSTEMS ARE ASSIMILATED 51
TABLE 19: PERCEIVED BEHAVIOURAL CHANGES WHEN DRIVING WITH THE SL 53
TABLE 20: PERCEIVED BEHAVIOURAL CHANGES WHEN DRIVING WITH THE SL 53
TABLE 21: PERCEIVED BEHAVIOURAL CHANGES WHEN DRIVING WITH THE CC 53
TABLE 22: PERCEIVED BEHAVIOURAL CHANGES WHEN DRIVING WITH THE CC 54
TABLE 23: DIFFERENCES ACCORDING TO AGE AS REGARDS REPORTED CHANGES WITH THE SL 54
TABLE 24: DIFFERENCES ACCORDING TO GENDER AS REGARDS REPORTED CHANGES WITH THE CC 55
TABLE 25: ANSWERS GIVEN (%) TO QUESTIONS ABOUT COMPARISONS AND RELATIONSHIPS BETWEEN THE SYSTEMS 60
TABLE 26: RATE OF ACCEPTANCE OF THE SL AND THE CC AS A FUNCTION OF THE USERS' PROFILE 61
TABLE 27: GROUPS COMPARISON REGARDING MEAN SPEED PER RIDE 67
TABLE 28: GROUPS COMPARISON REGARDING MEAN NUMBER OF IMMINENT FCW PER RIDE 69
TABLE 29: GROUPS COMPARISON REGARDING PERCENTAGE OF TIME DRIVING AT HEADWAY < 1 S PER RIDE 70
TABLE 30: GROUPS COMPARISON REGARDING MEAN NUMBER OF LDW PER RIDE 71
TABLE 31: GROUPS COMPARISON REGARDING STANDARD DEVIATION OF LATERAL POSITION PER RIDE 73
TABLE 32: GROUPS COMPARISON REGARDING PERCENTAGE OF LANE CHANGES WITH THE USE OF DIRECTION LIGHTS PER RIDE 74
TABLE 33: PARTICIPANTS SELECTED FOR THE TELEPHONE INTERVIEW 81
TABLE 34: SIGNIFICANT GROUP EFFECTS REGARDING LONGITUDINAL BEHAVIOUR 83
TABLE 35: SIGNIFICANT GROUP EFFECTS REGARDING LATERAL BEHAVIOUR. 83
TABLE 36: DIFFERENCES IN RESULTS REGARDING LONGITUDINAL BEHAVIOUR AMONG SHORT- AND LONG-TERM 86
TABLE 37: EXPECTED LONG-TERM EFFECTS OF LDWS 88
TABLE 38: SUMMARY OF TOPICS IN QUESTIONNAIRE 89
TABLE 39: SUMMARY OF INTERVIEW'S QUESTIONS 89
TABLE 40: BACKGROUND INFORMATION ON FRENCH AND DUTCH PARTICIPANTS 91
TABLE 41: SUMMARY OF EXPOSURE GROUPS 92
TABLE 42: GENDER, AGE AND PERCEPTION 93
TABLE 43:VEHICLE AND EQUIPMENT 94
TABLE 44: ATTITUDES IN EQUIPMENT USE 95
TABLE 45: DRIVING EXPERIENCE 95
TABLE 46: KNOWLEDGE OF THE LDWS AND MOTIVATION OF CAR PURCHASE 96

TABLE 47: RELIABILITY OF LDWS 97
TABLE 48: FEELING OF SAFETY AND SAFETY BENEFIT 99
TABLE 49: LDWS USEFULNESS FOR LANE POSITION 101
TABLE 50: ATTENTION PAID TO LANE POSITION 102
TABLE 51: CHANGE IN LANE POSITION 103
TABLE 52: WHITE LINE CROSSING 103
TABLE 53: CHANGE IN DIRECTION INDICATOR USE/FREQUENCY OF INDICATOR USE 105
TABLE 54: LDWS DEACTIVATION 107
TABLE 55: SUMMARY OF EXPOSURE TIME ON LDWS USE (GROUP 1 (2) = EXPOSURE GROUP 1 (2)) 107
TABLE 56: SUMMARY OF LONG-TERM EFFECT OF LDWS ON DRIVING 108
TABLE 57: SUMMARY OF AGE GROUPS 109
TABLE 58: AGE GROUPS AND DRIVING EXPERIENCE 109
TABLE 59: EFFECT OF AGE IN MANOEUVRES DURING DAYTIME DRIVING 110
TABLE 60: EFFECT OF AGE IN TIME HEADWAY DURING DAYTIME DRIVING 111
TABLE 61: EFFECT OF AGE IN FEELING OF STRESS DURING DAYTIME DRIVING 112
TABLE 62: EFFECT OF AGE ON EXCEEDING SPEED LIMIT DURING DAYTIME DRIVING 113
TABLE 63: EFFECT OF AGE IN FREQUENCY OF NIGHT DRIVING 114
TABLE 64: EFFECT OF AGE ON LANE CHANGES AND OVERTAKING DURING NIGHT DRIVING 114
TABLE 65 : EFFECT OF AGE ON TIME HEADWAY DURING NIGHT TIME DRIVING 115
TABLE 66: EFFECT OF AGE IN FEELING OF STRESS DURING NIGHT DRIVING 116
TABLE 67: EFFECT OF AGE IN EXCEEDING THE SPEED LIMIT DURING NIGHT DRIVING 117
TABLE 68: EFFECT OF AGE IN DRIVING CHANGES BETWEEN DAY AND 118
TABLE 69: EFFECT OF AGE ON CHANGES IN LANE POSITION BETWEEN 118
TABLE 70: SUMMARY OF AGE EFFECTS ON DRIVING 118
TABLE 71: BREAKDOWN OF LENGTH OF ROAD IN THE LEEDS METROPOLITAN DISTRICT 134
TABLE 72: TOTAL LENGTH OF ROAD FOR EACH ROAD TYPE 136
TABLE 73: NUMBER OF PARTICIPANTS ACROSS TRIALS BY SEX, AGE AND INTENTION GROUP 141
TABLE 74: CHARACTERISTICS OF PARTICIPANTS 142
TABLE 75: DATA COMPLETENESS ACROSS TRIALS 144
TABLE 76: VEHICLE KILOMETRES ACCRUED DURING PHASE 2 ACROSS TRIALS 145

List of figures

FIGURE 1 THE ACTIVE ACCELERATOR PEDAL USED IN THIS STUDY 6
FIGURE 2 V_{ABOVE} PLOTTED FOR 6 DRIVERS ILLUSTRATING THE FLUCTUATION IN THE DATA 9
FIGURE 3: DISTANCE TRAVELLED PER WEEK BY FOUR PARTICIPANTS 13
FIGURE 4: MEAN FREQUENCY OF OPT OUT 14
FIGURE 5: MEAN FREQUENCY OF OPT OUT ON 30MPH ROADS 15
FIGURE 6: MEAN FREQUENCY OF OPT OUT ON 60MPH ROADS 16
FIGURE 7: MEAN FREQUENCY OF OPT OUT ON 70MPH ROADS 16
FIGURE 8: PERCENTAGE OF DISTANCE TRAVELLED ON 30MPH ROADS WITH ISA OVERRIDDEN 18
FIGURE 9: PERCENTAGE OF DISTANCE TRAVELLED ON 40MPH ROADS WITH ISA OVERRIDDEN 19
FIGURE 10: PERCENTAGE OF DISTANCE TRAVELLED ON 70MPH ROADS WITH ISA OVERRIDDEN 19
FIGURE 11: MEAN SPEED ON 30MPH ROADS 20
FIGURE 12: MEAN SPEED ON 40MPH ROADS 21
FIGURE 13: MEAN SPEED ON 70MPH ROADS 21
FIGURE 14: 85TH PERCENTILE SPEED ON 30MPH ROADS 22
FIGURE 15: 85TH PERCENTILE SPEED ON 50MPH ROADS 23
FIGURE 16: 85TH PERCENTILE SPEED ON 70MPH ROAD 23
FIGURE 17: MEAN FREQUENCY OF OPT OUT DURING THE WEEK ON 30MPH ROADS 25
FIGURE 18: MEAN FREQUENCY OF OPT OUT DURING THE WEEKEND ON 30MPH ROADS 25
FIGURE 19: DISTRIBUTION OF TOTAL KILOMETRES DRIVEN 27
FIGURE 20: COMPARISON OF MEAN FREQUENCY OF OPT OUT BY TOTAL DISTANCE DRIVEN 28
FIGURE 21 THE DRIVERS V_{ABOVE} WITHOUT ISA DIVIDED INTO THREE GROUPS. 29
FIGURE 22 MEAN SI FOR THE FOUR AGE GROUPS IN THE STUDY. 30
FIGURE 23 THE PERCENTAGE OF DISTANCE DRIVEN 3 KM/H OR MORE OVER THE SPEED LIMIT FOR ALL DRIVERS AND FOR THE SI'S RESPECTIVELY 31
FIGURE 24 V_{ABOVE} FOR 70 KM/H ROADS 32
FIGURE 25 V_{ABOVE} FOR 50 KM/H ROADS 32
FIGURE 26 V_{ABOVE} FOR 30 KM/H ROADS 33
FIGURE 27 V_{ABOVE} FOR THE 30 DRIVERS WITH THE HIGHEST MILEAGE DURING THE EXPERIMENT. 36
FIGURE 28: PROPORTION OF DIFFERENT USER PROFILES ACCORDING TO PERIOD OF OWNERSHIP 43
FIGURE 29: FREQUENCY (%) WITH WHICH MOTIVES FOR OWNING THE SL WAS CITED ACCORDING TO THE PROFILE OF THE USER 45
FIGURE 30: FREQUENCY (%) WITH WHICH MOTIVES FOR OWNING THE CC WAS CITED ACCORDING TO THE PROFILE OF THE USER 45
FIGURE 31: AVERAGE FREQUENCY OF USE OF THE SL ACCORDING TO THE SITUATION. 56
FIGURE 32: CLASSIFICATION OF THE SITUATIONS IN WHICH THE SL IS USED (UR = URBAN ROADS; RR = RURAL ROADS; MW = MOTORWAYS) 56
FIGURE 33: AVERAGE FREQUENCY OF USE OF THE SL ON URBAN ROADS ACCORDING TO GENDER 57
FIGURE 34: AVERAGE FREQUENCY OF USE OF THE SL ON MOTORWAYS ACCORDING TO GENDER 58
FIGURE 35: AVERAGE FREQUENCY OF USE OF THE CC ACCORDING TO THE SITUATION 58
FIGURE 36: CLASSIFICATION OF THE SITUATIONS IN WHICH THE CC IS USED (UR = URBAN ROADS; RR = RURAL ROADS; MW = MOTORWAYS) 59
FIGURE 37: THE MEAN SPEED FOR THE DIFFERENT RIDES AND FOR EACH GROUP 67
FIGURE 38: MEAN NUMBER OF IMMINENT FRONTAL COLLISION WARNINGS (VISIBLE/AUDIBLE FOR GROUPS A AND C). 68
FIGURE 39: MEAN PERCENTAGE OF DRIVING TIME WHERE HEADWAY IS SHORTER THAN 1 S 70
FIGURE 40: MEAN NUMBER OF LANE DEPARTURE WARNINGS (AUDIBLE FOR LDW AND FCW+LDW GROUPS ONLY). 71
FIGURE 41: STANDARD DEVIATION OF LATERAL POSITION (DISTANCE FROM LANE CENTRE) 72
FIGURE 42: NUMBER OF LANE CHANGES PER RIDE 73
FIGURE 43: PERCENTAGE OF LANE CHANGES PER RIDE WITH THE USE OF DIRECTION LIGHTS 74
FIGURE 44: THE USEFULNESS SCORE FOR FCW SYSTEM (AUDIBLE TO FCW AND FCW+LDW GROUPS). 75
FIGURE 45: THE SATISFACTION SCORE FOR FCW SYSTEM (AUDIBLE TO FCW AND FCW+LDW GROUPS). 76
FIGURE 46: THE USEFULNESS SCORE FOR LDW SYSTEM (AUDIBLE TO LDW AND FCW+LDW GROUPS). 76

FIGURE 47: THE SATISFACTION SCORE FOR LDW SYSTEM (AUDIBLE TO LDW AND FCW+LDWGROUPS). 77
FIGURE 48: MEAN SUBJECTIVE RATINGS OF MENTAL EFFORT. 78
FIGURE 49: NUMBER OF FRONTAL COLLISION WARNINGS RECEIVED PER RIDE AMONG PARTICIPANTS IN EACH GROUP. 80
FIGURE 50: NUMBER OF LANE DEPARTURE WARNINGS RECEIVED PER RIDE AMONG PARTICIPANTS IN EACH GROUP. 81
FIGURE 51: CITROEN LDWS 87
FIGURE 52 : AGE OF CUSTOMERS FOR EACH EXPOSURE GROUP 93
FIGURE 53 : EXPERIENCED BENEFIT OF LDWS (FRENCH) 100
FIGURE 54: EXPERIENCED BENEFIT OF LDWS (DUTCH) 100
FIGURE 55 : PERCENTAGE OF CUSTOMERS INDICATING THAT LDWS HELPS TO ADOPT A BETTER POSITION IN THE LANE 101
FIGURE 56 : PERCENTAGE OF CUSTOMERS WHO REPORTED TO PAY MORE ATTENTION TO LANE POSITION WITH LDWS 102
FIGURE 57 : PERCENTAGE OF CUSTOMERS WHO CHANGED THE POSITION IN THE LANE 103
FIGURE 58: PERCENTAGE OF CUSTOMERS WHO INDICATED TO USE THE INDICATORS MORE OFTEN 105
FIGURE 59: PERCENTAGE OF CUSTOMERS WHO REPORTED TO AVOID LANE CHANGING DURING DAYTIME DRIVING 111
FIGURE 60 : TIME HEADWAY MANAGEMENT DURING DAYTIME DRIVING (FRENCH) 112
FIGURE 61 : TIME HEADWAY MANAGEMENT DURING DAYTIME DRIVING (DUTCH) 112
FIGURE 62 : PERCENTAGE OF CUSTOMERS WHO REPORTED TO AVOID LANE CHANGING DURING NIGHT DRIVING 115
FIGURE 63 : TIME HEADWAY MANAGEMENT DURING NIGHT TIME DRIVING (FRENCH) 116
FIGURE 64 : TIME HEADWAY MANAGEMENT DURING NIGHT TIME DRIVING (DUTCH) 116
FIGURE 65: ISA FLEET VEHICLE 132
FIGURE 66: STEERING-WHEEL-MOUNTED BUTTONS AND ISA SCREEN 133
FIGURE 67: ISA BRAKE ACTUATOR 133
FIGURE 68: LEEDS METROPOLITAN DISTRICT 134
FIGURE 69: DISTRIBUTION OF SPEED ZONES IN LEEDS METROPOLITAN DISTRICT 135
FIGURE 70: A MAP TO ILLUSTRATE THE SPEED LIMIT DISTRIBUTION WITHIN THE LEEDS METROPOLITAN DISTRICT 136
FIGURE 71: BOUNDARY OF THE SOUTH WEST LEICESTERSHIRE SPEED LIMIT MAP 137
FIGURE 72: ILLUSTRATION OF SPEED LIMIT DISTRIBUTION WITHIN THE SOUTH WEST LEICESTERSHIRE AREA 138
FIGURE 73: DISTRIBUTION OF SPEED ZONES IN THE SOUTH WEST LEICESTERSHIRE AREA 138
FIGURE 74: FIELD TRIAL PHASES 139

Glossary of Abbreviations

AAP	Active Accelerator Pedal
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
AIDE	Adaptive Integrated Driver-vehicle InterfacE
CC	Cruise Control
DIL	Driver Impairment Level
DS	Driver State
DVE	Driver-vehicle-environment
FCW	Frontal Collision Warning
FP6	Sixth Framework Programme
HMI	Human-machine Interaction
ICA	Interaction and Communication Assistant
ISA	Intelligent Speed Adaptation
IP	Integrated Project
ISO	International Standardization Organization
IVIS	In-vehicle Information Systems
JAB	Journey A-B
LDW	Lane Departure Warning
LDWS	Lane Departure Warning System
PDA	Personal Digital Assistant
PDT	Peripheral Detection Task
RTD	Research and Technological Development
SA	Situation Awareness
SI	Speed Index, indicating whether the drivers belong to the fastest 3rd, slowest 3rd or the group in between in the Lund ISA-trial
SL	Speed LImiter
SP	Sub-project
TD	Task Demand
TLC	Time to Line Crossing
TTC	Time to collision
UCD	User-Centred Design
V_{above}	The percentage distance driven at 3 km/h or more above the speed limit
VDM	Visual Demand Measurement
WP	Workpackage

Executive Summary

This deliverable presents the results of the work performed within activity 1.2.3 of AIDE project, entitled "Assessment of variables: Integration (long-term effects) phase. The objective of this work was to provide data on driving behavioural changes after long term use of five support systems, namely Cruise Control (CC), Speed Limiter (SL), Intelligent Speed Adaptation (ISA), Frontal Collision Warning (FCW) and Lane Departure Warning (LDW).

Six studies have been performed. Four of them investigated a stand alone support system. In the ULeeds – VTI studies the ISA system was investigated, while in the PSA –TNO studies the LDW was investigated. In the INRETS-Renault study two functionally compatible systems were investigated, namely the SL and CC. The CERTH/HIT study involved two systems, namely the FCW and LDW, which were studied either as stand alone or as concurrently functioning. The methods that were used in these studies are broadly grouped, according to the data collected, into two categories: those that provide subjective data on how participants describe their adaptation to a given support system (this is the case in the INRETS - Renault and PSA - TNO studies) and those that provide objective data on participants' driving behaviour after long-term exposure to a particular system based on various measures of vehicle parameters (this is the case in the ULeeds - VTI and CERTH/HIT studies).

The reported results indicate that long-term behavioural change is highly influenced by the number of the systems used, the compatibility of systems' functionality and the attitudes of participants. In specific, when two antagonistic support systems (namely FCW+LDW) function concurrently, drivers intentionally ignored both systems, whereas with two compatible support systems (SL/CC) no detrimental effects in regard to participants' interaction with the chosen support system was reported.

In contrast, considering the long-term effects of stand alone support systems there are certainly positive effects in accordance to the driving assistance function that a system has been designed for. Occasionally, some side-effects either related to system use (e.g. reported side-effect of FCW in lateral behaviour) or to wrong interpretation of system use (e.g. in LDWS study, a large part of participants said they bought the system because they tended to feel asleep, while the LDWS was not designed for this goal) have to be considered into systems' design. However, the reported results support the idea, either implicitly or explicitly, that a stand alone support system could have a positive effect in relation to driving behaviour but the magnitude of long-term effects is more dependent on the "attitudes of participants".

A further issue is the length of period needed for perceiving these behavioural changes. For all studied systems there are indications either implicit or explicit that systems are easy to learn and use, requiring little time to adapt. However the interaction between the driver and a support system increases in line with an increase in system exposure. Thus, time exposure is the most critical parameter for further developing the system "image", and this process cannot be confined in strict time terms.

1 Introduction

Driver support systems, such as Cruise Control (CC), Speed Limiter (SL), Intelligent Speed Adaptation (ISA), Frontal Collision Warning (FCW) and Lane Departure Warning (LDW), already exist in modern vehicles, and in the following years more vehicles are expected to be equipped with them. An emerging issue of particular concern is the potential changes that these systems might induce in driving behaviour after long- term use. However, no details of driving behavioural adaptation and how it is affected by attitude and system exposure after long-term use have been provided from current research work. Thus, the objective of the present studies is to provide data on driving behavioural changes after long term use of five support systems, namely CC, SL, ISA, FCW and LDW.

A major source of difficulty is to define how long a period is enough in order to consider the potential driving behaviour changes as a long-term effect of system exposure. Another difficulty is to determine which aspects of driving behaviour are of particular interest in order to evaluate the potential impact of system use in terms of driving behaviour and traffic safety.

Regarding the first issue, a major decision that has been made is that it is only feasible to distinguish between the possible short-term effects that are related to learning and appropriation phase of the system(s) used and the possible long-term effects that are related to driving behavioural changes after short-term use. Any conclusion about the duration of these changes as well as the occurrence of other potential changes -after a longer period of use- can be drawn on the basis of research work. Thus, the first objective of the present studies was to analyse the participants' driving behaviour changes due to the use of a particular support system
–after learning and appropriation phase - and these driving behaviour changes are clearly referred to behavioural changes for the given period being studied.

Regarding the second issue, several different aspects need to be clarified in order to evaluate the potential impact of a particular support system after long-term use e.g. changing attitudes in terms of perceived safety, development of wrong interpretation about system use, intentional activation/ deactivation of a system in particular traffic environment etc. After all, the core issue of behavioural adaptation is whether a particular intervention does lead to a change of drivers' motives or not, and accordingly, whether this motivational change does make drivers to adapt their behaviour to desired direction or not. To this extent, in the studies presented below different research methods have been used, addressing several different aspects about the long-term effect of a particular support system into driving behaviour. Moreover, different support systems have been studied, addressing different adaptation strategies in relation to their functionality and their traffic-context use.

In specific, five support systems namely ISA, CC, SL, FCW and LDW were studied. The methods that were used can be broadly grouped, according to the data collected, into two categories: those that provide subjective data on how participants describe their adaptation to a given support system (this is the case in the INRETS - Renault and PSA - TNO studies) and those that provide objective data on participants' driving behaviour after long-term exposure to a particular system based on various measures of vehicle parameters (this is the case in the ULeeds - VTI and CERTH/HIT studies).

An overview of systems investigated and methodologies used per study is given below.

Partners	**ULeeds- VTI**	**INRETS- Renault**	**CERTH/HIT**	**PSA- TNO**
Support system	ISA	SL/ CC	FDW+LDW	LDW
Method	Field study	Questionnaires	Objective recordings from on-road study Follow-up interviews	Interviews Questionnaires

Table 1: Overview of systems and methodologies per study

The questionnaires approach has the advantage of exploring more hidden aspects regarding to participants' internal representations about the system "image" and/ or participants' motivations of system use in long-term, but there is no precision on how each system is integrated in real driving (e.g. frequency of use of SL/CC, number of activation of LDWS, etc). The objective recordings from field studies, on the other hand, have the advantage of providing real measurements of vehicle parameters, reflecting the interaction between driver and support system(s) in real traffic conditions, but certain aspect about the drivers' motives behind potential changes are only implicit.

Thus, in the following studies apart from the analysis of participants' behavioural changes after long-term use of a particular support system, a further interest is placed on the methods used in each study for revealing different aspects of behavioural adaptation.

2 Long term effects of ISA

2.1 Introduction

In-vehicle speed-adapters, which have been researched for more than 20 years in various systems, have been ascribed great safety potential; ranging from a 10 % reduction in injury accidents for a system informing the driver of the speed limit, up to a 40 % reduction for a limiting dynamic system, i.e. where the highest appropriate speed is changed due to traffic, weather and road conditions etc. (Almqvist et al., 1991, Almqvist and Nygård, 1997, Carsten and Fowkes, 2000, Brookhuis and de Waard, 1999, Persson et al., 1993, Varhelyi and Makinen, 2001, Várhelyi, 1997, Varhelyi, 2002). These calculations are based on the assumption that all vehicles on the road have a system installed, or at least that the number of equipped vehicles is high enough to affect all the others. If systems like this are implemented, it is likely that it will take quite a long time to reach an implementation rate that is high enough to obtain the safety effects indicated above. According to the recommendations from the Swedish Large Scale Trial with Intelligent Speed Adaptation (ISA), carried out in 1999 – 2002, ISA-equipment should be available as an option in new cars or to be retrofitted in existing cars by 2005. ISA should become compulsory in new vehicles by 2010 and by 2020 80 % of all vehicles in Sweden should have ISA (Biding and Lind, 2002). Carsten and Fowkes (2000) presented a similar implementation strategy where usage of the system would be mandatory on all vehicles in the UK by 2019.

The studies of ISA carried out in the city of Lund, Sweden has shown that the drivers initially reduce the speed to a great extent but after long-term use most drivers had a higher mean speed compared to the short-term use, even though the mean speed was still below the mean speed when driving without the system (Hjälmdahl, 2004). Hjälmdahl further found that the difference between short and long-term behaviour differs depending on the driver and the driver's attitude to the system. It was concluded that drivers initially gives the system a chance but after time when they either accepted the system or grew tired of it they changed their behaviour. However, the details of the behavioural adaptation and how it was affected by attitude and system exposure was not clearly demonstrated in that study.

The purpose of the current study was to analyse how participants' behaviour changed as exposure to the ISA system increased. Studies have shown a clear reduction of speed during the early stages of system usage followed by a gradual increase back towards the initial behaviour. To date however, little work has clearly demonstrated this continuous relationship between exposure and behaviour. Data collected during the ISA UK study and the Lund ISA-trial provided the opportunity to investigate the exact nature of this relationship.

2.2 Project Overview

2.2.1 The ISA-UK Project

The ISA-UK project's major objective was to investigate user behaviour with Intelligent Speed Adaptation (ISA) by means of set of field trials. Twenty identical vehicles were converted with the capability to provide a voluntary (overridable) ISA system and to record data on each drive. Four successive trials were completed, each of six months duration. The four field trials were:

Trial 1: Leeds area with private motorists.
Trial 2: Leeds area with fleet motorists.
Trial 3: Leicestershire with private motorists.
Trial 4: Leicestershire with fleet motorists.

Participants were recruited from responses to local advertisements and 20 drivers took part in each trial. The trials were designed to be non-intrusive — the vehicles behaved like "normal" cars apart from the ISA feature. Data was logged automatically, and summary data was collected after each trip through a GSM link. The ISA system designed for the four field trials was user overridable by means of a button on the steering wheel or kick through on the accelerator pedal. The intention was to give drivers ISA support for almost all their regular driving.

The main focus of the trials was on driver behaviour when using ISA over a relatively long period, i.e. four months of driving. There was one-month driving without ISA functions before and after the four-month driving with ISA respectively. The inclusion of the post-ISA driving allowed the investigation of any carry-over effects of the ISA intervention. Details of the field trial methodology are provided in Annex 1.

2.2.2 The Swedish Lund ISA-trial

The system used in this study is known as an active accelerator pedal (AAP). It is based on a GPS receiver, continuously identifying the position of the vehicle, and a digital map, containing all the current speed limits within the test area. The interface with the driver consists of a display, showing the current speed limit, and an active accelerator pedal, which exerts a counterforce at speeds over the speed limit. In order to exceed the speed limit the pedal must be pressed approximately three to five times harder than normally. The vehicles were also equipped with a data-logger, recording, among other things time, position and speed.

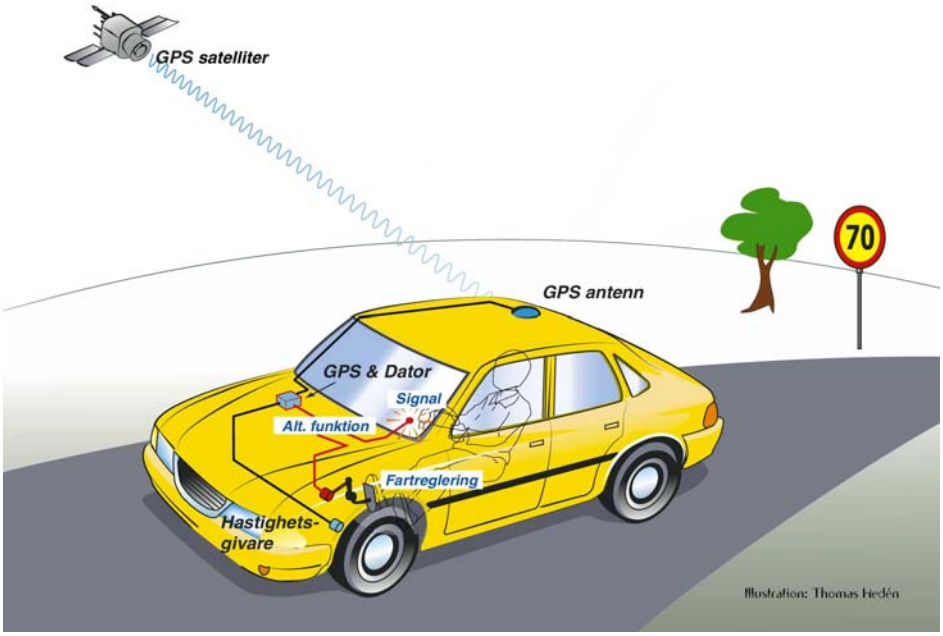


Figure 1 The Active Accelerator Pedal used in this study.

2.2.2.1 Study design

The data used for this analysis was collected during a trial with 284 vehicles equipped with an Active Accelerator Pedal (AAP) for up to one year in the city of Lund in 1999-2002. The test area consisted of the entire city of Lund (100,000 inhabitants) and included 30, 50 and 70 km/h speed limits. The system was activated automatically when the vehicle was within the test area and could not be turned off.

2.2.2.2 Driver recruitment

In the AAP trial in Lund there were both private drivers and drivers of fleet vehicles. The private drivers were selected randomly from the vehicle registry, the intention being to have an even distribution of drivers with regard to sex, age and initial attitude towards the AAP. (During the recruitment the drivers were asked: *"What do you think of having the following equipment in your car? A system that gives a counter force in the accelerator when the vehicle has reached the speed-limit, and the speed-limit can not be over-ridden except in an emergency; "Good"; "Not good"; "Neither"?"* The drivers were then classified as positive, negative or neutral according to their answers.) However, since drivers could not be forced to participate there was a bias towards drivers with a positive attitude towards the system. Due to vehicle-ownership demography there was also a bias towards middle-aged men. Still, all the above groups were well represented in the driver population. For the drivers of the fleet vehicles the selection method was somewhat different; a number of companies were contacted and asked whether they wanted to participate, and those that agreed selected the participating drivers.

2.3 Analysis of Vehicle Data

2.3.1 UK data

The purpose of the current study was to analyse how participants' behaviour changed as exposure to the ISA system increased. Studies have shown a clear reduction of speed during the early stages of system usage followed by a gradual increase back towards the initial behaviour. To date however, little work has clearly demonstrated this continuous relationship between exposure and behaviour. Data collected during the ISA activated phase within the current ISA UK study provided the opportunity to investigate the exact nature of this relationship.

The main aims of the analysis were to:

- Examine the nature and extent of behavioural changes associated with driving with an ISA system;
- Examine the conditions in which these changes take place;
- Examine the characteristics of the drivers more likely to present these behavioural changes.

Analysis therefore focuses on data collected during the ISA activated phase of the first three field trials (i.e. 60 drivers) since the fourth has only recently completed. Comparisons over time, accrued distance, and characteristics of driving environment (e.g. speed limit zones and weekday/weekend) allowed investigation into key issues regarding when and where behavioural adaptation manifests. In order to determine any individual differences across groups, comparisons were also made between intention groups. Participants were categorised (by means of a Theory of Planned Behaviour questionnaire, see Annex) as those intending or not intending to exceed the speed limit. It was hypothesised that 'Intenders' would demonstrate greater resistance to the system and thus show more pronounced changes in behaviour as exposure increased.

In the next section preliminary analysis within Trial 1 examines the best determinant of exposure (time against distance). Following this, a comprehensive comparison across key measures (such as system compliance and recorded vehicle speed etc.) investigates the continuous relationship between exposure and behaviour.

2.3.2 Swedish data

All vehicles were equipped with data-loggers that stored data five times per second. Variables logged and used in this study were time, vehicle ID, speed and speed limit. Data logging of the vehicles in the trial started one month before the AAP was activated and continued throughout the entire trial. The time each vehicle was equipped with the AAP varied between 6 and 11 months due to the lengthy process of installing them. There were also a few drivers who wished to abort the trial before hand due to various reason (mainly a strong dislike of the system). These drivers' vehicles were then activated for a shorter period than 5 months. Depending on the length of participation and how much each vehicle drives within the test area the amount of data differs between subjects.

Of the initial 284 vehicles there are 173 that are included in this study. The criteria for a vehicle to be included in this study were that there was data for the month before activation and data for the first period with the system activated. For some vehicles data logging failed for one of these periods which meant that one or several pieces of data were missing. Since the system interfered with the throttle some vehicles became difficult to handle with the system installed. Drivers of these vehicles often aborted the trial before the system was activated.

The data used in this analysis has been aggregated for each vehicle into sections containing 50 km driving within the test area. For each section the percentage of the distance driven below, at and above the speed limit has been calculated (*at* equals the interval from the speed-limit till 3 km/h above). In this study it is the percentage driven above the speed limit that has been analysed (hereinafter labelled V_{above}). These 50 km sections are generated and studied in four ways; for all data and for 70 km/h roads, 50 km/h roads and 30 km/h roads respectively. The distance driven is however always based on the total amount of driving. This may mean that for a certain driver and speed limit there could be data missing in some sections. This is the case if the driver has not been driving on that type of roads within that interval. Due to the geography of the city of Lund and the travel patterns of the drivers this is most likely to happen for 30 km/h roads.

Due to the high resolution in data (50 km) there is some fluctuation in the data. There may be several reasons for this fluctuation such as bad weather, congestion, route choices, different drivers etc. The main reason however is probably the fact that drivers do not drive in exactly the same manner from day to day. Figure 2 below shows V_{above} for six drivers individually and the graph illustrates the fluctuation.

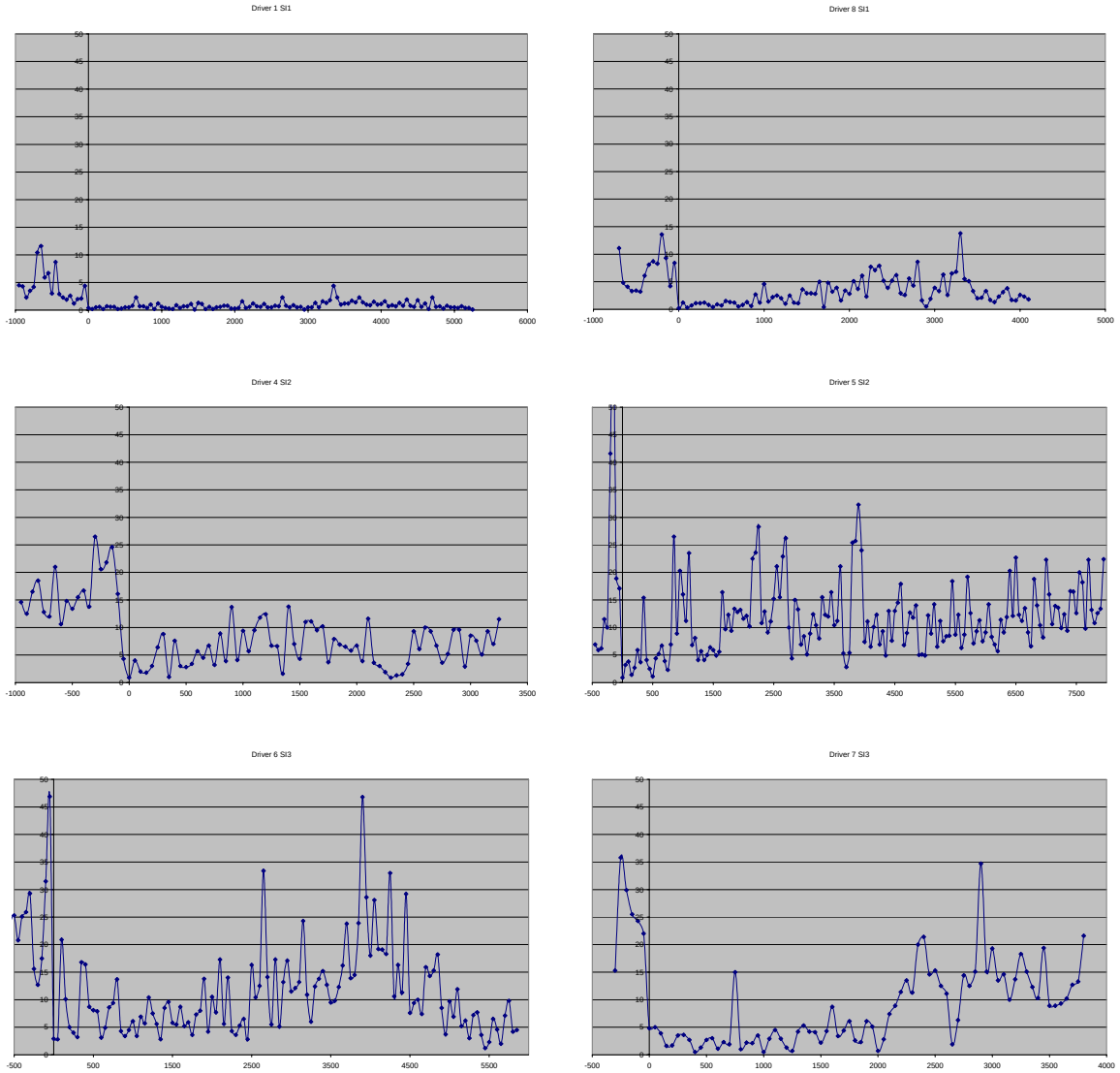


Figure 2 V_{above} plotted for 6 drivers illustrating the fluctuation in the data.

The top 2 are SI1, followed by 2 SI2 and 2 SI3.

2.3.2.1 Change point estimation

One assumption on the drivers' behaviour after the ISA devices are implemented is that during an initial driving distance the proportion of exceeding the speed limit will reduce to a comparable low level and then increase to a steady level. This assumption raises some questions.

1. How long is the initial driving distance with comparable low rate of exceeding the speed limit?
2. How high is the exceeding rate during the initial phase and how high is it afterwards?
3. Is there an initial phase for all drivers?

Then an initial phase is estimated for each driver in the study. This is done by change point estimation. In this case the maximum likelihood method is used. Although inference of changes in sequences has a history back to the 1930's in statistical theory the notion of change-point was introduced by Hinkley (1970). Research on change-point problems has been done since then, e.g. a Bayesian approach by Thomas (2001).

Each driver participating in the study is monitored continuously, so that it is possible to see when and for how long driving distance the speed limit is exceeded. This information is aggregated to 50 km driving distance. Then there is a sequence of observations for each driver, where each observation shows the proportion of the driven 50 km where the existing speed limit was exceeded.

The assumption above implies the observations in the beginning of a sequence will have a lower mean than the observations in the end. Then obviously there is a point where the mean changes from the lower to the higher level. Still, the change point might not be within range of the observed traffic mileage or it might not exist at all. In the latter case it is assumed that the change point is at zero, i.e. just before the ISA device is implemented. It should then be emphasised that whenever the change point is zero it might either imply that the higher lever of violate the speed limit is reached at once or that it is not reached within the range of observations.

Let $Y_1,\ldots,Y_n$ be the sequence of observations from an individual driver and assume that the drivers change of point is $r \in \{0,1,\ldots,n-1\}$, such that $Y_i \in N\left(\mu_{rl},\sigma_r^2\right)$ for $i \le r$ when $r \in \{1,\ldots,n-1\}$ and $Y_i \in N\left(\mu_{ru},\sigma_r^2\right)$ for $i > r$ when $r = \{0,1,\ldots,n-1\}$. For a given change point, r, μ_{rl} is estimated by $\hat{Y}_r = \sum_{i=1}^{r} Y_i \big/ r$ and μ_{ru} by $\breve{Y}_r = \sum_{i=r+1}^{n} Y_i \big/ (n-r)$ while σ_r^2 is estimated by $s_r^2 = \left(\sum_{i=1}^{r}\left(Y_i - \hat{Y}_r\right)^2 + \sum_{i=r+1}^{n}\left(Y_i - \breve{Y}_r\right)^2\right) \big/ (n-2)$. It is possible to show that under the condition that $\mu_{rl} \le \mu_{ru}$ the maximum likelihood estimation of the change point is given by the r that maximises the t-ratio

$$T_{n-2} = \frac{\breve{Y}_r - \hat{Y}_r}{s_r\sqrt{\frac{1}{r} + \frac{1}{n-r}}} \ .$$

Now, under the null hypothesis that there is no change point T_{n-2} is t-distributed with $n-2$ degrees of freedom, which makes it possible to test for each individual driver if there is a significant change point.

However, there is a problem with multiple significances. One way to solve that is by Bonferroni's method. Here is a development of Bonferroni's method, Holm's sequentially rejective, see Holm (1979), applied. The procedure is as follows. The significance level is set to α. Consider n drivers. The t-ratio is maximised for each driver and a corresponding p-value is calculated. If the smallest of those p-values is less than α/n, then it can be concluded that there is a significant change point for the corresponding driver. If the second smallest is less than $\alpha/(n-1)$, then it can be concluded that there is a significant change point for the corresponding driver. The procedure is repeated until the first driver is reached where there is no significant change point. For that driver and its followers there are no significant change points.

2.3.2.2 Validity of data

The data used in this study was validated by (Várhelyi et al., 2002) when they showed that the mean speeds logged in the vehicles in the study did not differ from the mean speeds of other vehicles measured with pneumatic tubes at 21 spots in the city of Lund. The validity of the data was further validated by Hjälmdahl (2004) where he compared the speeds of drivers with regard to their sex, age, annual driven mileage and comparing drivers of private cars with drivers of fleet vehicles. Studies have shown that men, young persons, drivers who have a high annual mileage and drivers of fleet vehicles usually choose a higher speed than their counterparts (Fields et al., 1991, Webster and Wells, 2000, Kaufmann, 2002, Cowley, 1983) and the drivers included in this data set where in correspondence with those studies.

2.4 Results UK-trial

2.4.1 Comparison between time and distance as measure of system exposure

It was initially thought best to examine participants' response to the ISA system on a week by week basis. However as between-driver mileage variation from week to week would be high it was not considered a reliable and robust measure of exposure.
Figure 3 illustrates the potential biases of examining the data on a week by week basis. Comparisons across the four drivers selected here, shows a considerable difference in mileage covered per week both between and within drivers. A week by week based analysis would not therefore reflect behavioural adaptation to a systematic increase in exposure to the ISA system. Defining exposure in terms of distance travelled was regarded as a much more reliable measure as this would allow identification of behavioural changes as actual on the road driving experience with the system increased.

As the total mileage accrued differed across drivers, patterns of behaviour could be attributable to variances in the sample size. Although the representativeness of the behavioural pattern is unavoidably affected by a drop in sample size, it remains possible to make reliable interpretations where the pattern of behavioural adaptation is demonstrated based on a relatively full sample size.

2.4.2 Distance based analysis

To investigate the long term effect of ISA on driver behavioural adaptation, system compliance provides an explicit indication of the interaction between the driver and the system, i.e. how often did the driver override the system? The next section presents analysis of the travel pattern affected by ISA intervention, i.e. percentage of distance driven with ISA overridden. As ISA is designed to influence driving speed, it is therefore of interest to investigate whether recorded vehicle speed fluctuated along system exposure. This is then followed by analysis of the difference in ISA usage between weekdays and weekends.

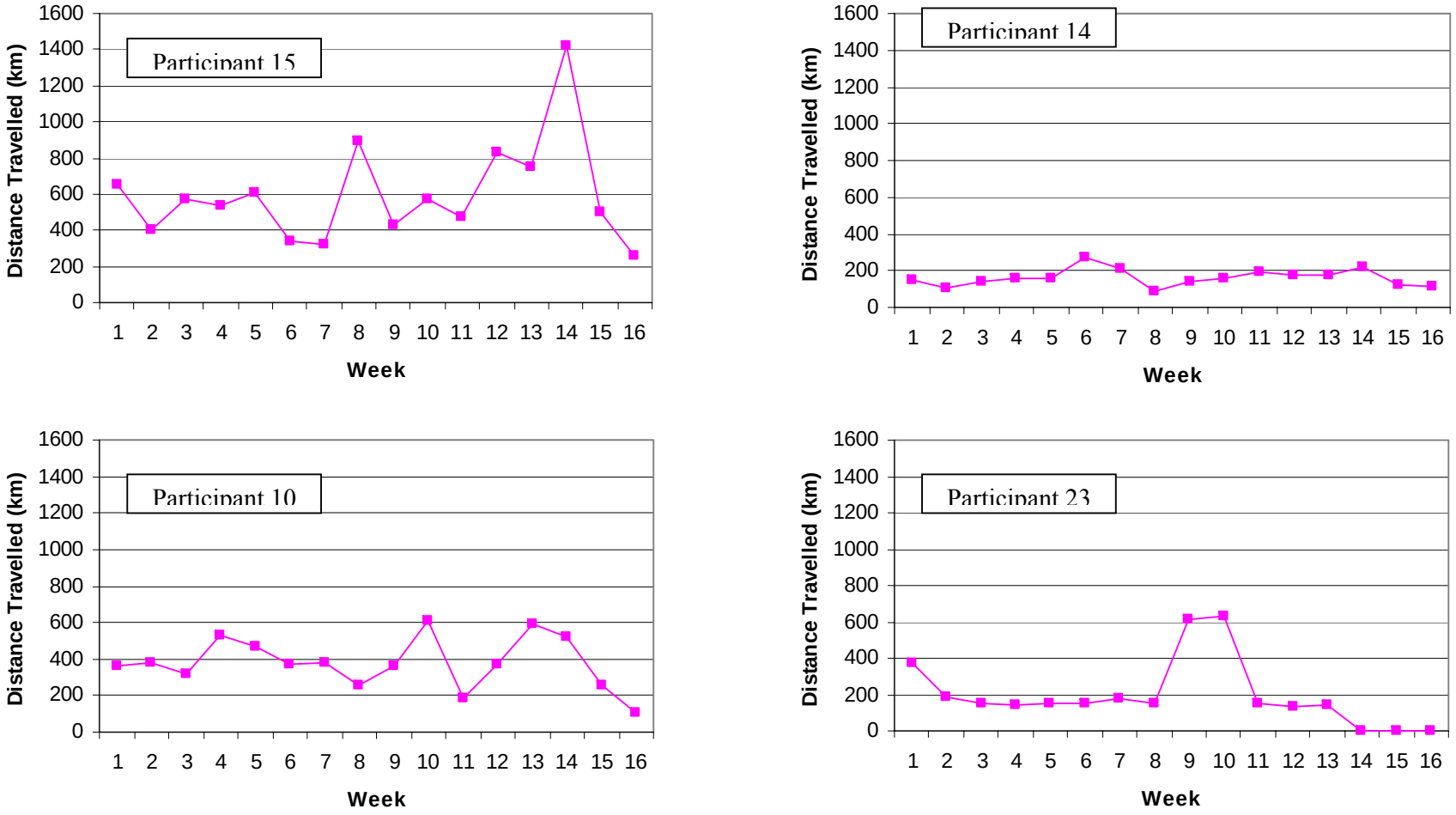


Figure 3: Distance travelled per week by four participants

2.4.2.1 System Compliance

Figure 4 reveals an upward trend in overriding behaviour as exposure to the ISA system increased. This suggests that drivers became increasingly frustrated with increased experience of the system. Although the graphs show an apparent decline in overriding behaviour as exposure progressed, this is likely to be biased by the low sample size. Intenders also demonstrate a greater propensity to override the ISA system compared to non intenders. In particular, intenders demonstrated a sharp rise in the frequency of opt-out in the early stage of system exposure (i.e. from 0-500 km to 501-1000 km in the top half of Figure 4), as opposed to a steady rise shown by non-intenders. This clearly suggests that driver characteristics have an impact on behavioural adaptation.

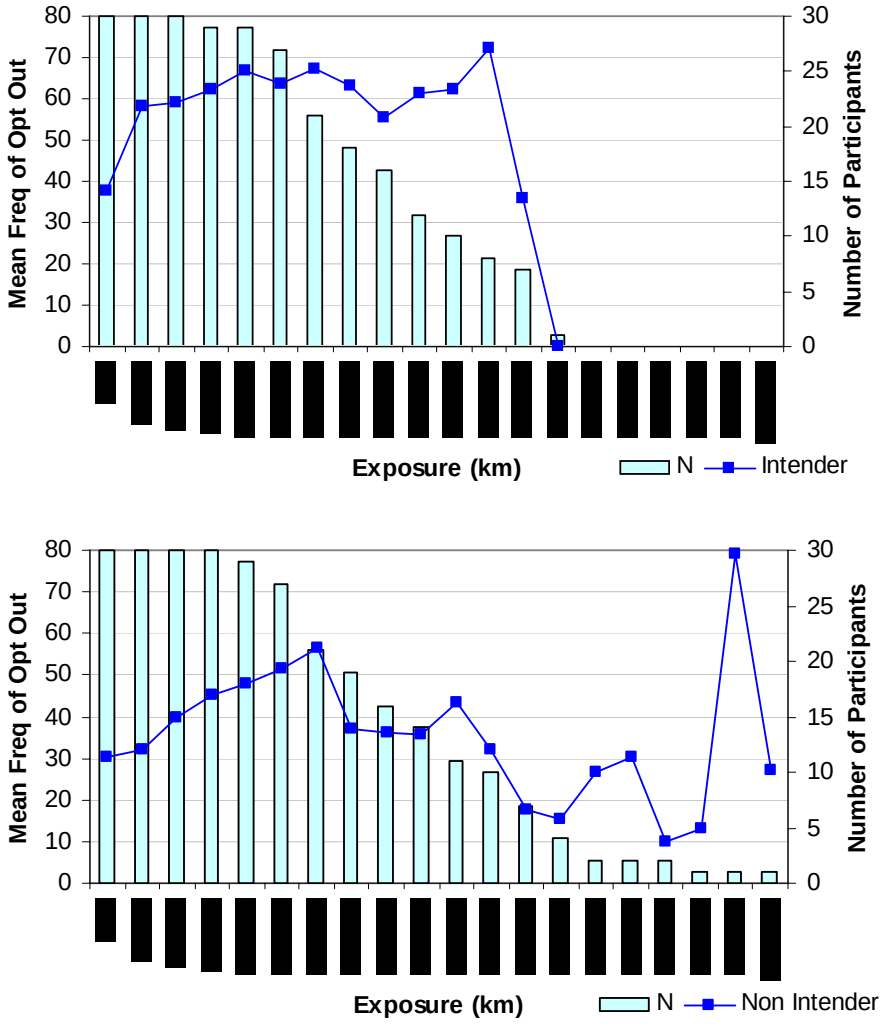


Figure 4: Mean frequency of opt out

Examining overriding behaviour by speed zone (Figure 5 through to **Figure 7**) suggests that overriding behaviour is more prominent in urban environments (i.e. the 30 mph zones), presumably because the complexity of the driving environment (where vulnerable road users, traffic signals, and more complex road fixtures are present) provides more opportunities of

interaction between the system and the driver. Overriding behaviour was relatively uncommon on the higher speed limits roads which may be due to natural constraints of the road geometry (e.g. rural single carriageway where 60 mph speed limit applies) or drivers feeling comfortable with keeping to speed limit on wide open roads during the majority of their trips (e.g. dual carriageway or motorway where 70 mph speed limit apply). This undoubtedly suggests that environment characteristics influences behavioural adaptation.

Differences across driver groups are apparent with non intenders displaying a lesser tendency to override the ISA system. Again, there was a difference in the pattern of behavioural adaptation along system exposure between the two groups of driver (i.e. intenders demonstrated a sharper rise in frequency of opt-out in the early stage of system exposure as opposed to non-intenders). However, the difference was only prominent in urban environments, presumably due to increased opportunities of system interference with driving as a result of environment complexity, which in turn magnifies the between-group difference.

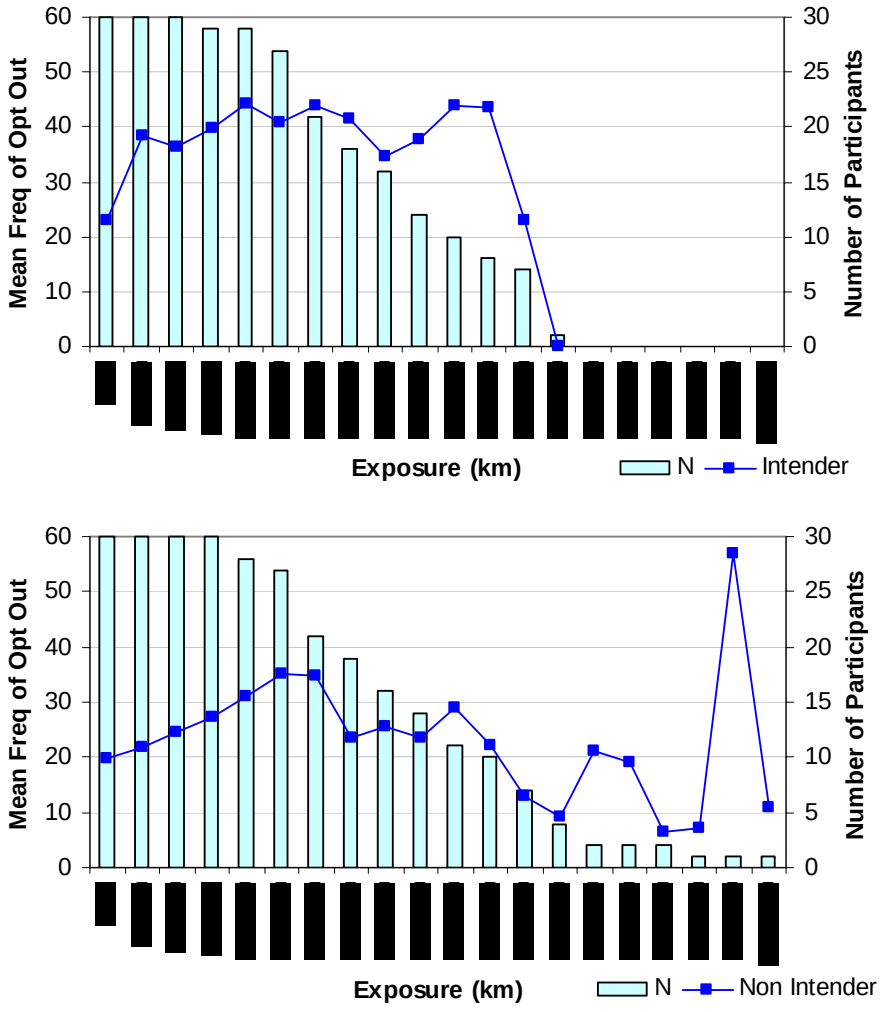
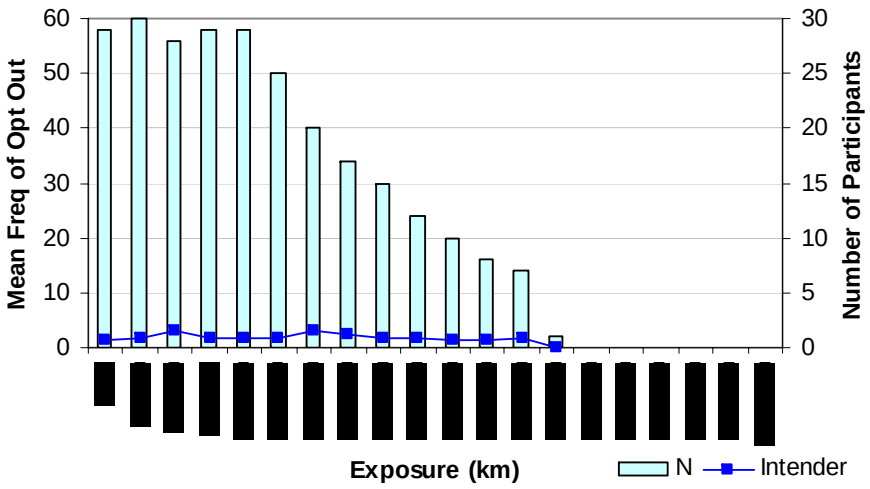


Figure 5: Mean frequency of opt out on 30mph roads



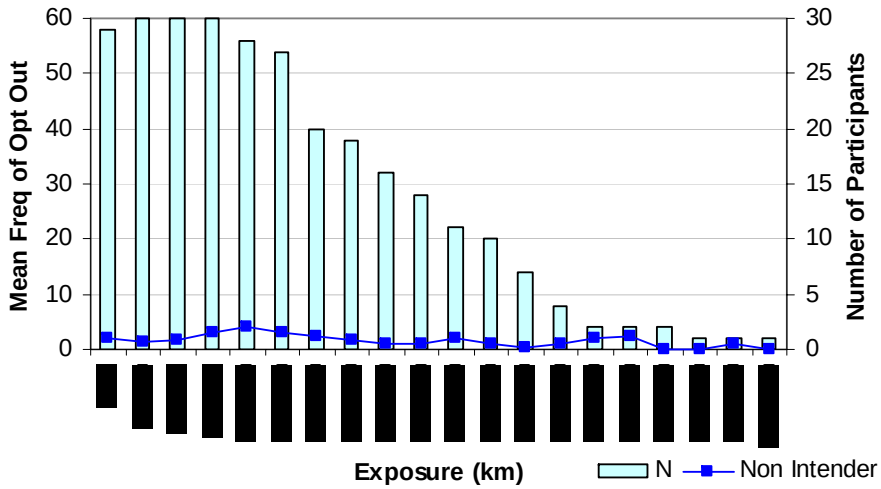
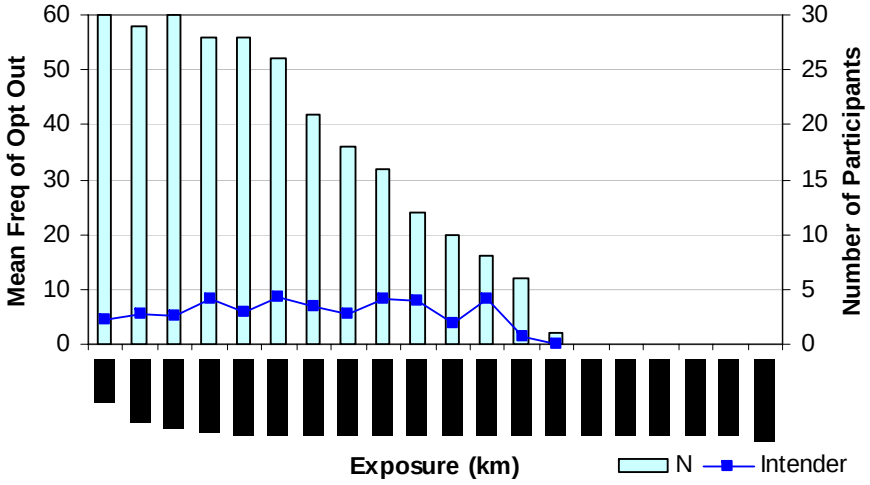


Figure 6: Mean frequency of opt out on 60mph roads



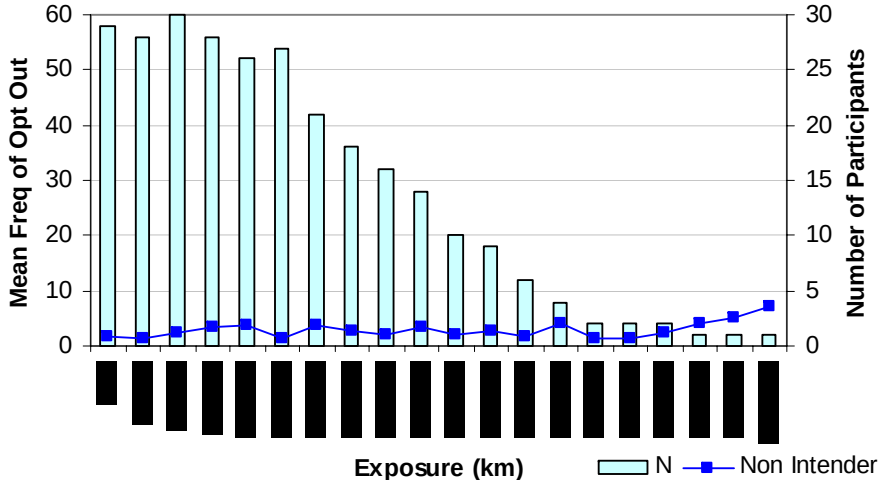
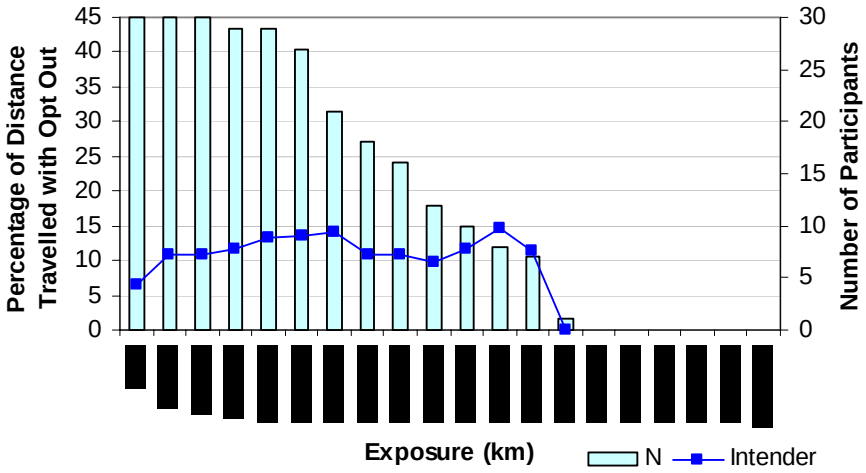


Figure 7: Mean frequency of opt out on 70mph roads

2.4.2.2 Percentage of distance travelled with ISA overridden

The percentage of distance travelled with ISA overridden was also regarded as a measure of system compliance. In addition, it serves as an indication of the durability of the influence of the (overridable) ISA system on driver behaviour. Similar to the upward trend revealed by frequency of overriding, Figure 8 through to Figure 10 demonstrate that the percentage of distance travelled with ISA overridden increased along with an increase in system exposure, which suggests that as participants' experience with ISA increased the less they used the system. As a result, the influence of ISA on vehicle speed faded away in line with an increase in system exposure.

However, there is less of a noticeable trend within the 70mph zone (i.e. Figure 10) which may be attributable to unknown variances from the driving environment outside the vehicle. Driving is inherently a highly dynamic task, with its surrounding environment changing from time to time. External variables, such as traffic density or weather conditions etc, could influence how the participants behaved and, as a result, the level of system interference. It is worth noting that variables outside the vehicle were not monitored during unsupervised trips (which contributed to the data used for this analysis), and hence the variance in driver behaviour attributable to such external factors is unknown. The unknown variance in the data representing travel distance could be further magnified by driving speed, and therefore the pattern of distance travelled with ISA overridden in the 70 mph zones could have been distorted to some extent.



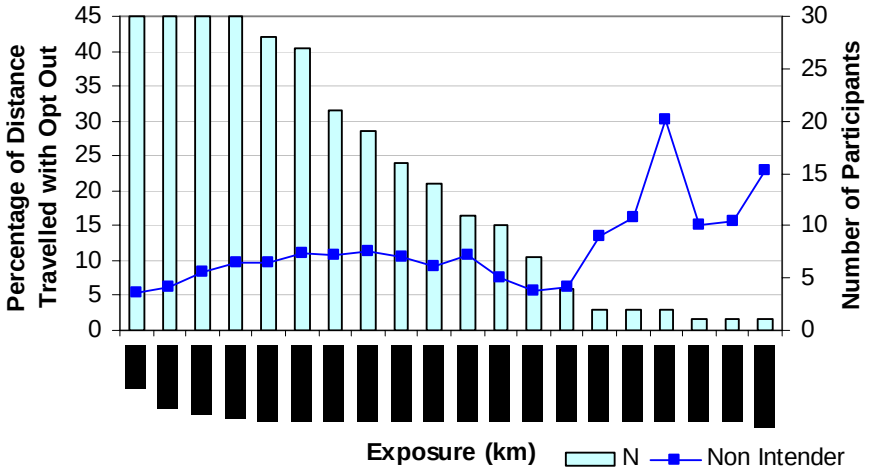


Figure 8: Percentage of distance travelled on 30mph roads with ISA overridden

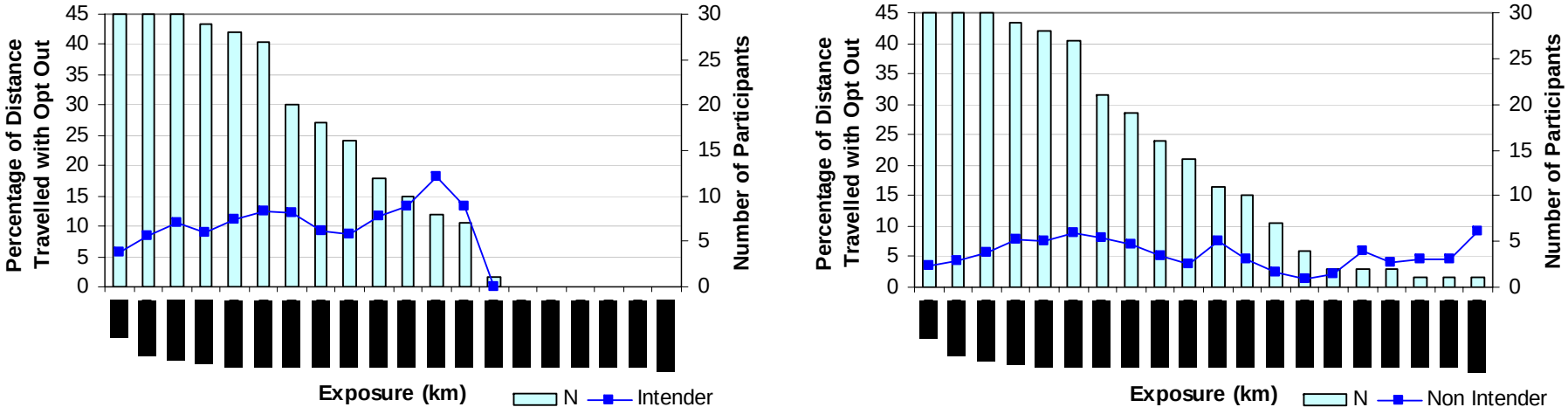


Figure 9: Percentage of distance travelled on 40mph roads with ISA overridden

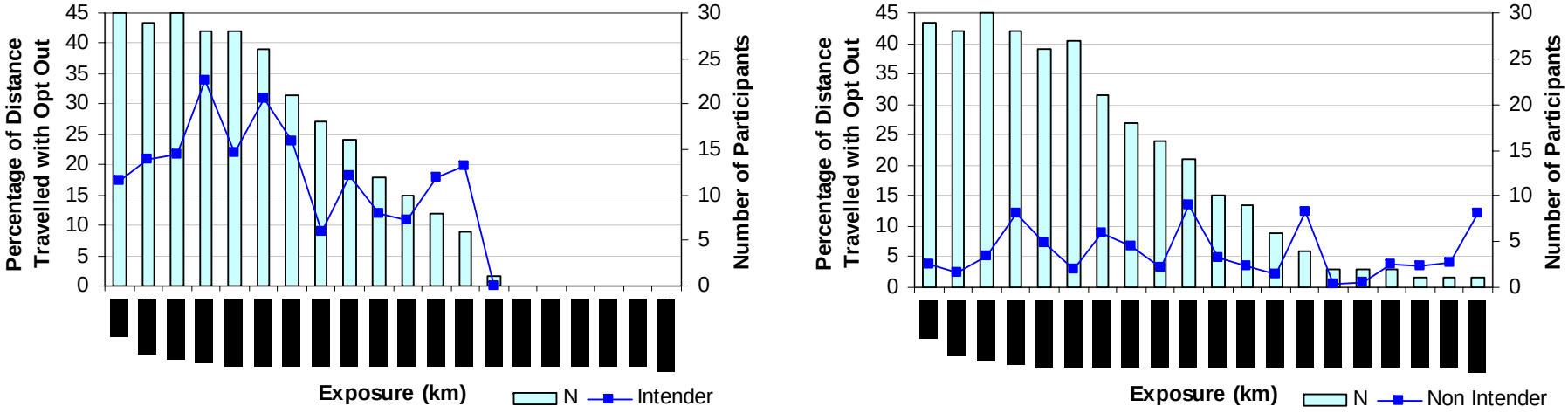


Figure 10: Percentage of distance travelled on 70mph roads with ISA overridden

Across all speed zones, intenders showed a greater propensity to drive without using ISA. In addition, Intenders also demonstrated a sharper rise in the distance travelled with ISA overridden along system exposure than their counterpart across individual speed zones. These trends further support the findings from the previous section that behavioural adaptation is subject to individual as well as environmental characteristics.

2.4.2.3 Mean speed

Although analysis depicted in the previous two sections suggests that system compliance decreased in line with in increase in system exposure, mean vehicle speed showed little change along increased system exposure, as displayed in Figure 11 through to Figure 13. This may be due to constraints imposed by external factors (e.g. presence of a lead car) or by perceived risks (e.g. Wilde, 1982; 1988) on the speed that a driver can afford to go over the speed limits, which may be in particular applicable to urban environments (i.e. Figure 11 and Figure 12). Mean speed derived from the 70 mph zones fluctuated slightly along increased system exposure, in comparison with lower speed zones, but the changes seem to be minimal. Overall, the analysis results imply that mean speed appears to be insensitive to behavioural changes with exposure and individual differences (i.e. intention to speed) and suggest that mean speed was a weak indicator of behavioural adaptation to an ISA system.

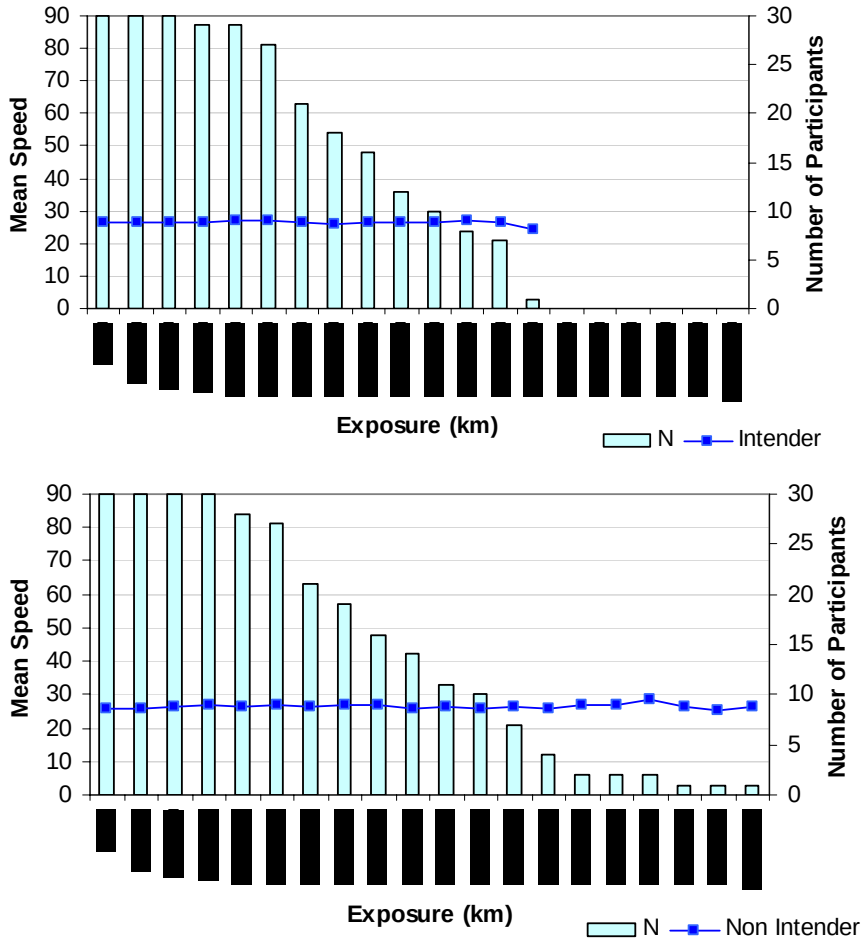
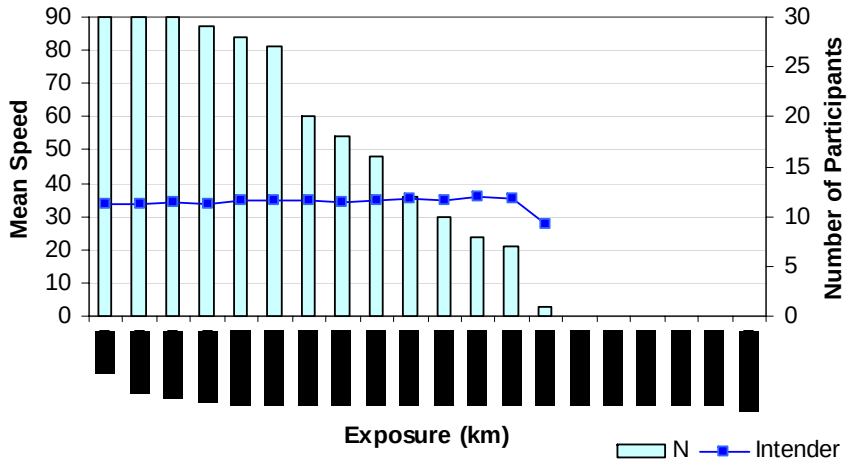


Figure 11: Mean speed on 30mph roads



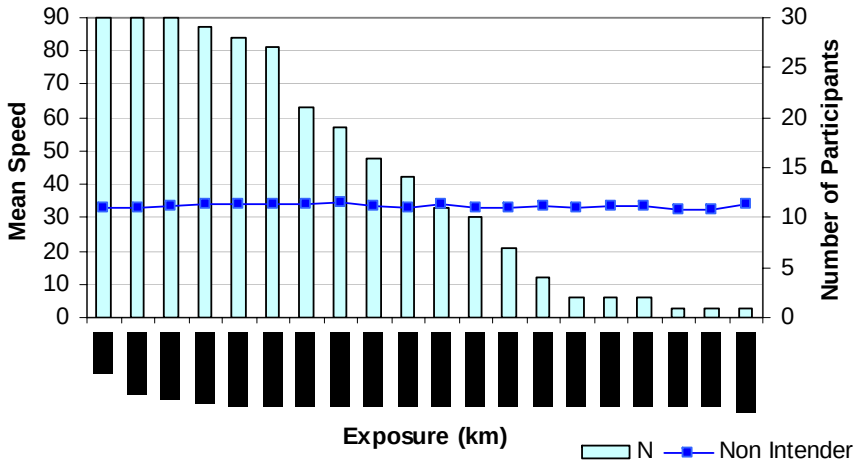
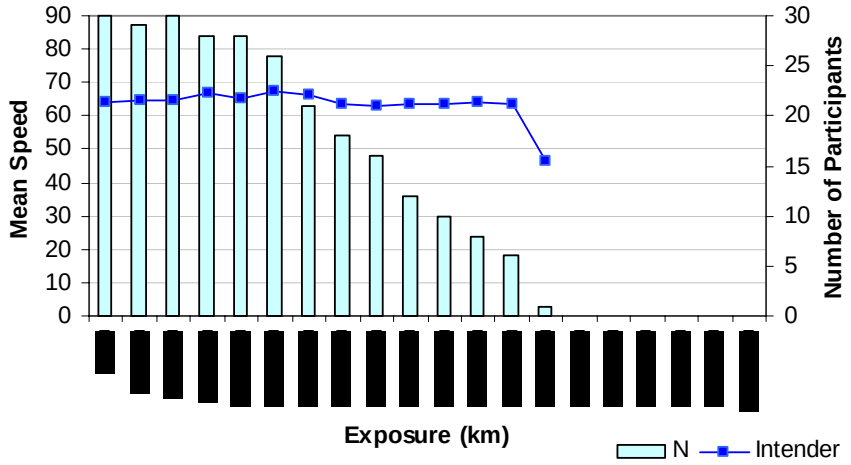


Figure 12: Mean speed on 40mph roads



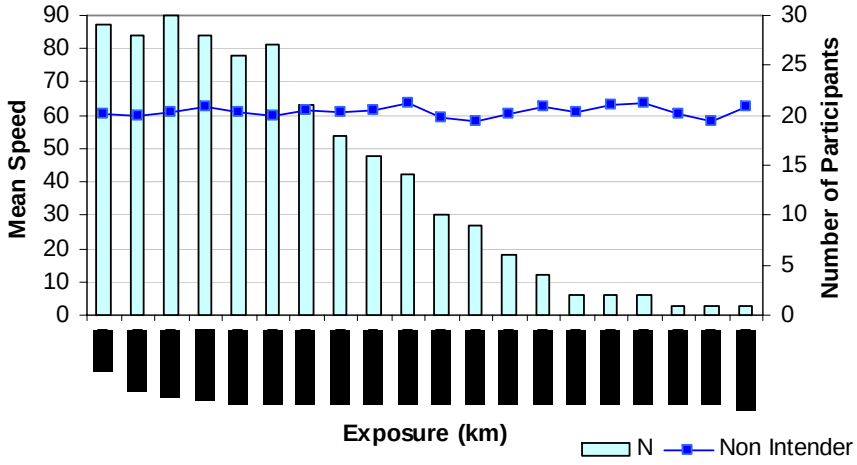


Figure 13: Mean speed on 70mph roads

2.4.2.4 85th percentile speeds

In addition to mean speed, the 85th percentile speed is also a commonly adopted measure for investigation into driving behaviour, as it is widely used by traffic engineers to determine appropriate speed limits. However, similar to mean speeds, 85th percentile speeds showed little change along increased system exposure, as illustrated in Figure 14 through to **Figure 16**. The only exception was demonstrated by data derived from intenders in the 70 mph zones (i.e. Figure 16), which illustrates an upward trend along system exposure.

As discussed in the previous section, the little change in vehicle speed along increased system exposure may be due to constraints on what speed a driver can afford to go over the posted speed limits under the circumstances in question. When circumstances permitted (e.g. sufficient headway, wide open road, and good surface condition), participants may have pushed their safety boundary further (Wilde, 1982; 1988) and gone faster. This may in particular be applicable to motorways when the traffic flow was light, and the comparison between intenders and non-intenders (Figure 16) shows some support for this assumption; i.e. intenders pushed their safety boundary when driving environment permitted but non-intenders did not. In addition, the 85th percentile speed represents the higher end of the speed distribution and may therefore reveal what was evened out by means (i.e. comparing **Figure 13** and Figure 16). Despite this, vehicle speed was still in general insensitive to behavioural changes, which suggests that it was a weak indicator of behavioural adaptation in the presence of an ISA system.

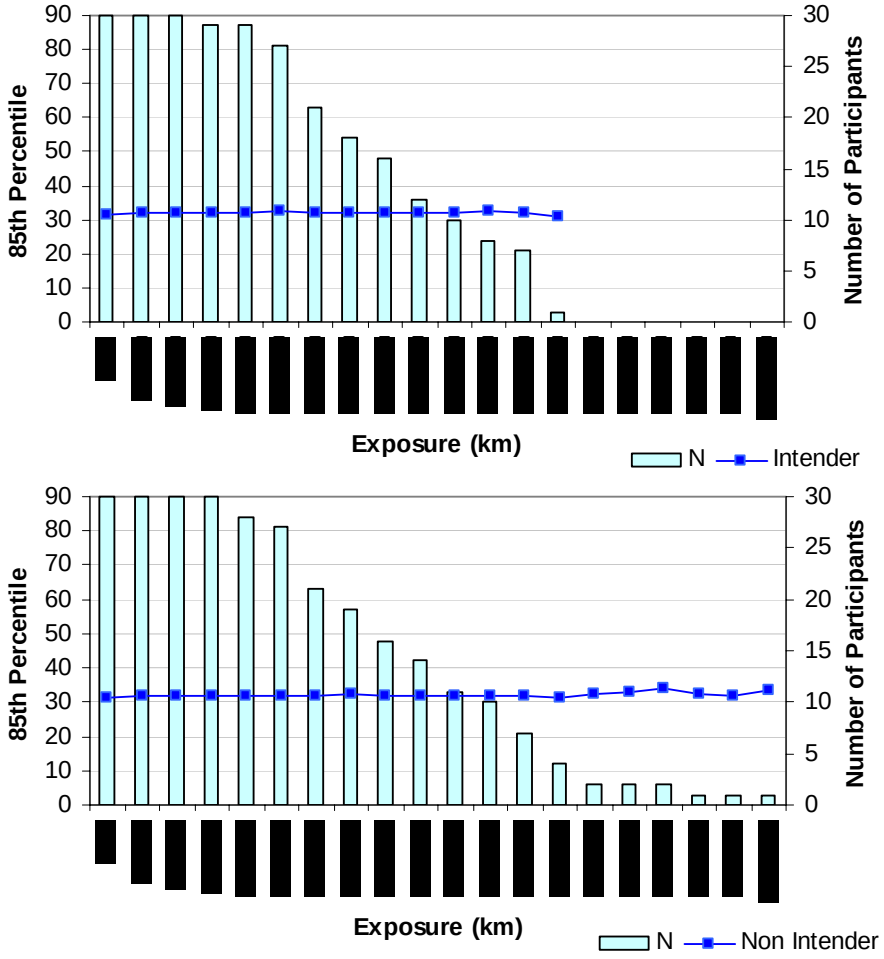
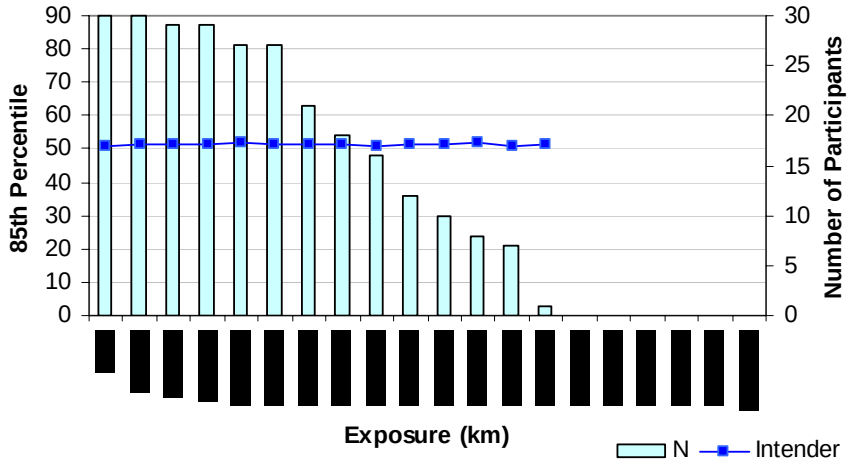


Figure 14: 85th percentile speed on 30mph roads



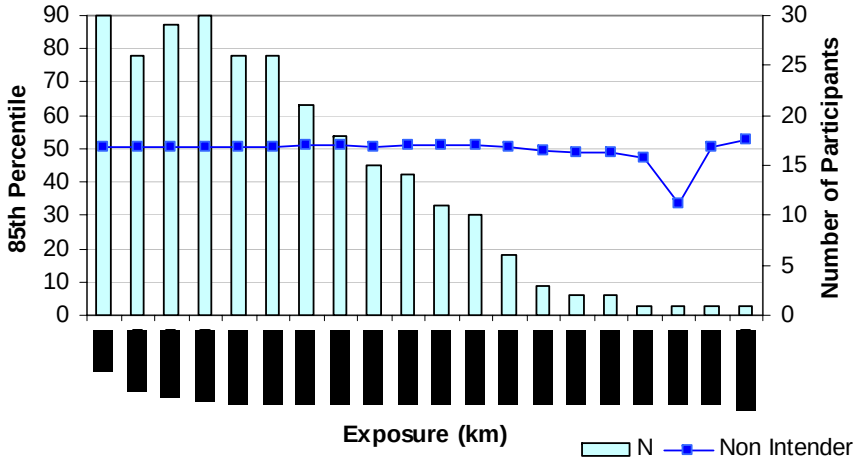
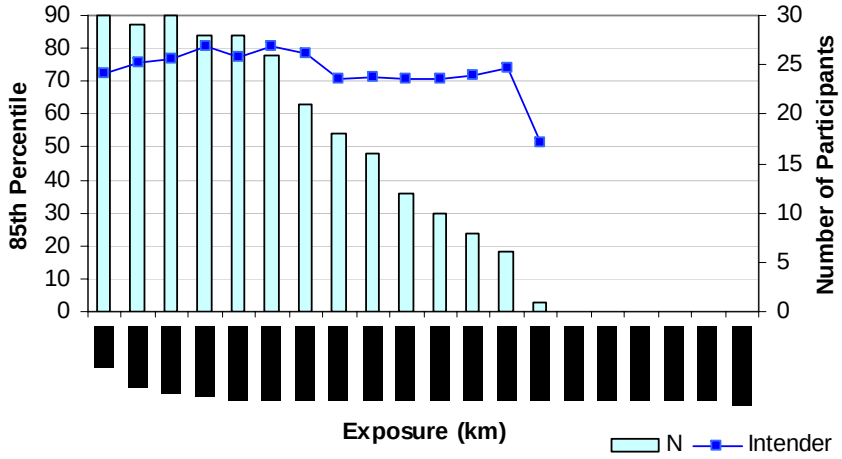


Figure 15: 85th percentile speed on 50mph roads



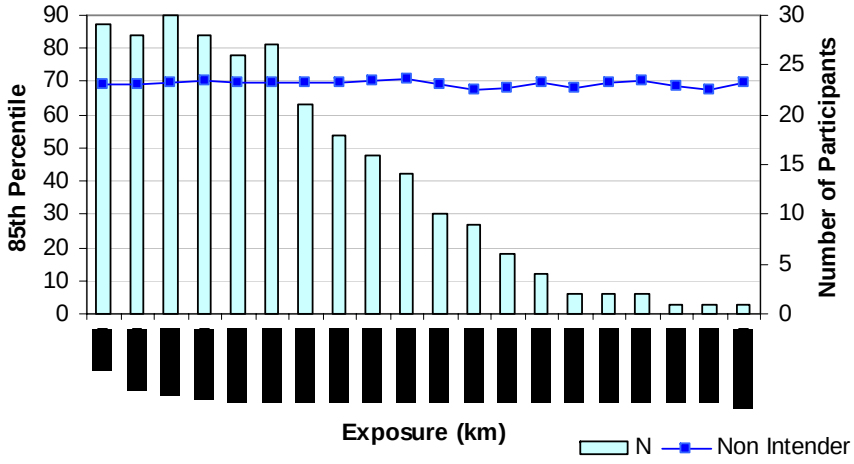


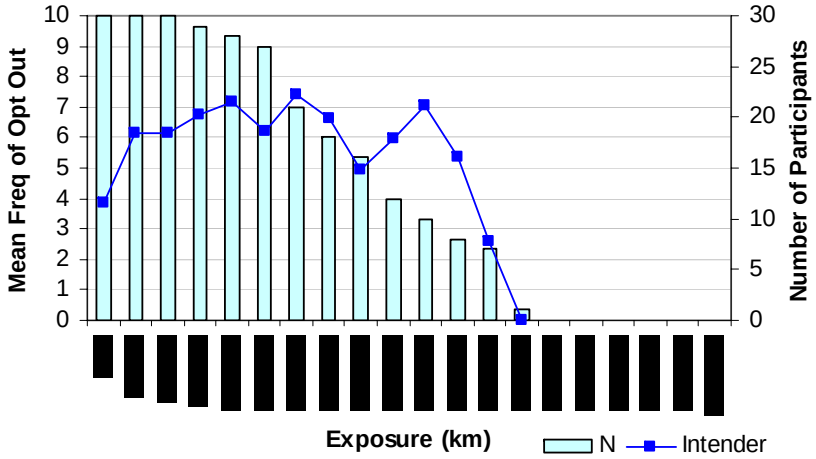
Figure 16: 85th percentile speed on 70mph road

2.4.2.5 Weekday vs weekend

Since measures of system compliance provided the most reliable measures of behavioural adaptation, comparisons across weekend and weekday were limited to these. In addition, due to the imbalanced number of days during the week and weekend (i.e. 5 days against 2 days), mean daily frequency of opt out was adopted to enable the comparison between weekday and weekend being made on the same basis.

Comparison across Figure 17 to **Figure 18** highlight that participants, in the 30 mph zones, overrode the ISA system slightly more frequently during the week. This was presumably due to a more relaxed driving style during the weekend as a result of variations in traffic density and individuals' value of time (Shinar and Compton, 2004) and hence the participants felt less need to override the ISA system. However, intenders still demonstrated a higher frequency of opt out than their counterparts regardless of time of week, which again highlights the role of individual differences in the pattern of behavioural adaptation.

The difference in frequency of opt out between weekday and weekend was less pronounced amongst other speed zones, presumably because the driving environment was less complex in comparison with urban environment and therefore diminished opportunities of system interference; the underlying trend of behavioural adaptation in the presence of an ISA system may, as a consequence, be distorted to some extent.



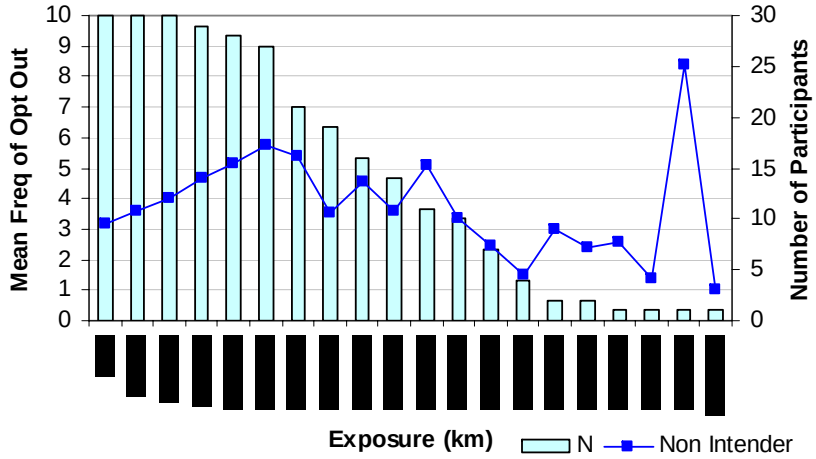
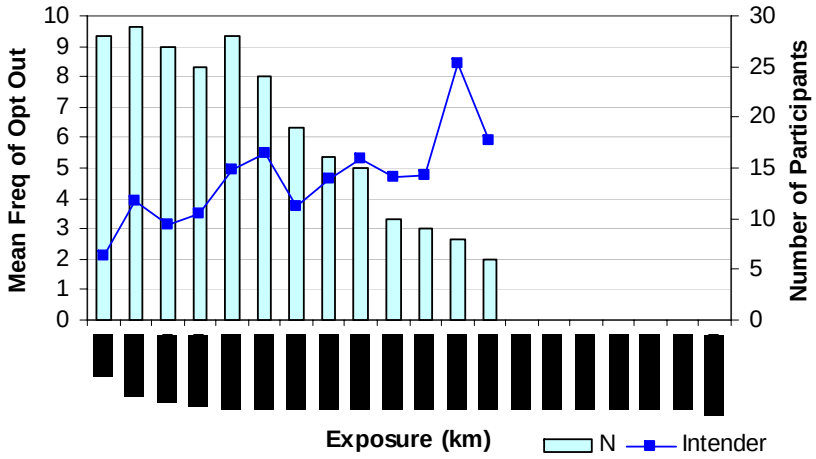


Figure 17: Mean frequency of opt out during the week on 30mph roads



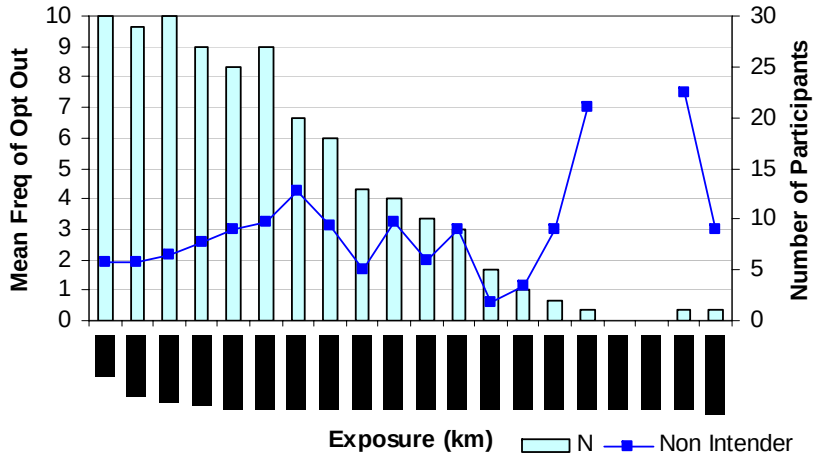


Figure 18: Mean frequency of opt out during the weekend on 30mph roads

2.4.3 Further consideration of distance as measure of system exposure

Despite the apparent merits of using distance as measure of system exposure (i.e. Section 2.4.1), the analysis presented throughout Section 2.4.2 demonstrated that sample size decreases along kilometres driven, which is in fact a valid representation of the driving population, since annual mileage naturally varies from one driver to another. However, as a result, interpretation of the underlying trend after the point where the sample size starts dropping becomes difficult. Therefore, attempts were made to further analyse the data by grouping participants based on bands of total kilometres driven. This would warrant that the sample size of a group of participants remains unchanged along the exposure but the drawback is that analysis would be less reliable due to small samples.

Figure 19 illustrates the distribution of total kilometres driven from all 60 participants, which suggests that it seems feasible to group participants by multipliers of 1000 km; e.g. participants who drove between 1000 km and 2000 km during the trial period were grouped together, and so forth. In addition, following the analysis results based on full sample size (i.e. Section 2.4.2), system compliance provided the most reliable measures of behavioural adaptation, and therefore further analyses based on total kilometres driven were limited to these.

Figure 20 compares the mean frequency of opt out among four groups of kilometre bands; within each group, participants were further split into two sub-groups according to their intention to obey speed limits. As can be seen in Figure 20, participants demonstrated an upward trend of overriding the ISA system along system exposure and intenders showed stronger tendency in overriding the ISA system than non-intenders, apart from those drove between 5000 and 6000 km. It is worth noting that the sample size in the band of 5000-6000 km is very small, which may affect the reliability of the analysis result.

In addition, Figure 20 seems to suggest that non-intenders ‘stopped’ overriding the ISA system after certain amount of system exposure. While this might appear to be a turning point of behavioural adaptation, interpretation should be made with caution. The illustrated trends were fluctuated along system exposure, which implies that the trends might turn upward again if the survey period was prolonged (i.e. how long is long-term?). More importantly, the point at which the trend plateaus or even starts dropping was not consistent across different kilometre bands, which no doubt diminishes the confidence in suggesting a generalised turning point of behavioural adaptation (e.g. 3000km, 4000km, or 5000km).

It is worth noting that not all bands of total kilometres driven are presented in Figure 20 because some bands have extremely small number of participants in each intention group and some bands have very imbalanced number of participants across the two intention groups. In addition, attempts were made to split the sample by speed zones and time of week within bands of total kilometres driven. However, the sample size in individual sub-groups is mostly extremely small, which led to difficulty in producing meaningful comparisons.

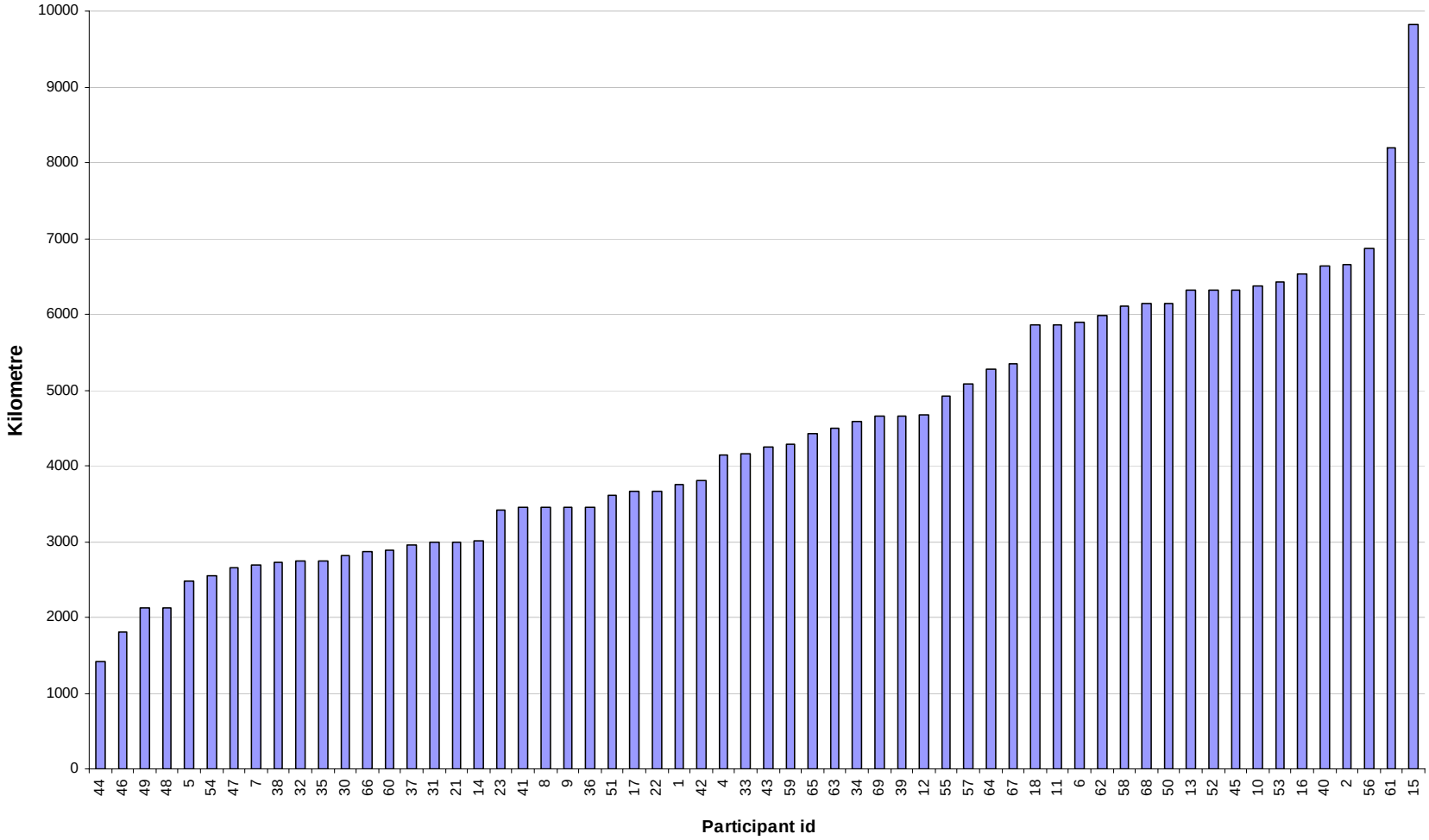


Figure 19: Distribution of total kilometres driven

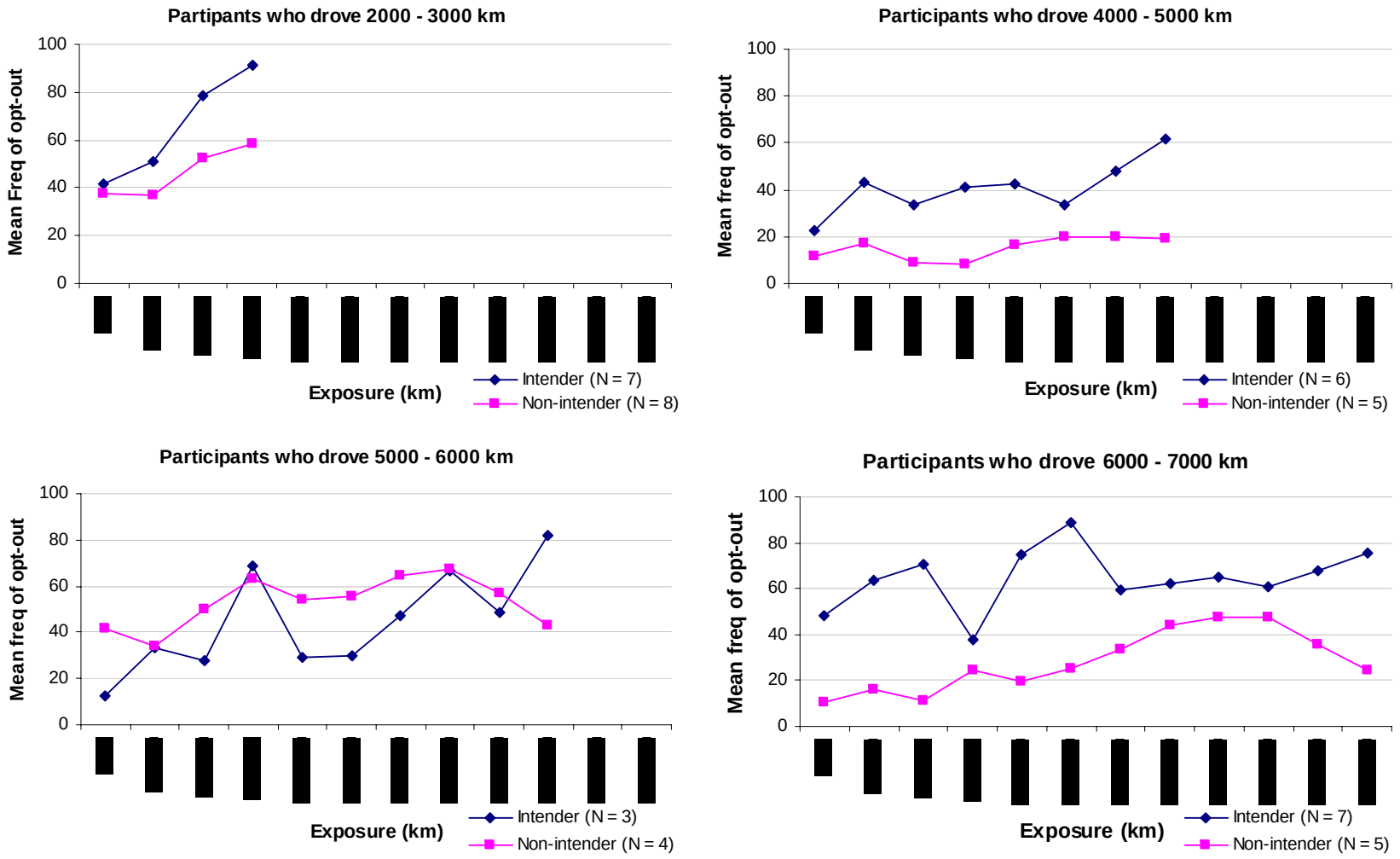


Figure 20: Comparison of mean frequency of opt out by total distance driven

2.5 Results Swedish Lund ISA-trial

2.5.1 The driver population

In this study the drivers where classified according to their speed behaviour. The average percentage of distance driven above the speed limit (hereinafter labelled V_{above}) when driving without the system activated was calculated and the drivers where divided into three groups, the slowest 3rd, the middle 3rd and the fastest 3rd of the drivers. They are hereinafter labelled as SI1, 2 and 3 (Speed Index) (Figure 21).

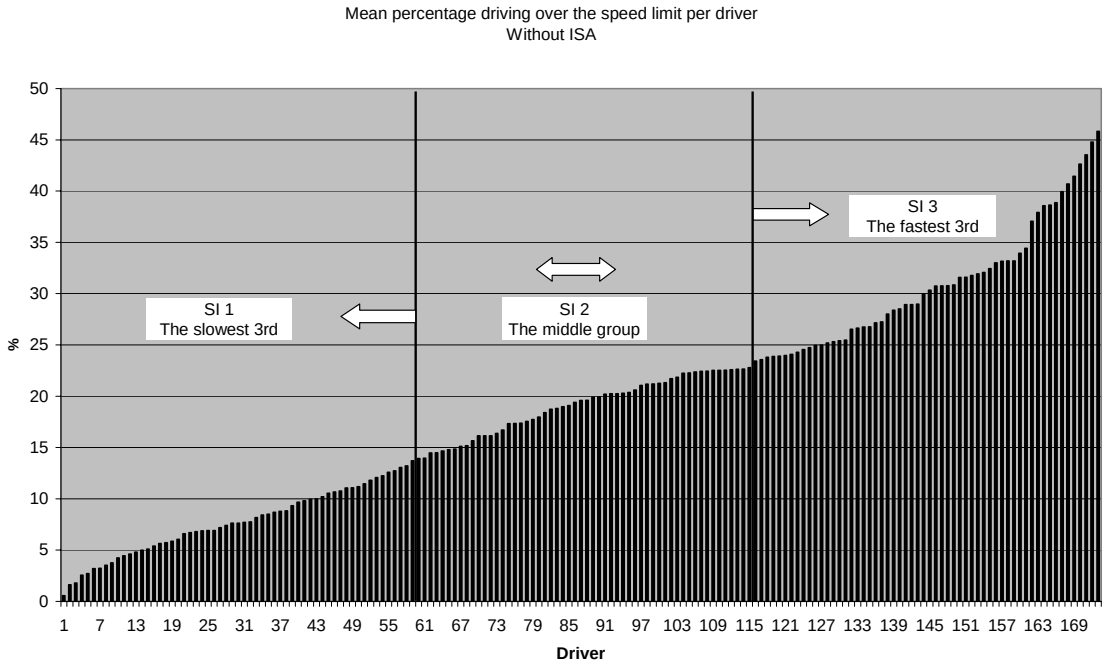


Figure 21 The drivers V_{above} without ISA divided into three groups.

An analysis was carried out to see how the SI correlated with other variables such as Age, Sex and Attitude to the system. It turned out that there was no difference in SI-distribution due to sex (p=0.643) (Table 2).

		Speed Index			
		Slow	Medium	Fast	Total
Sex	Men	34	36	36	106
	Women	19	16	17	52
Total		53	52	53	158

Table 2 The distribution of men and women across the SI-groups

(the total differs from the total number of drivers due to missing data)

For age however there is a clear difference for SI where the younger drivers are more prone to drive fast. The mean difference is significant at the 0.5 level.

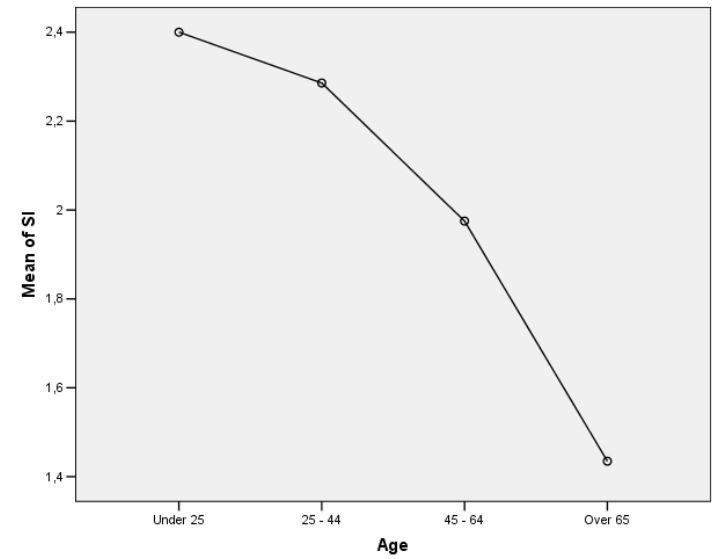


Figure 22 Mean SI for the four age groups in the study.

2.5.2 Overall results

Based on the results from the ISA UK study distance driven was chosen as the best measure of system exposure. Data is studied for all drivers and for the three SI-groups respectively.

In Figure 23 V_{above} is plotted against the distance driven with the system, the negative distance indicates distance driven without the system. As Figure 23 shows the system affects the drivers immediately at system activation. The V_{above} is reduced drastically from the first kilometre driven. The effect is greater for the fast drivers and then smaller for the medium drivers and even smaller for the slow drivers due to the different starting points. Despite the greater reduction in V_{above} the fast drivers does not come down to the same level as the slow drivers, in fact, they do not even come down to the same level as the slowest drivers have without the system.

After the initial reduction in V_{above} it slowly starts increasing back towards its initial value. The increase appears to be linear, at least when studied at group level. As shown in Figure 23, bottom right graph, the increase is greater for the fast drivers. The medium fast and even the slow drivers also increase their V_{above} but less rapidly and to a lesser extent.

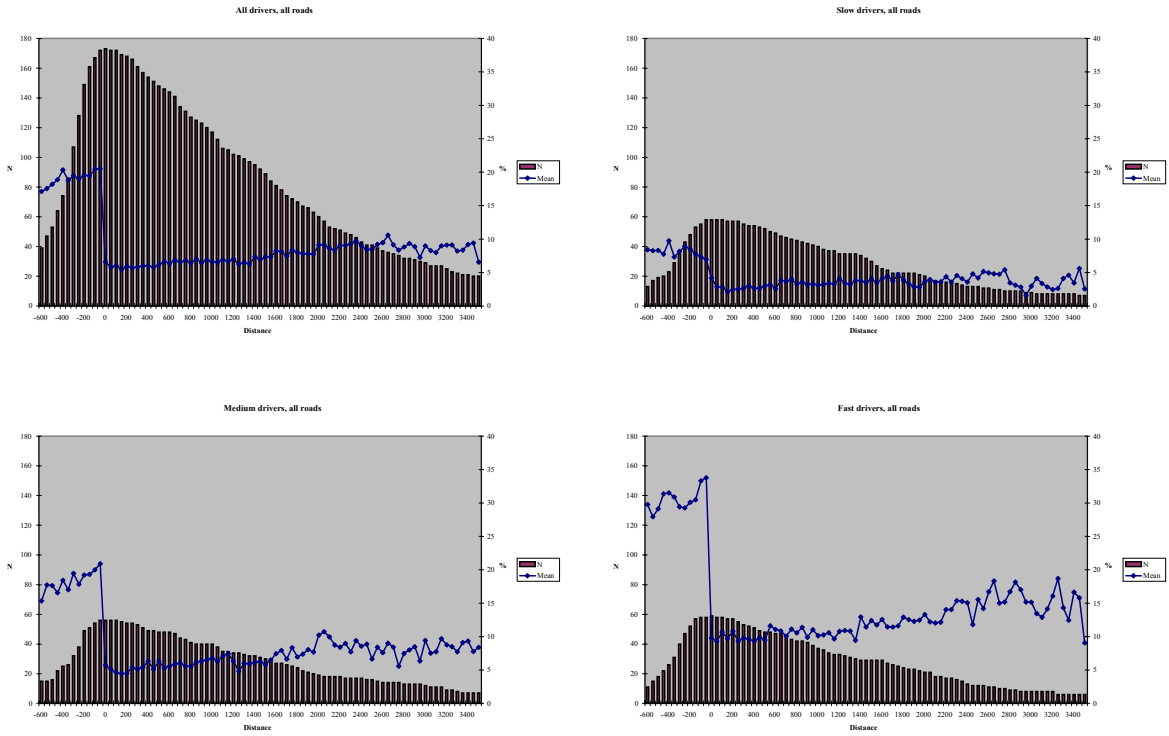
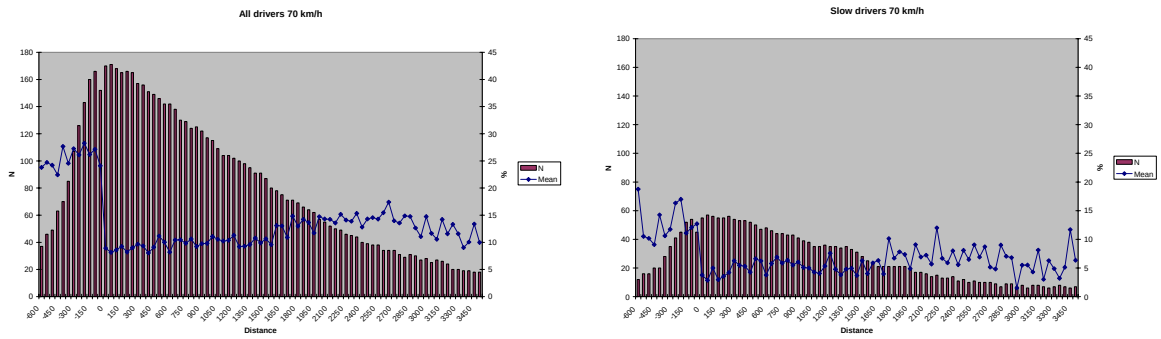


Figure 23 The percentage of distance driven 3 km/h or more over the speed limit for all drivers and for the SI's respectively.

Top left, all drivers; top right, slow drivers; bottom left, medium drivers and bottom right, fast drivers.

2.5.3 Results on 70 km/h roads

The 70 km/h roads in the city of the Lund are the ones that best provide opportunities to speed and this is reflected in the high percentage of $V_{above.}$ The drivers also consider that it is more ok to speed on these roads than on the slower more urban roads (Falk et al., 2002). It is especially the fast drivers that have a high proportion of speeding and their V_{above} is more than 40 percent when driving without ISA. After long term use the V_{above} is back to almost 30 percent again. There is some decline in the V_{above} again after 3 000 kilometres of driving with the system, but this could be an effect of the reduced sample size as well as an actual effect.



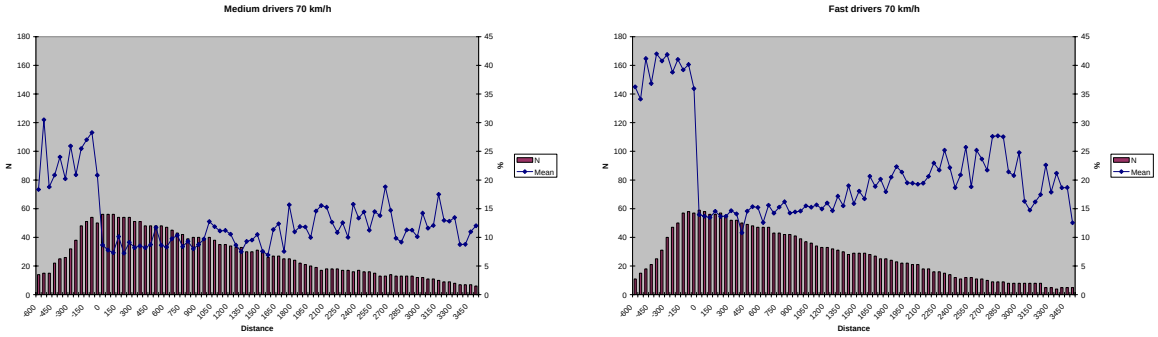


Figure 24 V_{above} for 70 km/h roads

Top left, all drivers; top right, slow drivers; bottom left, medium drivers and bottom right, fast drivers.

2.5.4 Results on 50 km/h roads

The 50 km/h roads in Lund are more varied than the 70 km/h roads where some of them provide free flowing conditions where it is possible to speed while others are more crowded with other cars, cyclist and pedestrian crossings. On these roads the drivers generally state that they intend to keep the speed limit (Falk et al., 2002). As for the 70 km/h roads there is a difference depending on the drivers SI, however it is not as great as it is for the faster roads. The fastest drivers reduce their V_{above} from ca 30 percent without the system to ca 10 percent with the system. This means that 1/3rd of the initial reduction in V_{above} is regained compared to more than half for the 70 km/h roads.

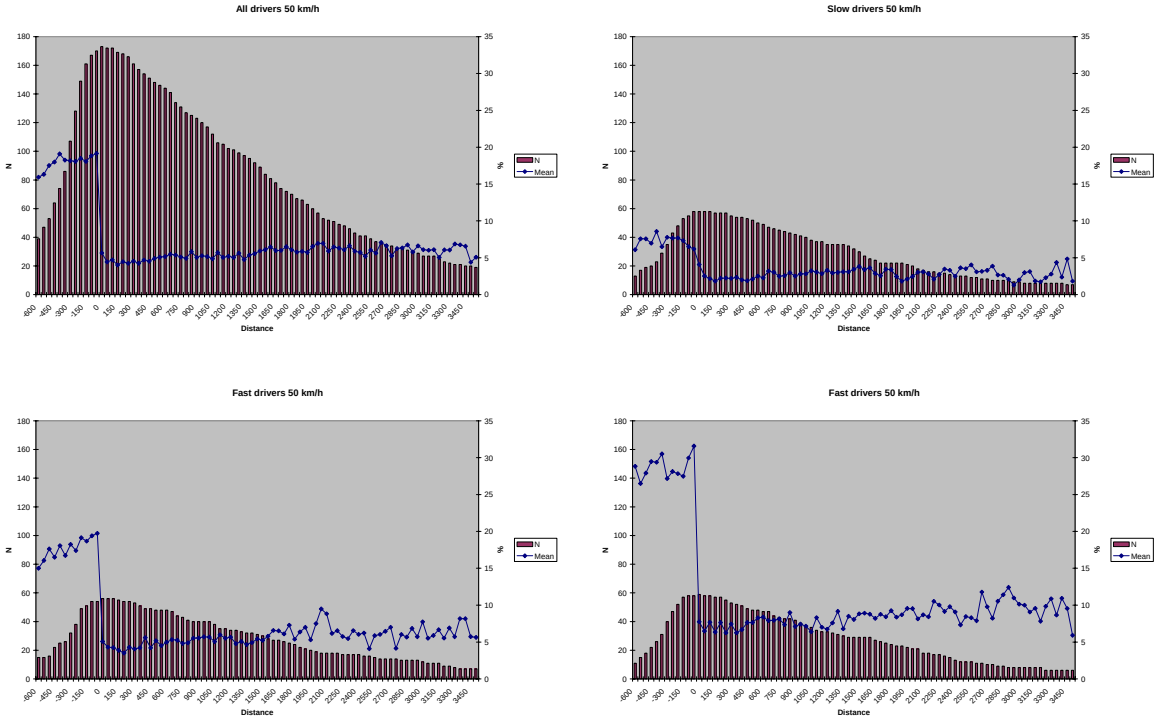


Figure 25 V_{above} for 50 km/h roads

Top left, all drivers; top right, slow drivers; bottom left, medium drivers and bottom right, fast drivers.

2.5.5 Results on 30 km/h roads

The 30 km/h roads in Lund are mainly located in the centre of Lund and they comprise a mixture of cars, cyclists and pedestrian. Many of them also have cobble-stone paving and this is reflected in the speed. Unfortunately for this study the number of kilometres travelled on these roads is quite low and even though many drivers may have travelled on them one should bear in mind that the distance driven per driver in each 50 kilometre section is low, maybe as low as a few hundred metres. This is the reason for the fluctuation in data which makes it hard to draw any clear conclusions. The results however does appear to be similar to the results for the 50 km/h roads, i.e. there is a increase in V_{above} after the initial reduction but not as great as for the 70 km/h roads.

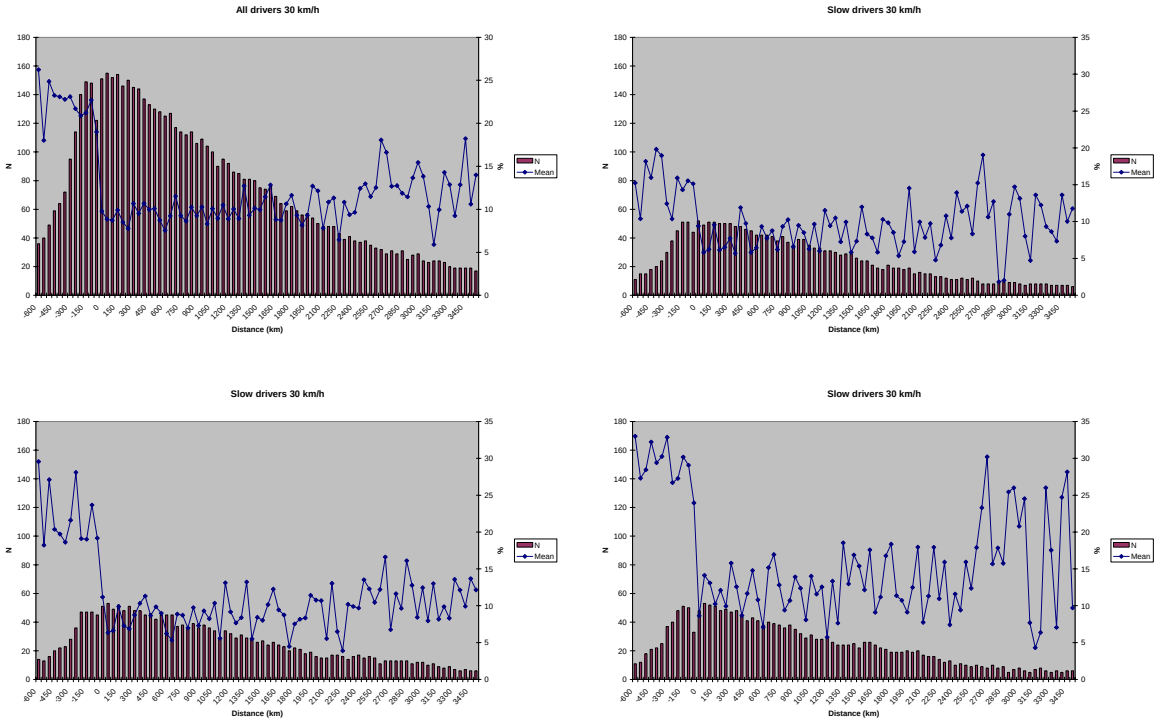


Figure 26 V_{above} for 30 km/h roads

Top left, all drivers; top right, slow drivers; bottom left, medium drivers and bottom right, fast drivers.

2.5.6 Change point estimation

In order to ensure pure estimates of a change point only drivers with at least 2500 km with ISA-device were included in the analysis, so then there were at least 50 observations for each driver. That condition resulted in that 41 drivers were included in the analysis. The significance level was set to 5 per cent. There were significant change points for 22 drivers.
Below 95% confidence interval is indicated by ±.
The mean driving distance for the group with significant change point was 4784 ± 946 km while it was 3200 ± 319 km. Unfortunately the difference between the mean driving distances differed significantly from zero, 1584 ± 1032 km.

2.5.6.1 With significant change point

In the group of drivers with significant change points there were no significant differences between the slow, medium and fast drivers see Table 3 and Table 4.

Slow	914 ± 341 km
Medium	650 ± 341 km
Fast	788 ± 319 km

Table 3 Estimated change points (km)

	Medium	Fast
Slow	264 ± 586 km	127 ± 567 km
Medium	- 138 ± 567 km	

Table 4 Estimated differences for change points, row minus column

Table 5 and Table 6 show the immediate effect on the proportion exceeding the speed limit form the ISA-device. There is significant effects for all three groups as well as significant differences between the groups.

Slow	- 7.6 ± 3.5 percentage units
Medium	- 18,9 ± 3.5
Fast	- 28.4 ± 3.2

Table 5 Estimated immediate effect, percentage unit

	Medium	Fast
Slow	11,2 ± 5.9	20,8 ± 5.8
Medium	9.5 ± 5.8	

Table 6 Estimated differences for immediate effect, row minus column

Table 7 and Table 8 show the long term effects (after the change point). There are significant long term effects for the fast end medium fast drivers. The long term effect for the slower drives is significantly lower than for the other drivers.

Slow	- 3.4 ± 3.7
Medium	- 9.3 ± 3.7
Fast	- 16.0 ± 3.5

Table 7 Estimated long term effect, percentage unit

	Medium	Fast
Slow	5.9 ± 6.4	12.6 ± 6.2
Medium	6.7 ± 6.2	

Table 8 Estimated differences for long term effect, row minus column

2.5.6.2 Without significant change point

Table 9 and Table 10 show the effect, when there are no significant change points. The proportion of driving distance above the speed limit is reduced significantly for all drivers and there are significant differences between the groups.

Slow	- 5.6 ± 3.4
Medium	- 13.3 ± 2.8
Fast	- 23.3 ± 4.2

Table 9 Estimated effect, percentage unit

	Medium	Fast
Slow	7.8 ± 5.3	17.8 ± 6.5
Medium	10.0 ± 6.1	

Table 10 Estimated differences for effects, row minus column

2.5.7 Further considerations of the data

From the graphs in the previous sections there seems to be a plateau effect after about 2 000 kilometres. It is however impossible from those graphs to say whether that is an effect of the sample size being reduced or if it is an actual effect. For that reason the drivers who had driven the longest distance during the experiment were isolated and studied separately. There were thirty drivers who had driven up to 3 000 kilometres or more during the experiment and these drivers were selected for analysis. Of these thirty drivers nine very classified as slow, thirteen as medium and eight as fast. In Figure 27 the progress of V_{above} for these thirty drivers is displayed for the duration of 3 000 kilometres travelled.

As Figure 27 shows all three groups of drivers show the same pattern where V_{above} starts low and then increases gradually, and more so the faster the driver. The plateau effect that was predicted from the graphs in Figure 23 to Figure 26 can be seen in Figure 27 as well. For the slow drivers the effect is small and the graph is fairly constant for the duration of the experiment. For the medium fast drivers the effect is more clear and it even seems that the V_{above} is actually decreasing again after 2 000 kilometres. For the fastest drivers there are no signs of the increase in V_{above} is flattening out. If this is due to the experimental period not being long enough or whether no such effect exists cannot be told by this study. It should also be noted that the finding that there is a plateau effect is based on a small sample of drivers and that there is no way of telling that it actually is a plateau and not just a continuous fluctuation.

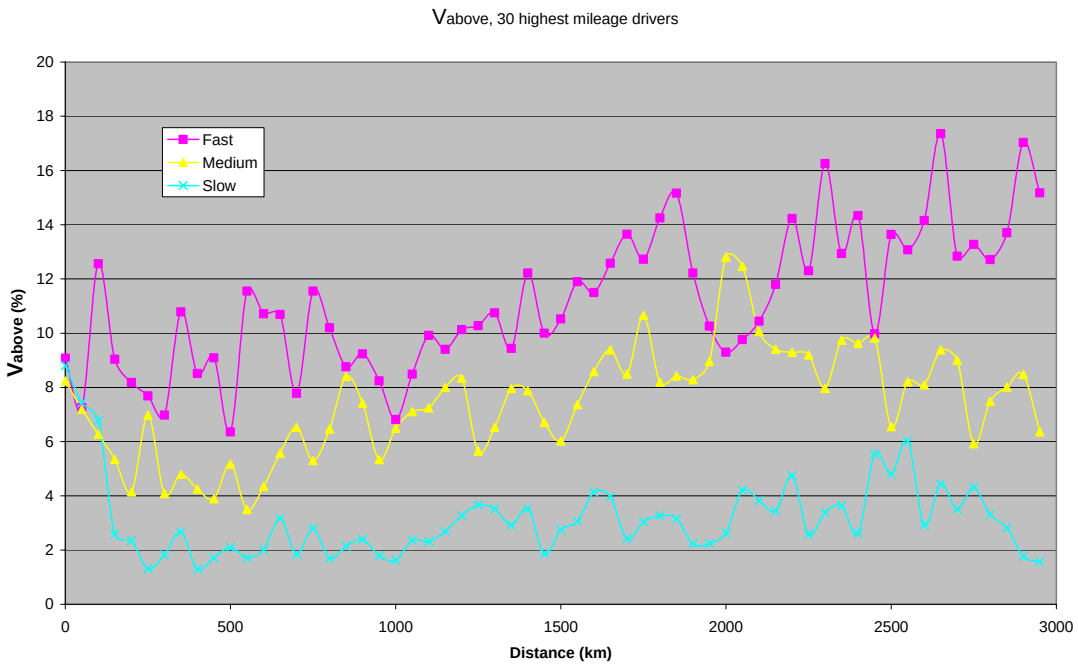


Figure 27 V_{above} for the 30 drivers with the highest mileage during the experiment.

2.6 Discussion

Current analysis demonstrated that distance was a robust and reliable measure of exposure to an ISA system. Comparisons across various measures showed that variables relating to system compliance (i.e. a participant's tendency to override the system) were most sensitive to behavioural changes and highlighted key trends regarding an individual's behavioural adaptation to an ISA system.

Vehicle speed was thought to be a meaningful indication of behavioural adaptation in the presence of an ISA system, as the ISA system is designed to influence driving speed. However, the analysis results revealed that vehicle speed showed little change along increased system exposure. This may be due to constraints imposed by external factors (e.g. presence of a lead car) or by perceived risks (Wilde, 1982; 1988) on the speed that a driver can afford to achieve in a given driving environment. Therefore, vehicle speed did not show an apparent upward pattern, although both frequency of opt out and distance driven with ISA overridden demonstrated an upward trend along an increase in system exposure. Such constraints may be less prominent on motorways due to its openness. Hence, when circumstances permitted (e.g. absence of lead car, low traffic volume etc), participants demonstrated a slight upward trend in their 85th percentile speed (i.e. Figure 16).

Although the results based on the current dataset suggest that vehicle speed is a weak indicator of behavioural adaptation, it is worth noting that the sensitivity of vehicle speed as an indicator of behavioural adaptation may depend on the function of the ADAS in question; i.e. vehicle speed may be a good indicator in the presence of an ADAS system providing assistance in vehicle longitudinal (e.g. forward collision warning) or lateral (e.g. lane departure warning) control.

One assumption on the drivers' behaviour after the ISA devices are implemented is that during an initial driving distance the proportion of exceeding the speed limit will reduce to a comparable low level and then increase to a steady level. To study whether such a change point exists and when it occurs a change point estimation was carried out on a subset[1] of the Swedish data. It revealed that about half of the drivers had a significant change point. The other half did not have any significant change point. The analysis showed that those drivers with a change point had a rapid increase in their V_{above} after between 650 – 914 kilometres driving (± 340 km). The group with a change point had a higher degree of Vabove after long term use than the group that did not have a change point; even though they did not go back to their initial level. The underlying motives for this difference could not be established by this study.

Interrogation of the system compliance data demonstrated a concommittal increase in overriding behaviour and exposure. More simply, participants' tendency to override the system increased as their experience with the system progressed, which implies that prolonged use of the ISA system caused frustration amongst the participants which manifested itself as increased overriding behaviour. This trend is clear for both the UK data and the Swedish data which suggests that the effect is not dependent on the specific system design but rather for all ISA-applications which has an override function. Unfortunately due to a drop in sample size it is not possible to ascertain whether and when this trend plateaus. Further analyses to tackle the issue of dropping sample size (i.e. Section 2.4.3 & 2.5.7) also led to inconclusive results. It is clear however that participants' frustration is still apparent having accrued up to 3000 km of driving experience with the UK ISA system and up to 2000 km for the Swedish system.

The frustration may be due to locus of control (Rotter, 1966; Rotter and Hochreich, 1975). Based on the results from a previous ISA field trial carried out in Leeds (Comte, 1999), participants reported that they felt they were not "in control" of the car and that the system disrupted "normal" driving habits; e.g. being able to go over speed limits when they regard the circumstances being necessary, such as overtaking or merging into traffic. The ISA system also made them feel vulnerable sometimes as they were driving much more slowly than the surrounding traffic (i.e. a great percentage of traffic go over speed limit) and felt this annoyed other drivers. Some participants mentioned that they were aware of close following traffic behind them when they were unable to exceed the speed limit, and this was therefore deemed as unsafe. Not surprisingly, most participants, both in the UK and in Sweden expressed that they preferred overridable ISA to mandatory ISA (i.e. non-overridable).

Across all scenarios, intenders consistently demonstrated a greater propensity to override the ISA system as exposure increased. Findings here suggest that cognitions play an important role in understanding driving behaviour and responses to intelligent transport systems such an ISA system. This is unsurprising given the literature relating cognitions to future speeding intentions (Parker, Lajunen and Stradling, 1998; Parker, Manstead, Stradling, Reason and Baxter, 1992; Parker, Manstead and Stradling, 1995) and behaviour (Elliott, Armitage and Baughan, in press). Rudin-Brown and Parkers (2004) qualitative theory of behavioural adaptation to in-vehicle intelligent transport systems also "views driving behaviour as dependent on an individual's mental model of the diving task. The mental model is directly influenced by a driver's psychological characteristics as well as feedback from the in-vehicle system and the degree to which the driver trusts that the device will do what it is intended to

[1] The 44 drivers that had accumulated more than 2500 kilometres during the experiment.

do"(p.60). It is therefore important to understand and accommodate for individual differences when deploying an ADAS system; i.e. the driver element in the DVE model.

The data from the UK also suggest that drivers' overriding behaviour would be greatest when driving in the lower speed zones. In urban environments, there is considerably more variation in traffic speeds due to environmental complexity (e.g. presence of vulnerable road users, traffic signals, and more complex road fixtures etc). The ISA system is therefore much more likely to 'interfere' with driving and thus increased interaction with the system may evoke increased frustration. The Swedish data does not comprise any rural roads but there is a clear difference between urban roads where the faster 70 km/h roads have a higher degree of overriding than the slower 50 and 30 km/h roads. If this is due to the fact that it is easier to speed on these roads, the faster traffic rhythm or just that the drivers consider it to be more ok to speed on these roads is difficult to say. Most likely it is a combination of the three which would fit the Theory of Planned Behaviour well.

In addition, comparisons relating to time of week suggested that overriding was slightly more likely during the week. These findings reflect the influence of situational variables on drivers' behavioural adaptation in the presence of an ADAS system; i.e. the environment element in the DVE model.

3 Behavioural changes due to long term use of Speed Limiter and Cruise Control

3.1 Introduction

INRETS, the social psychology laboratory of the University of Provence and Renault collaborated closely with the particular aim of studying the long-term use and integration of, and the behavioural changes induced by two ADAS systems which offers two complementary modes of speed management : a speed limiter (SL) and a cruise control (CC).

The impacts of the use of these systems, their integration in driving and the changes they occasion, especially in terms of speed reduction, have been studied from a short-term perspective (Saad et al., 2006). The interest of the present study is that it adopts a standpoint geared to the long term in order to gain a better knowledge of the development over several months/years of phenomena. Thus the main objectives of the study are:

- To study the quantitative and qualitative impact of the use of these two systems, as well as the long-term development of the phenomena studied.
- To estimate to what extent certain personal characteristics, such as gender and age, are at the root of substantial differences in the use of the support systems.
- To examine drivers' perceptions (or "images") of the support systems and how they influence their use and acceptance.

3.2 Method

3.2.1 Data collection

The method used was a postal questionnaire survey. In view of the time allowed for the study (January to June 2006), a transversal perspective was retained, so that different groups of drivers could be compared with different potential levels of driving support utilisation.

The population surveyed is composed exclusively of customers of the car manufacturer Renault living in mainland France. This type of population is very interesting because it represents a "real" population, namely people driving their own vehicle as part of their daily travel. They all possessed a vehicle equipped with the same driving aids - a speed limiter and a cruise control - thus offering the opportunity of studying their daily use of these support systems.

A file of 1,200 people was created. They were all contacted by a letter that included a questionnaire and a stamped addressed envelope for returning it. These 1,200 people were chosen on the basis of two sampling variables: gender and the date the vehicle was first licensed (T_1 = the 10-11/2005 period; T_2 = the 06-07/2005 period; T_3 = the 05-06/2004 period). This sampling thus defines six groups of participants with 200 people in them according to a Date (3) X Gender (2) plan. The questionnaire was composed of the same questions for the limiter as for the cruise control. To neutralise a possible effect of the order in which they were answered, half the participants (600) answered the questions on the limiter first, and then those on the cruise control (the SL_CC version), while the other half replied

firstly to the questions on the cruise control, and then those on the limiter (the CC_SL version). These two versions of the questionnaire were distributed equally in each group of the sample.

The questionnaire was the fruit of collaboration between INRETS and the social psychology laboratory of the University of Provence. Different types of phenomena were studied. The main ones related to the use of the systems, to the process of learning to use them, and to the experience of driving with them, as well as to perceived differences between driving with and driving without them, to comparisons between the systems and to the behavioural changes they induce. Two personal data (notably gender and age) were taken into consideration.

Of the 1,200 questionnaires sent out, 236 were returned filled out and 28 were returned to sender. The rate of return was thus 19.66%, which is sufficient for reliable analyses and attests to the good acceptance of the questionnaire.

3.2.2 Data analysis

All the analysis carried out was performed using the Statistica software and starting from a single data file. The different data collected served as a basis for different, almost systematic comparisons according to different variables: the "time they have possessed the system" variable (5, 10 or 24 months), the "gender" variable and the "age" variable (20-29, 40-59 and 60 or over). Furthermore, particular attention was paid to the distinction between users and non-users of a system. Statistical analysis was carried out by means of, depending on the case, the "t" test, Chi^2, ascending hierarchical classification analysis, and ANOVA/MANOVA, with a Post Hoc test. These different Post Hoc tests are the Fischer LSD and Scheffé tests. Preference was given to the Scheffé test, the "most severe" of them, since it ensures that the differences observed are measured with considerable statistical robustness. However, the Fischer LSD test was also used as a complement and was sometimes preferred, since it sheds light on certain interesting results. Hence, the results obtained do not have the same degree of certainty depending on the test used. The reason for this choice of analysis was to avoid the risk of ignoring some interesting trends. The same perspective was adopted as regards the value "p", on the basis of which an effect is considered significant. Starting from a value $p<08$, the result is given, although it cannot be considered to have as much interest as a result with $p<.0001$.

As far as the MANOVA tests are concerned, they yield a statistic called "Wilks' Lambda" (situated between 0 and 1). The lower this is, the stronger the effect, and a value p is associated with this statistic. One detail has absolutely to be taken into account: while, in some tables, the sum of the percentages is not equal to 100%, and while, in inferential analysis (ANOVA and Chi^2), the degrees of liberty are lower than those expected, this *is due to missing values* that are not exploitable for analytical purposes. They are not errors, therefore.

3.3 Results

3.3.1 Characteristics of the respondents

Firstly, let us analyse the composition of the population according to gender, age, time they have possessed the systems ("MV" indicates "missing values").

In Table 11, we see that nearly 20% of the respondents have possessed the systems for about five months (group 1), nearly one-third have possessed them for about 10 months (group 2) and about one-third for about 24 months (group 3). Unfortunately, about 15% of the people either did not understand the question and referred to a former vehicle (indicating the year they drove with a system for the first time), or did not reply. Thus, it will not be possible to include these 15% of replies in the analyses involving the "time they have possessed the system" variable.

It should be noted that, when one weights time of possession by removing the time during which the driver did not yet use the system, that does not alter the results of the analysis carried out with this variable at all. In effect, a very large majority of users of a system started using it in the first few days or month following its purchase (82% for the SL and 90% for the CC).

	Men	***Women***	***MV***	***Age 20-39***	***Age 40-59***	***Age 60 and over***	***MV***	***Line total***
For 5 months	15	31	0	7	27	12	0	46
%age column	22.73%	18.45%	0%	14.58%	26.47%	14.29%	0%	19.49%
For 10 months	23	54	0	22	29	26	0	77
%age column	34.85%	32.14%	0%	45.83%	28.43%	30.95%	0%	32.63%
For 24 months	20	56	2	13	33	30	2	78
%age column	30.30%	33.33%	100%	27.08%	32.35%	35.71%	100%	33.05%
Over 24 months	6	23	0	5	11	13	0	29
%age column	9.09%	13.69%	0%	10.42%	10.78%	15.48%	0%	12.29%
MV	2	4	0	1	2	3	0	6
%age column	3.03%	2.38%	0%	2.08%	1.96%	3.57%	0%	2.54%
Column total	66	168	2	48	102	84	2	236
%age table	27.97%	71.19%	0.85%	20.34%	43.22%	35.59%	0.85%	100%

Table 11: Characteristics of the sample according to gender, age and period of ownership of the systems.

As regards the gender of the respondents, it is important to discuss the over-representation of men (168, or 71%) and the under-representation of women (66, or 28%). In effect, two and a half times more men participated in the survey than women, although as many women as men were approached. Could this imbalance be due to a greater interest shown in these systems by men? Or again, does it reflect the fact that men use the family car more often than women (if a woman is officially the owner of the vehicle, that does not mean she is the main user)? One can scarcely draw any conclusion on that point. Be that as it may, from a statistical standpoint, there is no real imbalance (insignificant Chi2) as regards the breakdown by gender of the respondents in the different groups (5, 10 or 24 months). Similarly, the number of women is sufficient to enable the "gender" variable to be exploited statistically.

As far as the respondents' age is concerned, one finds a majority of people aged 40-59 (102, or 43%) and a minority of 20-39-year-olds (48, or 20%). We would point out that age was not a variable in the sampling, and as a result one cannot know whether this apparent imbalance is a faithful reflection of the age pyramid of the targeted population or is due to more psychological factors. However, since there are many more young drivers driving unequipped second-hand cars, the age distribution is nevertheless likely to be relatively close to the reality

of the targeted population as a whole. Be that as it may, from a statistical standpoint, there is no real imbalance (insignificant Chi2) as regards the breakdown by age of the respondents in the different groups (5, 10 or 24 months). Similarly, the number of 20-39-year-olds is sufficient to enable the three modes of the "age" variable to be exploited statistically.
Finally, it should be pointed out that the men in our sample are older than the women on average ($F(1; 232) = 18.88$; $p<.0001$; 55.63 years vs. 46.58 years).

3.3.2 Overall description of the system's usage

Now, let us consider the breakdown of the respondents by their gender and their age as a function of the use they make or not of each system (Table 12).

We can distinguish four groups of drivers: the "dual SL/CC users" who utilise both systems, those who use solely the CC (and do not use the SL), those who use solely the SL (and do not use the CC), and those who use neither the SL nor the CC. The group of dual users is the largest, representing 44% of the population. Conversely, those who use only the SL are the least numerous, representing only 7% of the population. There is an almost equal proportion of those who use solely the CC (25%) and those who use neither (20%). There are thus 162 CC users (69%) and 121 SL users (51%). This suggests a "system effect", with the CC being the most used.

However, one must treat this result with some caution to the extent that one finds that the men use the CC significantly more than the women (74% as against 53%; $F(1; 228) = 13.33$; $p<.0004$). Given that there are 2.5 times more men than women in our population, it is normal that the CC seems to be used more than the SL. As regards SL use, one does not find a significant difference according to the gender of the respondents.

As far as CC use in terms of age is concerned, a higher proportion of the 20-29 age group only use this system and a lower proportion are non-users than in the 40-59 and over-60 age groups. The average age of sole CC users is significantly lower than that of non-users (49.17 as against 55.92; $p<.02$) and also significantly lower than that of dual users (49.17 as against 53.71; $p<.06$), according to the Fischer LSD Post Hoc test. As regards SL use, one does not find a significant difference according to the age of the respondents.

	Women	*Men*	*MV*	*Age 20-39*	*Age 40-59*	*Age 60 and over*	*MV*	*Line total*
Dual SL/CC users	24	78	2	19	46	37	2	104
%age column	36.36%	46.43%	100%	39.58%	45.10%	44.05%	100%	44.07%
CC users who do not use the SL	11	47	0	18	22	18	0	58
%age column	16.67%	27.98%	0%	37.50%	21.57%	21.43%	0%	24.58%
SL users who do not use the CC	7	10	0	3	9	5	0	17
%age column	10.61%	5.95%	0%	6.25%	8.82%	5.95%	0%	7.20%
Those who use neither the SL nor the CC	21	27	0	6	22	20	0	48
%age column	31.82%	16.07%	0%	12.50%	21.57%	23.81%	0%	20.34%
MV	3	6	0	2	3	4	0	9
%age column	4.55%	3.57%	0%	4.17%	2.94%	4.76%	0%	3.81%
Column total	66	168	2	48	102	84	2	236
%age table	27.97%	71.19%	0.9%	20.34%	43.22%	35.59%	0.9%	100%

Table 12: Breakdown of the different user profiles by gender and age

Finally (Figure 28), there is a significant relationship between the time drivers have owned the systems and their use (Pearson Chi^2 (6) = 14.42; p<.03). The proportion of those using solely the CC rises with time (from 17% to 36%), while the number of non-users falls (from 28% to 12%).

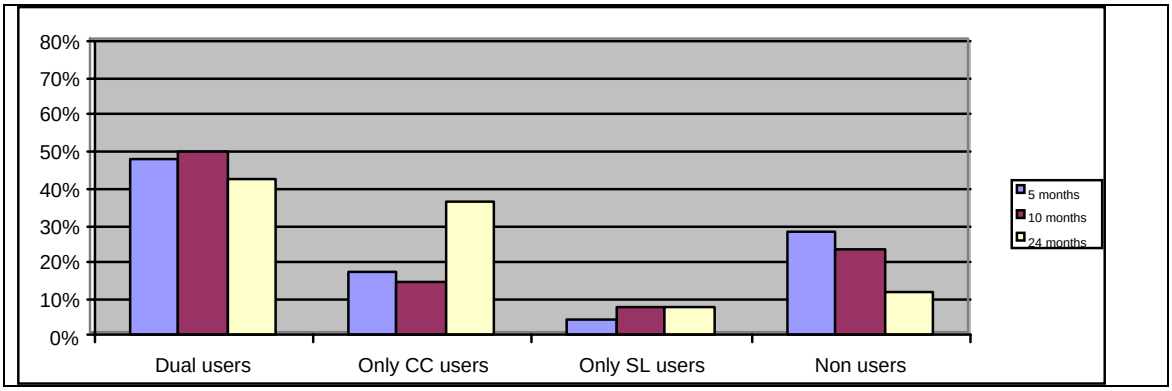


Figure 28: Proportion of different user profiles according to period of ownership

We thus have a large majority of users, whether they be "dual" users or users of only one system (179, or 76%). This fact already informs us about the overall integration of the systems in respondents' everyday driving habits. Furthermore, it gives us access to a sufficiently large number of users for making the analysis needed to study the utilisation context and the changes observed in driving behaviour. It has to be pointed out, however, that some drivers do not use either of the systems available on their vehicle (20%), while others use only one of them, either the CC (25%) or the SL (7%). There is thus a need to examine in greater detail the reasons that could account for the use or non-use of these systems. There could be a number of reasons. In particular, they could be linked to the very motives that led the drivers to acquire the systems in the first place. This is the first factor we discuss below.

3.3.3 Motives for owning the systems and their links with the use made of them

In Table 12 below, we can see in what proportions the participants selected the different "motives" from which they were able to choose freely to explain their ownership of the SL or the CC.

	SL	CC		SL	CC
Because it was standard equipment	71.19%	65.68%	To economise on fuel consumption	7.63%	11.86%
In order not to worry about police checks	20.34%	22.88%	Interest in new technology	6.78%	9.32%
For greater driving comfort	16.95%	30.93%	Because I had had the opportunity to try it earlier	6.36%	8.05%
For the assistance it provides	13.98%	13.56%	Because someone mentioned it to me	4.24%	4.24%
For greater driving safety	11.44%	12.29%	**Total**	100% (236)	100% (236)

Table 13: Frequency (%) with which the different motives for owning the systems were selected

One item in particular was selected overwhelmingly: "because it was standard equipment". Since it was a relatively factual point (the systems were effectively installed as standard equipment on the vehicles), it is not surprising that it was chosen the most frequently. The next most frequently selected options were "in order not to worry about police checks", "for greater driving comfort" and "for the assistance it provides".

The general trend is the same for the SL as for the CC, although one finds appreciable differences when one compares the frequency of the different motives given for each system. In effect, the "standard equipment" item is selected significantly more frequently for the SL than for the CC (66% as against 71%; $t = 2.83$; $p<.006$), while comfort is selected more for the CC than the SL (31% as against 17%; $t = 4.43$; $p<.0001$) and fuel savings also more for the CC than the SL (12% as against 8%; $t = 2.26$; $p<.03$).

There are thus variations as regards drivers' expectations about each system. Drivers seem to have relatively more expectations ("comfort" and "savings") about the CC than the SL. All these factors may constitute potential motives for using a system or not.

3.3.3.1 Motives for owning the SL and their links with its use

A MANOVA (Multiple ANalysis Of VAriance) with SL use (yes vs. no) and CC use (yes vs. no) as independent variables and the nine items relating to the **SL** as dependent variables shows a simple SL effect (Wilks' Lambda = 0.85; $p<.0001$). One finds differences between SL users and non-users for the items "standard equipment" ($F(1; 221) = 3.73$; $p<.06$), "safety" ($F(1; 221) = 11.63$; $p<.0008$), "comfort" ($F(1; 221) = 11.80$; $p<.0008$), "assistance" ($F(1; 221) = 20.59$; $p<.0001$), "police checks" ($F(1; 221) = 7.71$; $p<.006$) and " fuel savings" ($F(1; 221) = 9.93$; $p<.002$).
These results (Figure 37) indicate a relationship between existing expectations about a system and its use or non-use. For example, SL users (dual users as well as SL only users) cite "so as not to worry about police checks", "for greater driving comfort", "for the assistance it provides", "for greater driving safety" and "to make fuel savings" as motives far more often

than non-SL users (those who use only the CC and those who use neither the SL nor the CC). Furthermore, dual users mention the fact that the SL was standard equipment far less than the other three groups.

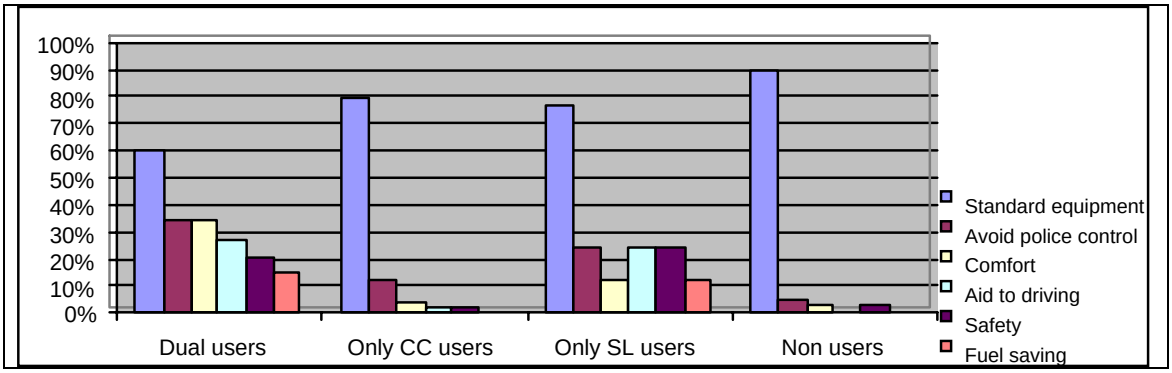


Figure 29: Frequency (%) with which motives for owning the SL was cited according to the profile of the user

3.3.3.2 Motives for owning the CC and their links with its use

A MANOVA with SL use (yes vs. no) and CC use (yes vs. no) as independent variables and the nine items concerning the **CC** as dependent variables shows a simple CC use effect (Wilks' Lambda = 0.79; p<.0001) on the reasons given for owning a CC. Differences were observed between CC users and non-users for the items "standard equipment" (F(1; 220) = 25.63; p<.0001), "safety" (F(1; 220) = 7.18; p<.008), "comfort" (F(1; 220) = 33.32; p<.0001), "assistance" (F(1; 220) = 10.99; p<.002), "police checks" (F(1; 220) = 25.44; p<.0001), "fuel savings" (F(1; 220) = 6.89; p<.01) and "had previously tried it" (F(1; 220) = 7.03; p<.009).

One also finds a relationship between the motives for owning a system (the "expectations") and its use or non-use (Figure 38). Users of the CC (both dual users and CC only users) choose the motives "so as not to worry about police checks", "for greater driving comfort", "for the assistance it provides", "for greater driving safety", "to save on fuel" and "because I had previously had the opportunity to try it" far more than non-CC users (SL only users or users of neither). Furthermore, non-CC users choose the option "because it was standard equipment" far more than CC users.

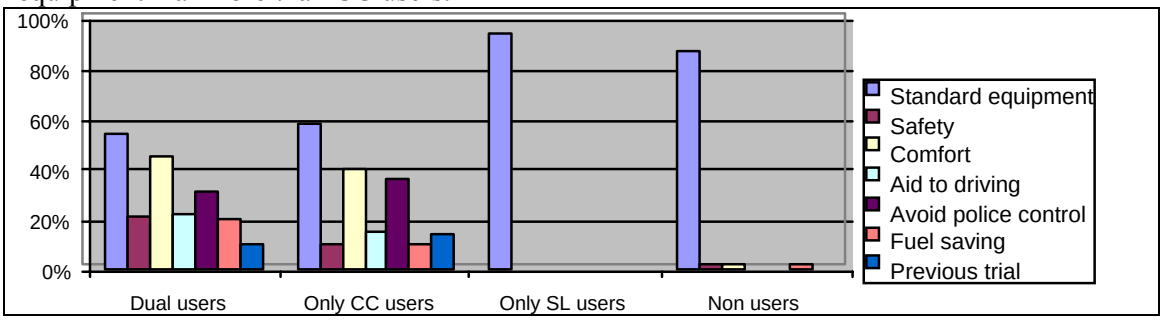


Figure 30: Frequency (%) with which motives for owning the CC was cited according to the profile of the user

Apart from the fact that the systems were standard equipment, it emerges that the most frequently cited motives for owning a system are comfort, not having to worry about police checks, a driving aid and safety. It appears that the greatest expectations surround the CC. Furthermore, the motives put forward relate to the use or non-use of the systems. The users of

the systems are more likely to give reasons of a functional nature (comfort, driving aid, fuel savings, and so on), while non-users are more likely to mention the fact that the system is standard equipment. Other elements in the questionnaire will enable us to deepen the analysis. We will firstly examine the reasons mentioned by drivers to account for their non-use of the systems, and then examine the characteristics (positive or negative) they impute to these systems (the "image" they have of support systems).

3.3.4 The reasons for not using the driving support systems

3.3.4.1 The reasons for not using the SL

Table 29 below shows in what proportions the participants selected the different "reasons" proposed to explain their non-use of the SL. It breaks the subjects down between men and women and according to three age brackets. Participants were allowed to choose as many reasons as they wanted.

Overall, the three main reasons given for not using the SL are "I prefer to adjust my speed myself", "I don't find it useful" and "I find it dangerous".

There is only one significant difference between men and women to take note of. It concerns the item "I don't know how to use it" ($F(1; 85) = 9.27$; $p<.004$). There are thus more women (19%) than men (3%) saying they do not use the SL because they do not know how to use it. There are no significant differences in terms of respondents' age

For the SL	Female non-users	Male non-users	Non-users aged 20-39	Non-users aged 40-59	Non-users aged 60 and over	Total
Prefer to adjust my speed myself	56.25%	52.63%	54.17%	54.55%	52.50%	53.70%
Not useful	15.63%	28.95%	25%	29.55%	20%	25%
Dangerous	21.88%	21.05%	20.83%	22.73%	20%	21.30%
Too constraining	6.25%	13.16%	16.67%	9.09%	10%	11.11%
Prefer to adjust my speed to that of others	9.38%	9.21%	12.50%	9.09%	7.50%	9.26%
I don't know how to use it	18.75%	2.63%	4.17%	11.36%	5%	7.41%
No one explained to me how it works	9.38%	2.63%	0%	2.27%	10%	4.63%
Too unpleasant	6.25%	3.95%	0%	6.82%	5%	4.63%
Too hard to use	0%	5.26%	0%	4.55%	5%	3.70%
There aren't any radars where I drive	0%	0%	0%	0%	0%	0%
	29.63% (32)	70.37% (76)	22.22% (24)	40.74% (44)	37.04% (40)	100% (108)

Table 14: Frequency (%) with which the different reasons were given for not using the SL, according to gender and age

3.3.4.2 The reasons for not using the CC

The three main reasons advanced for not using the CC are similar to those for not using the SL (Table 15). There is only one significant difference between men and women. It relates to the item "dangerous" ($F(1; 47) = 3.58$; $p<.07$). There are thus relatively more women (43%) than men (19%) who say they do not use the CC because they think it is dangerous.

In terms of the participants' age, one finds two significant differences. They relate to the items "dangerous" ($F(1; 46) = 3.37$; $p<.05$), which the 40-59 age group choose significantly more than the over-60s (de Scheffé Post Hoc test; $p<.05$), and "unpleasant" ($F(1; 46) = 3.09$; $p<.06$), which the 40-59-year-olds also select significantly more than that over-60s (de Scheffé Post Hoc test; $p<.02$).

For the CC	Female non-users	Male non-users	Non-users aged 20-39	Non-users aged 40-59	Non-users aged 60 and over	Total
Prefer to adjust my speed myself	43,33%	41,67%	30%	40,63%	50%	42,42%
Dangerous	43,33%	19,44%	20%	43,75%	16,67%	30,30%
Not useful	20%	22,22%	30%	18,75%	20,83%	21,21%
I don't know how to use it	20%	5,56%	20%	9,38%	12,50%	12,12%
No one explained to me how it works	13,33%	8,33%	0%	6,25%	20,83%	10,61%
Too unpleasant	10%	5,56%	0%	15,63%	0%	7,58%
Prefer to adjust my speed to that of others	6,67%	5,56%	0%	3,13%	12,50%	6,06%
Too constraining	3,33%	8,33%	0%	12,50%	0%	6,06%
Too hard to use	3,33%	5,56%	0%	6,25%	4,17%	4,55%
There aren't any radars where I drive	0%	2,78%	0%	0%	4,17%	1,52%
	45,45% (30)	54,55% (36)	15,15% (10)	48,48% (32)	36,36% (24)	100% (66)

Table 15: Frequency (%) with which the different reasons were given for not using the CC, according to gender and age

It should also be noted that there is no "reason" that is selected significantly more for one system than for the other. One should also note that the reasons advanced to explain the non-use of the systems (SL and CC) do not vary according to the period of ownership of the system.

3.3.4.3 Characteristics imputed to the support systems by non-users

To complete the analysis, one can also take into account the answers given by non-users of the two systems when they have to select the characteristics of each system from a list of possibilities (for more information about the method see Abric, 2003). Nine characteristics were proposed, and respondents had to indicate the three most relevant, then the three least relevant to describe what they think of each system (three characteristics remained unselected). If one studies Table 16 below, one finds that non-users of the systems are generally not in agreement with the positive characteristics proposed and far more in agreement with some of the negative ones.

The most interesting answers to explain non-use of the SL and the CC are the rejection of the notion that they are an "aid to driving" and a factor of "safety" and the agreement shown with the notion that they represent a "loss of control over the vehicle" and that they are a "factor of monotony" when driving. Similarly, the idea of "constraint" receives a substantial measure of agreement, while those of "peace of mind when driving", an "economy" factor and "peace of mind vis-à-vis police checks" do not attract much support.

		Non-users' answers	For the SL	For the CC
Positive characteristics	Driving aid	**NO**	**41.67%**	**35.42%**
		YES	27.08%	16.67%
	Factor of safety	**NO**	**27.08%**	**33.33%**
		YES	18.75%	12.50%
	Peace of mind when driving	NO	20.83%	27.08%
		YES	37.50%	33.33%
	Fuel savings	NO	14.58%	14.58%
		YES	35.42%	27.08%
	Peace of mind vis-à-vis police checks	NO	16.67%	16.67%
		YES	37.50%	29.17%
Negative characteristics	Loss of control over the vehicle	NO	25%	25%
		YES	**43.75%**	**54.17%**
	Factor of monotony	NO	16.67%	16.67%
		YES	**43.75%**	**54.17%**
	Constraining	NO	37.50%	29.17%
		YES	35.42%	37.50%
	Loss of freedom	NO	39.58%	43.75%
		YES	14.58%	20.83%

Table 16: Frequency (%) with which non-users select or reject the different characteristics proposed

Some important reasons for not using the systems were identified ("I prefer to adjust my speed myself", "not useful" and "dangerous"), and differences were also found between men and women. Non-users generally consider that the systems result in a loss of control over the vehicle, are a factor of monotony and are not an aid or a safety factor.

3.3.5 Using the driver support systems

Several aspects of the use of driver support systems were examined. We will tackle in order the characteristics imputed to the systems by users, then drivers' familiarisation with and integration of support systems, and after that we will deal with the changes in behaviour engendered by the systems. The context in which they are used will also be analysed, after which several comparisons between the systems will be discussed

3.3.5.1 Characteristics imputed to the support systems by users

We saw above that users of the systems are more likely to mention reasons of an operational nature than non-users to account for their ownership of support systems. As in the case of non-users, we rounded off the analysis by taking account of the characteristics that users impute to the system. Table 17 below shows the frequency with which the different characteristics mentioned above are selected or rejected.

Users overwhelmingly agree with the positive characteristics proposed (Table 17). Among them, the most frequently selected are "peace of mind when driving" and "peace of mind vis-à-vis police checks". Mirroring these replies, the negative characteristics were equally strongly rejected, especially "loss of freedom" and "constraining". The reasons that could explain the use of the SL and the CC are thus identified more clearly: driving aids are perceived by users as factors of "peace of mind", whether in relation to police checks or by relieving them of concerns about control over their speed.

		Users' answers	for the SL	for the CC
Positive characteristics	Driving aid	NO	9.09%	5.42%
		YES	**50.41%**	**56.63%**
	Factor of safety	NO	13.22%	16.87%
		YES	**41.32%**	**31.33%**
	Peace of mind when driving	NO	0%	2.41%
		YES	**83.47%**	**83.73%**
	Fuel savings	NO	14.05%	11.45%
		YES	**36.36%**	**43,37%**
	Peace of mind vis-à-vis police checks	NO	4.96%	6.02%
		YES	**73.55%**	**59.04%**
Negative characteristics	Loss of control over the vehicle	**NO**	**57.85%**	**53.61%**
		YES	4.96%	7.83%
	Factor of monotony	**NO**	**39.67%**	**27.71%**
		YES	7.44%	16.27%
	Constraining	**NO**	**56.20%**	**72.89%**
		YES	2.48%	1.20%
	Loss of freedom	**NO**	**75.21%**	**75.90%**
		YES	0%	0%

Table 17: Frequency (%) with which users select or reject the different characteristics proposed

3.3.5.2 Familiarisation with and integration of the support systems

Using a system necessitates a prior phase of familiarisation with the way it operates. It is thus important to find out the relative frequency with which different methods of familiarisation with the SL and CC were used. Four methods were proposed: reading the instructions, having its use explained by a salesman, having it explained by a friend, and trying it alone to discover how the system operates before starting to use it. Participants were asked to indicate which familiarisation methods concerned them. We could then study the relative frequency with which SL and CC users were exposed to these different familiarisation methods.

It emerges that about 66% of users say they had the system explained to them by a salesman. This seems to be the most common familiarisation method, and as a result it is extremely important when it comes to the future use of the systems. More than half of users say they did not read the manual. Next come those who think they have learned how the system operates by trying it alone – they represent between 40% (SL) and 45% (CC). Lastly, the most infrequently used familiarisation method is to have the system explained by a friend.

- Apart from these general trends, there are differences according to gender. In the case of both systems, women have had the system explained by a friend far more frequently than men (SL: 26% as against 3%; $F(2; 116) = 15.01$; $p<.0002$; CC: 31% as against 5%; $F(2; 162) = 20.10$; $p<.0001$).

- There are also differences according to age. For both systems, those in the 20-39 age range are the ones who read the instruction manual least (SL: $F(2; 115) = 3.50$; $p<.04$; CC: $F(2; 161) = 4.06$; $p<.02$). In the case of the SL, a Scheffé Post Hoc test shows a significant difference between the age group and the others (26% as against 41% for the 40-59 group and 55% for the over-60s.), while for the CC 20-39-year-olds stand out only in relation to the over-60s (27% as against 38% for the 40-59 age group and 57% for the over-60s).

- There are no differences between the three categories of the "period of ownership" variable as regards the frequency with which the different methods of familiarisation are used, whether it be the SL or the CC.

Several questions were asked about the ease of learning, the ease of use, and the time to adapt that proved necessary in order to be at ease with the system, as well as about their perceived mastery of the system and their experience of being surprised or scared when driving with the system. The Table 18 below summarizes the frequency with which respondents chose the different possible answers to each question for each system.

From a global standpoint, the SL and CC are perceived as easy to learn and use, as requiring little time to adapt and as systems in which drivers feel they acquire considerable proficiency. For the majority of users, neither the SL nor the CC seem to induce situations of surprise or fear. One may thus conclude that most users perceived that they successfully integrate the support systems into their realm of competence.

		SL	**CC**
Ease of learning process	Easy	50.41%	55.42%
	Quite easy	43.80%	39.16%
	Quite difficult	3.31%	2.41%
	Difficult	0.83%	1.20%
Ease of use	Easy	55.37%	55.42%
	Quite easy	38.02%	38.55%
	Quite difficult	4.96%	4.82%
	Difficult	0%	0%
Time to be at ease	From the first use	30.58%	25.30%
	After using it several times	57.85%	65.06%
	After using it many times	6.61%	5.42%
	I still don't feel at ease	4.13%	3.61%
Proficient?	No	4.96%	0.60%
	To some extent	50.41%	46.99%
	Yes	43.80%	51.20%
Frequency with which surprised	Never	46.28%	36.14%
	On the first occasions I used it	34.71%	39.16%
	Sometimes	16.53%	22.29%
	Each time I use it	1.65%	0%
Frequency with which scared	Never	75.21%	56.63%
	On the first occasions I used it	10.74%	28.92%
	Sometimes	11.57%	13.25%
	Each time I use it	0.83%	0%

Table 18: Perceived ease with which systems are assimilated

Whether it be in terms of ease of learning, ease of use, time to adapt or the feeling of surprise experienced when driving with the system, there is no significant difference between the SL and the CC. But there is a significant difference between them when it comes to the "fear" item ($t = 1.93$; $p<.06$), in the sense that there seems to be a greater tendency for fearful situations to be experienced when driving with the CC than with the SL. There is also a difference as regards perceived proficiency ($t = 1.81$; $p<.08$), insofar as drivers feel they become more proficient with the CC than the SL.

In the case of the SL, there is a relationship between the familiarisation methods used and the perceived ease of learning to use it. The fact of having read the manual effectively facilitates the learning process ($F(1; 111) = 8.48$; $p<.005$), as does the fact of having had the system explained by the salesman ($F(1; 111) = 5.08$; $p<.03$), and of having tried it alone to find out how the system works before using it ($F(1; 111) = 6.20$; $p<.02$). As regards the CC, the reading the manual, having the system explained by the salesman and trying it to find out for oneself how it works ($F(1; 156) = 4.7$; $p<.04$) has an interactive effect on the user's perceived proficiency with the CC. It appears that those who tried the system to discover how it works after having it explained by the salesman claim a greater degree of proficiency than those who only read the manual before using it (Fischer LSD, $p<.02$).

There was no significant effect in the "period of ownership" variable. On the other hand, differences by gender and age should be mentioned.

- As regards the SL, women report a lower degree of proficiency than men (35% as against 47% think they are very proficient; $F(1; 115) = 3.56$; $p<.07$) and a larger number of fearful experiences (19% as against 8%; $F(1; 115) = 3.50$; $p<.07$).

- In the case of the CC, women consider the learning process more difficult than men (11% as against 2%; $F(1; 157) = 5.27$; $p<.03$) and have less of an impression of proficiency (36% as against 55% feel they are perfectly proficient; $F(1; 157) = 5.62$; $p<.02$).

- For the SL, fewer people in the 20-39 age group say they master the system than the other age groups (23% as against 51% of the 40-59 age group and 45% of the over-60s; $F(2; 115) = 3.02$; $p<.06$ and Fischer LSD Post Hoc test). As regards the CC, the 40-59 age group report a larger number of surprises than the 20-39 group and the over-60s (27% say they have never had a surprise as against 47% of the 20-39 group and 41% of the over-60s; $F(2; 156) = 3.54$; $p<.04$ and the Fischer LSD Port Hoc test).

The explanation provided by the salesman is the most common familiarisation method, and its importance thus has to be emphasised. Users' appropriation of the systems seems to be very satisfactory overall. Some relationships between the familiarisation methods used and the appropriation of the systems were observed in terms of the perceived ease of learning to use the SL and the perceived mastery of the CC. As a general rule, women report a relatively lower degree of appropriation of the systems than men. There were also differences in terms of respondents' age. The variable "period of ownership of the systems" was not found to have any effect.

3.3.5.3 Perceived behavioural changes when driving with the support systems

In order to assess behavioural changes when driving with the support systems twelve items were proposed to the users. They had to indicate to what extent in their view the system leads them to change their behaviour relative to driving without the system. For each item, the respondent had the possibility of saying the system led him to adopt the behaviour "more", to adopt it "less", that the system "did not change anything", or that he "doesn't know". The results are summarised in Table 19 and Table 20for SL, in Table 21 and Table 22 for the CC.

SL	Less	More	No change	I don't know
Looking at the speedometer	**71,9%**	16,5%	6,6%	0%
Level of Driving speed	**79,3%**	0,8%	12,4%	0%
Control over my driving speed	7,4%	**66,9%**	14,1%	2,5%
Effort	**47,9%**	12,4%	33,1%	0%
Attention	16,5%	27,3%	**47,9%**	0,8%
Control over my vehicle	14,9%	32,2%	**40,5%**	3,3%
An hindrance to other driver	19,8%	**26,5%**	**35,5%**	7,4%
Trouble merging into traffic	9,1%	**26,5%**	**44,6%**	7,4%
Difficulty for adjusting my speed to that of others	17,4%	**23,1**%	**45,5%**	4,9%

Table 19: Perceived behavioural changes when driving with the SL

	Yes	No	I don't know
I check the proper account of set speed by SL	**70,25%**	17,36%	4,96%
It changes the way I drive	**40,50%**	**41,32%**	10,74%
It enables me to avoid speeding fines	**75,21%**	5,79%	11,57%

Table 20: Perceived behavioural changes when driving with the SL

	Less	More	No change	I don't know
Looking at the speedometer	**74,10%**	13,25%	9,64%	0%
Driving speed	**69,88%**	3,01%	21,69%	1,20%
Control over my driving speed	8,43%	**70,48%**	15,66%	1,81%
Effort	**70,48%**	4,22%	17,47%	1,20%
Attention	16,27%	28,31%	**46,99%**	1,81%
Control over my vehicle	14,46%	33,13%	**42,77%**	3,61%
An hindrance to other driver	24,70%	**18,67%**	**40,96%**	9,04%
Trouble merging into traffic.	9,04%	**24,70**%	**50,60%**	5,42%
Difficulty for adjusting my speed to that of others	**27,11%**	**32,53%**	**31,33%**	2,41%

Table 21: Perceived behavioural changes when driving with the CC

	Yes	No	I don't know
I check the proper account of set speed	**77,11%**	13,86%	3,61%
It changes the way I drive	**57,23%**	30,72%	7,23%
It enables me to avoid speeding fines	**76,51%**	6,02%	12,65%

Table 22: Perceived behavioural changes when driving with the CC

Overall, if one considers the majority replies, the two systems are perceived as having beneficial effects as regards speed control (less need to look at the speedometer, lower driving speed, more control over driving speed, avoiding speeding fines) and effort (especially when driving with the CC). A majority also considers that using the systems does not induce major changes in the control of their vehicle and in the way they interact with other road users. However, there are large minorities reporting some negative effects, mainly as regards managing interaction with others. For example, 27% say they feel they are more of an hindrance to others and they have more difficulty merging into traffic with the SL. The same tendencies are observed with the CC.

While the two systems inspire the same majority attitudes, there are differences between the systems. Several "t" tests were carried out bringing together the replies "did not change anything" and "don't know" (the latter are very rare though). One thus finds that the SL has a greater tendency to make people drive less fast than the CC (79% as against 70%; $t = -2.24$; $p<.03$), that the SL gives more of an impression of being an hindrance to other drivers than the CC (26% as against 19%; $t = 2.74$; $p<.008$), that the SL requires a greater effort when driving than the CC (12% as against 4%; $t = 3.08$; $p<.003$) and that the CC changes people's way of driving more than the SL (57% as against 41%; $t = -2.80$; $p<.007$).

Several ANOVA were carried out with gender, age and period of ownership as independent variables. After analysis, there does not appear to be any difference according to gender in the perceived changes when driving with the SL. On the other hand, there are differences according to the age of the respondents. These differences relate to the items "speed" ($F(2; 98) = 5.27$; $p<.007$) and "control over speed" ($F(2; 98) = 3.23$; $p<.05$). In effect, different Post Hoc tests show that far fewer people in the 20-39 age group than those in the 40-59 group and the over-60s report a lower speed when driving with the SL than without. Similarly, fewer 20-39-year-olds say they have greater control over their speed compared with the other age groups (Fischer LSD).

Age Group		Less	More	Changed nothing	Don't know
Speed practised	20-39	68.18%	4.55%	27.27%	0%
	40-59	89.09%	0%	7.27%	0%
	60 and over	73.81%	0%	9.52%	0%
Feeling of control over speed	20-39	13.64%	45.45%	27.27%	4.55%
	40-59	7.27%	76.36%	12.73%	1.82%
	60 and over	2.38%	66.67%	9.52%	2.38%

Table 23: Differences according to age as regards reported changes with the SL

As far as the "period of ownership of the systems" variable is concerned, one finds only one significant difference regarding the item "it changed my way of driving" for the SL ($F(2; 87) = 2.78$; $p<.07$). A Fischer LSD Post Hoc test shows that drivers that have had the system for

five months differ from the other two groups since they are far more likely to say that the SL changed their way of driving.

With the CC, in terms of the respondents' gender, one finds differences for the item "difficulties merging into traffic" ($F(1; 138) = 8.41$; $p<.005$). Women are more likely than men to report that the CC makes it harder for them to merge with traffic.

		Less	More	Changed nothing	Don't know
Difficulties merging	Men	11.11%	2.78%	61.11%	11.11%
	Women	8.59%	30.47%	47.66%	3.91%

Table 24: Differences according to gender as regards reported changes with the CC

No significant differences as regards reported changes with the CC or the SL are found as a function of the period of ownership of the systems.

For most users, the two support systems seem to induce positive changes as regard speed control and effort. A majority also considers that using the systems does not induce other major changes in their driving. However, there are large minorities reporting some negative effects, mainly as regards managing interaction with others. While the two systems seem to have the same effects generally speaking, there are nevertheless differences between them: for instance, the SL seems to have a better impact in terms of reducing speed, but also seems to induce more negative effects in some drivers (greater effort and bigger hindrance for others). As regards the CC, there were differences between women and men and according to age, but only as a function of age in the case of the SL. The period of ownership of the systems does not seem to have any appreciable impact on perceived changes.

3.3.5.4 Situations in which the systems are used

To study the frequency of use of the systems according to different driving situations, users of a system were presented with 24 cases for which they had to answer "never" (answer coded 1), "sometimes" (answer coded 2), "often" (answer coded 3) or "always" (answer coded 4). For the 24 different driving situations proposed, we arrived at a frequency-of-use score on a scale of 1 to 4. The 24 situations were generated by crossing the type of road (urban, rural roads and motorways) with eight other sets of conditions (driving alone, with one or more passengers, in heavy traffic, in fluid traffic, at night, during the day, in fine weather and in bad weather). Eight cases in point were thus postulated for each type of road.

- Situations in which the SL is used

By calculating the average frequency of use in each situation for users of the SL, this is what we find. The 24 situations are shown on the horizontal axis and the scale from 1 to 4 on the vertical axis.

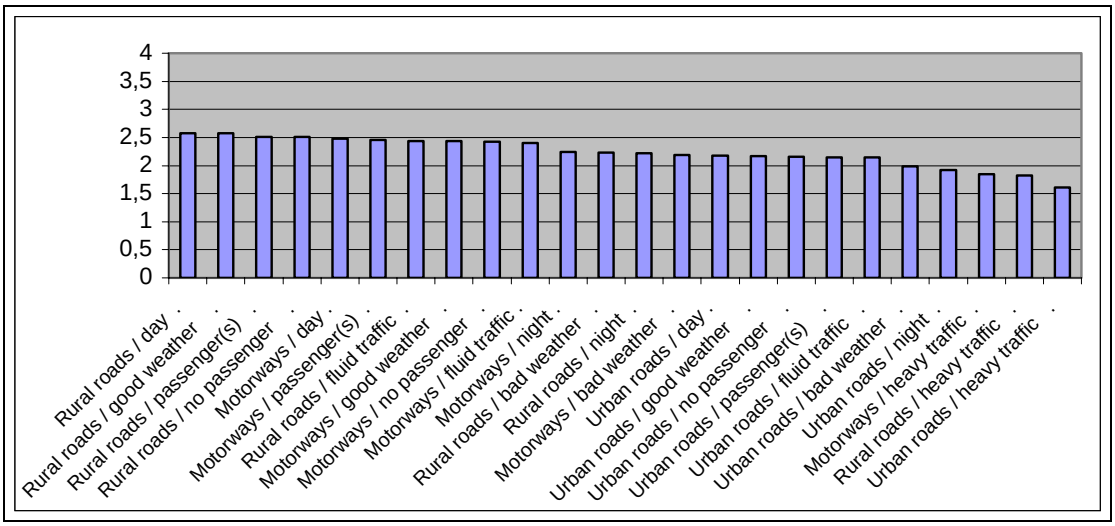


Figure 31: Average frequency of use of the SL according to the situation.

The majority of averages are closer to the answer "sometimes" (apart from the four situations on the left of the chart). On average, the SL thus seems to be used occasionally. Furthermore, there is very little variation in use according to the situation.

If, however, one wants to analyse the variations in the use of the SL, it is possible to carry out an ascending hierarchical classification analysis. This type of analysis makes it possible to classify the different measures according to the proximity or distance between them. Here, this analysis enables us to produce a typology of situations of use, as well as to identify the varying measures together.

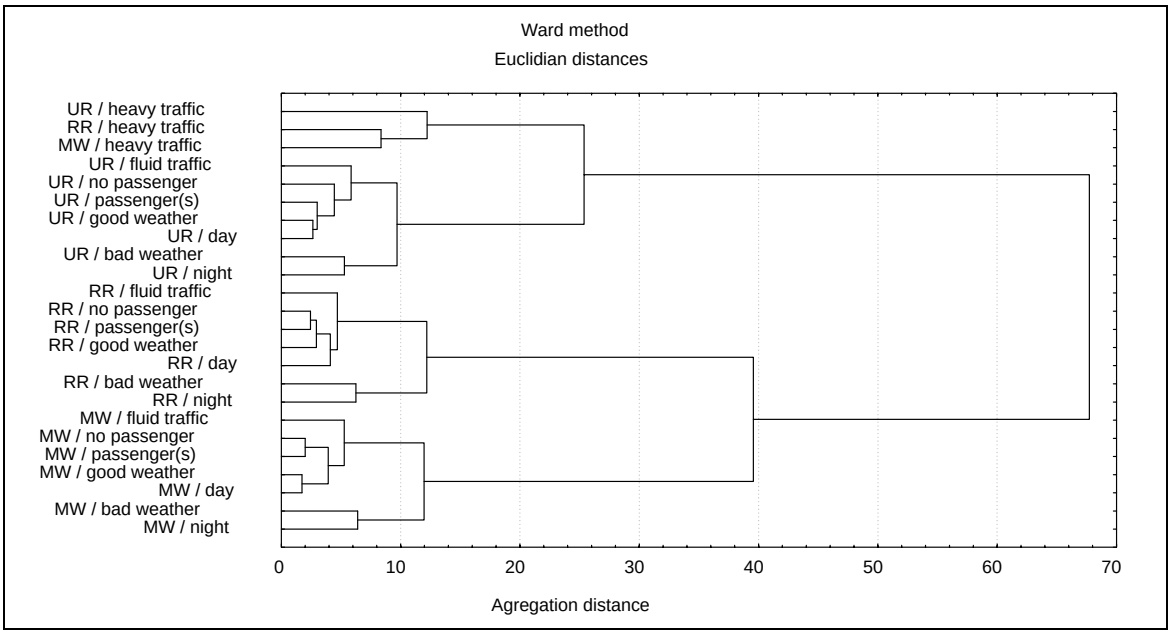


Figure 32: Classification of the situations in which the SL is used (UR = urban roads; RR = rural roads; MW = motorways)

Starting from the right side of the chart, one observes an initial difference with, on the top side all the "urban" driving situations as well as the three situations of "heavy traffic" and on the bottom, the majority of cases concerning driving on "rural roads" and "motorways". We thus have the class of the least propitious situations for SL use (in town and/or in heavy traffic) and.the class of situations that are most propitious for using the SL (generally on "rural roads" and "motorways", except in heavy traffic). Then, if one wants to be more precise, one takes account of the sub-classes. For example, in the class of the most propitious situations, one can distinguish between "motorway" situations and "rural road" situations, the latter being those where the SL is used the most (cf. Figure 32). One can also carry out the same exercise for the class of least propitious situations, where one finds that "urban" driving situations differ from "heavy traffic" driving situations, the latter being those in which the SL is used the least. If one narrows things down even further, one sees that the situations of poor visibility ("night-time" and "bad weather") systematically stand out among the situations relating to the same type of road. In effect, apart from the situations of heavy traffic, these two are always the two situations in which the SL is systematically used less frequently compared with other situations on the same types of road. Hence, the situations "rural roads at night" and "rural roads in bad weather" are those in which the SL is used least on "rural roads". It should be noted that; in the case of the situations "urban roads in heavy traffic", "rural roads in heavy traffic" and "motorways in heavy traffic", it is not the type of road that is important here but the fact that the traffic is heavy. To sum up this kind of analysis enables to identify the main criteria that differentiate the frequency of use of the SL, namely, the type of road and the traffic condition followed by the visibility condition. The presence of passager does not seem to be discriminative.

The frequency of use of the SL varies as a function of drivers' gender, but not as a function of their age. One sees differences between men and women as regards the frequency of SL use according to the driving situation. In particular, one finds that the frequency of SL use reported by women is significantly lower than that of men on urban roads and motorways, regardless of the driving situation (Figure 33 and Figure 34).

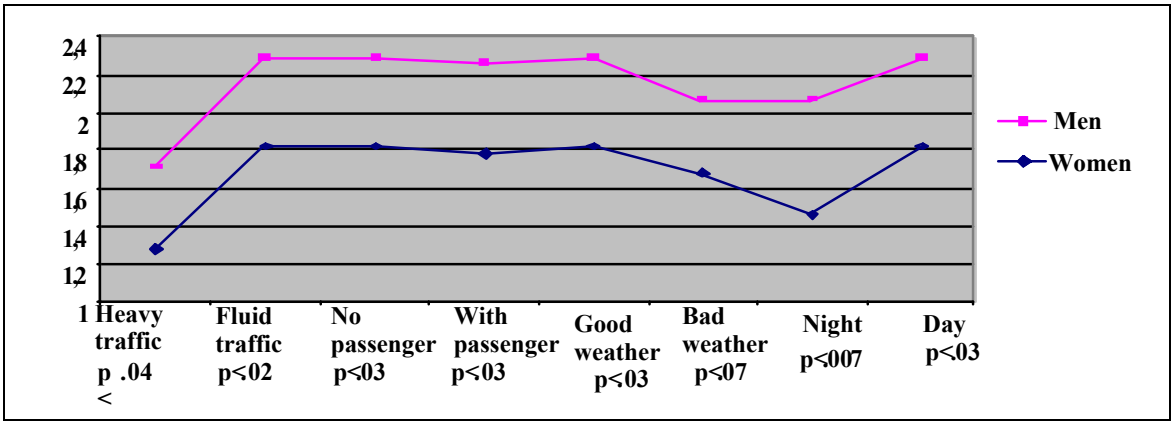


Figure 33: Average frequency of use of the SL on urban roads according to gender

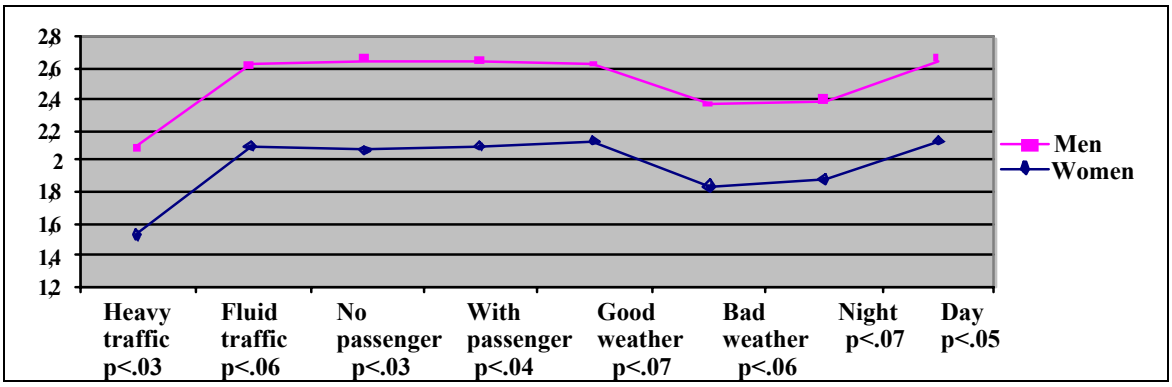


Figure 34: Average frequency of use of the SL on motorways according to gender

- Situations in which the CC is used

Things appear quite different with the CC compared with the SL. The use of the CC seems to be influenced far more by the driving situation. Generally speaking, these variations are mainly due to the type of road. Let us look at what the following ascending hierarchical classification analysis yields.

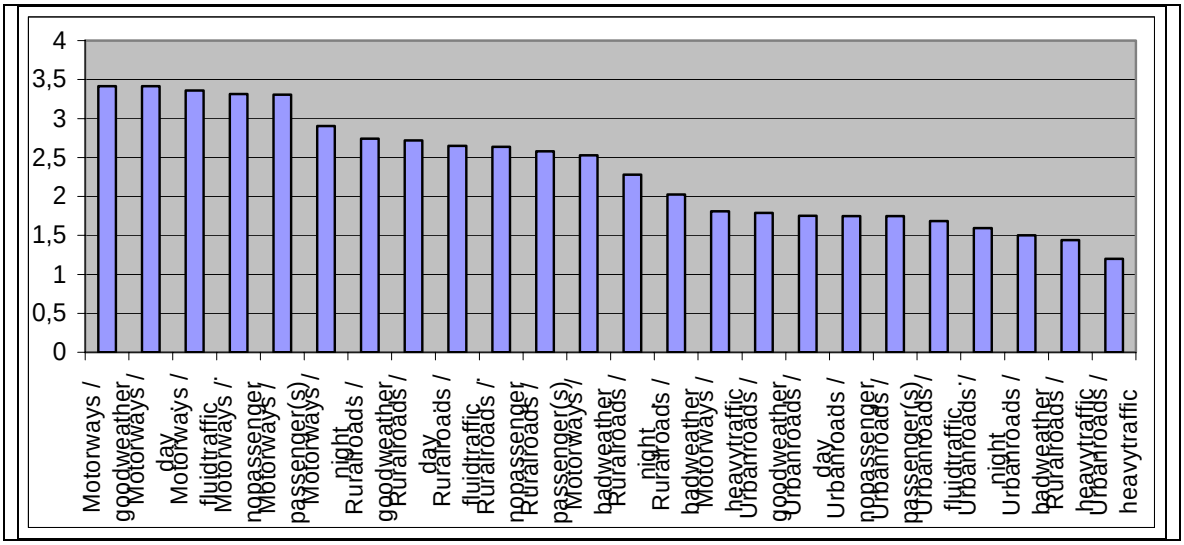


Figure 35: Average frequency of use of the CC according to the situation

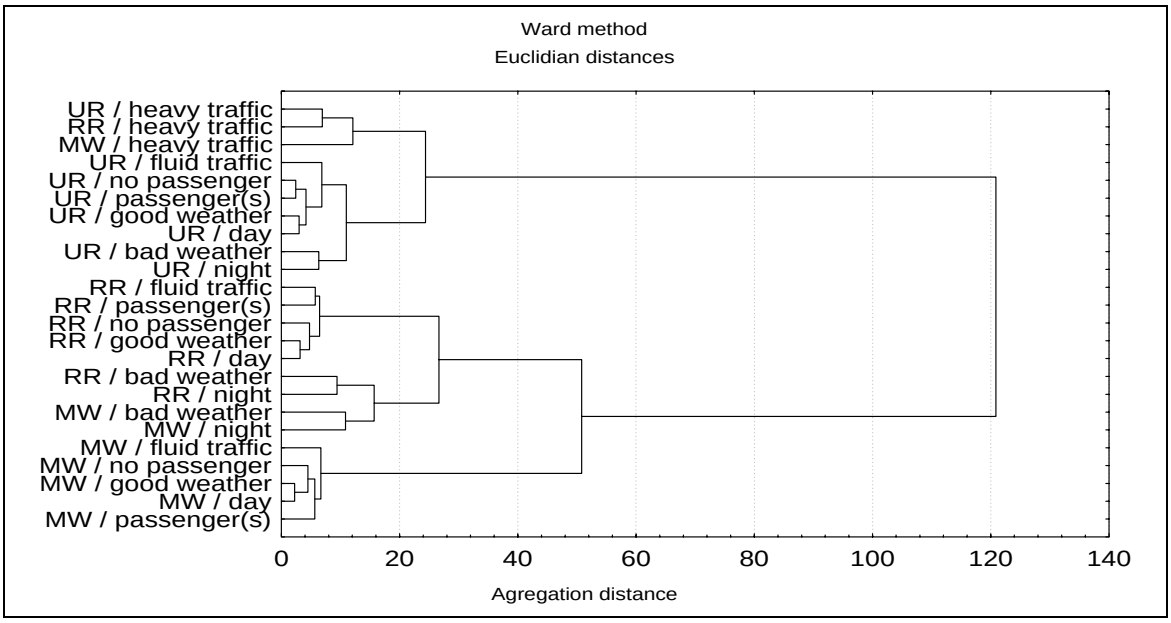


Figure 36: Classification of the situations in which the CC is used (UR = urban roads; RR = rural roads; MW = motorways)

Starting from the right of the chart, the first difference one finds is identical to that found with the use of the SL. There is a sharp distinction between the large majority of "rural road" and "motorway" situations, which are in the bottom class, and the "urban road" and "heavy traffic" situations, which are in the top class. While in the top-hand class one then finds the same sub-classes as those found for the SL, that is not the case of the bottom-hand sub-classes. One finds first and foremost a difference between, on the one hand, "motorway" situations in conditions of good visibility and fluid traffic and, on the other, "rural road" situations and "motorway" situations with poor visibility. To be more precise, in this last sub-class one can single out conditions of poor visibility (night-time, bad weather), whatever the type of road (rural roads and motorways), and "rural road" situations in conditions of good visibility and fluid traffic. Once again, one can produce a hierarchy of the different utilisation criteria. The first and most important criterion is the type of road. The second criterion seems to be the state of the traffic. The third criterion is visibility.

As for the variables that interest us (age, gender and period of ownership of the systems), they do not have a significant impact on the use of the CC.

Finally, when one compares the average frequency of SL and CC use for each type of road (by adding up the answers by type of road divided by eight), one finds that the SL is used significantly more frequently on urban roads than the CC ($t = 3.31$; $p<.002$) and the latter is used significantly more frequently on motorways than the SL ($t = 5.24$; $p<.0001$). On rural roads, the two systems are used as much as each other on average.

The results confirm the influence of the situational context (type of road, traffic conditions and visibility conditions) on the frequency of use the support systems. They also reveal differences between SL and CC. Firstly, the CC seems to be used more often than the SL overall and its use seems more subject to variations according to the situation. A hierarchical classification of these situations enables different criteria influencing the use of each system to be identified. Age and the period of ownership of the systems do not seem to have an influence on the use of the systems. Gender only has an effect on the use of the SL on urban roads and motorways. Overall, the SL is generally used more on urban roads than the CC

and the latter is used more frequently on motorways than the SL. On rural roads, there is no significant difference in the frequency with which the SL and the CC are used.

3.3.5.5 Inter-system comparisons and relationships as perceived by dual users

Dual users (those who use CC **and** SL) were asked to answer various questions dealing with the comparison between the systems. Table 25 summarises the results. If one takes only the majority answers, the CC appears as the most useful (47%), the most appreciated (61%) and the one that most changes driving behaviour (44%). However, a majority of respondents trust the two systems equally (51%).

The most useful?	SL	17.31%	Changes driving behaviour?	SL	14.42%
	CC	47.12%		CC	44.23%
	Neither	0.96%		Neither	22.12%
	Both	32.69%		Both	15.38%
The most appreciated?	SL	14.42%	Complementary?	No	12.50%
	CC	61.54%		Don't know	9.62%
	Neither	0%		Yes	75.96%
	Both	21.15%	Confusion in the past?	No	76.92%
The most trusted?	SL	15.38%		Yes	20.19%
	CC	28.85%	If yes, still going on?	No	85.71%
	Neither	2.88%		Yes	14.29%
	Both	50.96%	Switching between the systems?	Never	29.81%
				Sometimes	52.88%
				Frequently	7.69%

Table 25: Answers given (%) to questions about comparisons and relationships between the systems

Overall, these results illustrate a preference for the CC, but without showing any rejection for the SL, which probably seems less "attractive" for dual users. This point is confirmed by the fact that 76% consider them complementary, as against 13% who do not agree with this idea and the fact that 70% switch between the systems (sometimes or frequently).

The preference for CC possibly highlights a relationship between the degree to which "driving behaviour is changed" and measures of usefulness and preference. This point is confirmed solely as regards usefulness. In effect, there is a relationship between the answers to the question "Which system changed your driving the most?" and that given to the question "Which system is the most useful in your driving?" (Chi^2 (9) = 16.93; $p<.05$). The system perceived as changing driving behaviour the most is regarded as the most useful more often than when it is not considered to have altered driving behaviour the most.

It should also be noted that the answer "neither" is never given by more than 3% of respondents for the items "usefulness", "trust" and "appreciation". More than three-quarters of respondents (77%) say they have not confused the two systems when driving as against about 20% who have, while very few of the latter say they still confuse them (14%, or 3% of dual users as a whole). One does not find any differences according to the gender and age of the respondents, nor in terms of the period of ownership (exept for the item “confusion” which diminish with time)

The CC generally seems to be the system that dual users prefer. Nevertheless, the SL is not rejected insofar as a majority of respondents have as much trust in it as in the CC and a majority also sees the two systems as complementary. The fact of perceiving one system to be the one that modifies driving behaviour the most seems to have an influence on which will be perceived as the most useful. This result suggests a relationship between the perceived change in driving behaviour and the usefulness of the system. The number of dual users saying they have confused the two systems is low and falls over time.

3.3.6 Acceptance of the support systems in the next vehicle

This part falls slightly outside the framework of the principal objectives of this research. Nevertheless, in view of the particularly clear and illustrative results produced, it is interesting to dwell on them for a moment. The table below crosses the different user profiles (dual SL/CC users, SL only users, CC only users, and users of neither) with the degree of latters' acceptance of these systems in a future vehicle. All participants were asked to indicate whether they would like their next vehicle to be equipped at no extra charge with just a SL, with just a CC, with both systems or with neither. The results are summarised in Table 26 below.

	Dual users	CC only users	SL only users	Non-users	Total
Only accept the SL	5,77%	5,17%	**70,59%**	6,25%	10,17%
Only accept the CC	9,62%	**60,34%**	0%	10,42%	22,46%
Accept both	**78,85%**	34,48%	29,41%	31,25%	**52,12%**
Accept neither	2,88%	0%	0%	**43,75%**	12,29%

Table 26: Rate of acceptance of the SL and the CC as a function of the users' profile

It appears that the number of drivers who do not want either system in their next vehicle is very low (12%). The systems thus seem to be generally well accepted, and this phenomenon is even more marked in the case of the CC. There is a strong relationship between the use and acceptance of the systems (Chi^2 (16) = 220.71; p<.00001). It should be noted that the reply "both" attracted the largest number of selections (52%). Hence, even among those who are not "dual users", there were around 30% who selected this answer. This can certainly be explained by the fact that it was made clear that there would be "no extra charge", which possibly tilted respondents in favour of this answer.

It has lastly to be pointed out that the acceptance of these support systems is strongly linked to the characteristics imputed to them. In effect, one observes, for example, that among those who would agree to have a SL in their next vehicle (answers "both" and "only the SL"), 73% think it gives them "peace of mind when driving", 71% think it "enables them to avoid speeding fines" and 62% regard it as a "driving aid". Conversely, of those who would not like to have either a SL or a CC in their next vehicle, 48% regard the SL as "constraining" and a "loss of control over the vehicle", while 41% consider it a "factor of monotony".

The same phenomenon is found with the CC. Of those who would agree to have a CC in their next vehicle (answers "both" and "only the CC"), 78% think it gives them "peace of mind when driving", 58% think it "enables them to avoid speeding fines" and 53% regard it as a "driving aid". Once again, of those would not like either a SL or a CC in their next vehicle, 57% think the CC results in a "loss of control over the vehicle", while 45% consider it a "factor of monotony".

Whether it be the CC or the SL, drivers who accept only one of the two systems have "mixed" orientations towards the system they do not want to have. In effect, they do not massively reject the positive items, nor do they overwhelmingly choose the negative ones. There is no strong rejection of the unwanted system, there is more an expression of preference for one system. Only those who do not want either system have a negative image of both the SL and the CC.

There is generally strong acceptance of these support systems among the respondents. Moreover, it is strongly linked to whether they are used or not, just as it is determined by the positive or negative characteristics associated with them. Among these, "peace of mind when driving", "enables me to avoid fines", "a driving aid", "constraining", "loss of control over the vehicle" and "a factor of monotony" appeared to be particularly significant in differentiating drivers' orientation towards the systems.

3.4 Summary and conclusion

The purpose of this survey is to gauge the utilisation and long-term behavioural effects of two driver support systems that offer two complementary means of speed management: a speed limiter (SL) and a cruise control (CC). The main results of the survey are summarised and discussed below.

3.4.1 Use and non-use of the systems

The results indicate that a large majority of the respondents use at least one of the systems installed on their vehicle (76%). More specifically, four groups of drivers could be differentiated: the "dual SL/CC users", who use both systems (44%); those who use solely a CC (25%); those who use solely an SL (7%): and those who use neither the SL nor the CC (20%).

It can be seen that there are more women than men among those who use neither system (32% as against 16%) and that, overall, the CC is used more by men than by women (74% as against 53%). As far as CC use is concerned, this result is in line with the findings of a similar survey carried out as part of the Improver project (2005), which found that men are more in favour of the CC than women, both as regards having their car equipped with a CC and as regards using it once they have it in their car.

The use of the systems seems to be closely linked to drivers' "expectations" of them (gauged here through the reasons given for owning the systems) and more generally to the "image" drivers have of them.

An analysis of the motives that led drivers to acquire the systems shows that they relate to the use or non-use of the system. In particular, users of a system are more likely to give reasons

of a functional nature (comfort, driving aid, fuel savings, and so on), while non-users are more likely to mention the fact that the system is standard equipment. Some important reasons for not using the systems were identified ("I prefer to adjust my speed myself", "not useful" and "dangerous").

Significant differences were also found between men and women. In particular, more women than men state that they do not use the SL because they do not know how to use it (one observes the same trend as regard the CC, though the difference is not significant) and that they do not use the CC because they think it is dangerous.

More generally, when taking into account the “image” of support systems, one finds that non-users generally consider that the systems result in a “loss of control over the vehicle”, are a “factor of monotony” and are not “an aid” or a “safety” factor. Conversely, users of the systems overwhelmingly agree with the idea that they afford "peace of mind when driving" and "peace of mind vis-à-vis police checks" and strongly reject the idea that they induce a “loss of freedom" and are a "constraint" on driving. The same tendencies were observed when studying drivers' acceptance of the systems on their next vehicle. The “image” of the systems (whether positive or negative) is thus an important dimension to take into account for understanding the use and acceptance of support systems.

3.4.2 Familiarisation with and appropriation of support systems

Using a system necessitates a prior phase of familiarisation with the way it operates. The explanation provided by the salesman is the most common familiarisation method, and its importance thus has to be emphasised, in particular when considering that more than half of users did not read the manual. Some relationships between the familiarisation methods used and the appropriation of the systems were observed in terms of the perceived ease of learning to use the SL and the perceived mastery of the CC, reinforcing the importance of this familiarisation phase.

Overall, users' appropriation of the systems seems to be satisfactory. The SL and CC are perceived as easy to learn and use, as requiring little time to adapt, and as systems in which drivers feel they acquire considerable proficiency. For the majority of users, neither the SL nor the CC seems to induce situations of surprise or fear. One may thus conclude that most users think they successfully integrate the support systems into their field of competence.

Overall, women report a relatively lower degree of appropriation of the systems than men. They also report a larger number of fearful experiences when driving with an SL and they consider the learning process of the CC more difficult than men. Such problems probably account for the fact that they use support systems less frequently than men.

3.4.3 Frequency of use of support systems: the role of the situational context

First of all, the results confirm the influence of the situational context (type of road, traffic conditions and visibility conditions) on the frequency of use of support systems. It should be noted that the use of the CC is more subject to variations according to the situational context than the SL, which is quite pertinent considering its mode of functioning (automatically maintaining the driving speed selected by the driver). The SL is generally used more on urban roads than the CC and the latter is used more frequently on motorways than the SL. On rural

roads, there is no significant difference in the frequency with which the SL and the CC are used. Overall, women use the SL less frequently than men, especially on urban roads and motorways, regardless of the driving situation.

3.4.4 Perceived behavioural changes when using support systems

Most users think the systems provide the assistance they are designed to. For the majority of them, the two systems are perceived as having beneficial effects as regards speed control (less need to look at the speedometer, lower driving speed, more control over driving speed, avoiding speeding fines) and effort (especially when driving with the CC). A majority also considers that using the systems does not induce major changes in their driving. That said, large minorities report some negative effects, mainly as regards the management of their interactions with others (an hindrance to other drivers, trouble merging in traffic). Previous studies in real driving situations have also found this kind of limitation as regards the assistance provided (see, for example, for ISA systems, Saad et Malaterre, 1982; Carsten and Fowkes; 2000).

Some differences between the two systems were also observed: in particular, the SL seems to have a better impact in terms of reducing speed (even though this effect is less important for the 20-39 age group), but also seems to induce more negative effects in some drivers (greater effort when driving with the SL and bigger hindrance for other drivers). The CC is perceived as changing the user's way of driving more than the SL and requiring less effort than the SL.

3.4.5 Length of period of ownership of the system

There is a significant relationship between the time drivers have owned the systems and the use they make of them. The proportion of those using solely the CC rises with time (from 17% to 36%), while the number of non-users falls (from 28% to 12%). However, no significant differences were observed for the other aspects studied, in particular the frequency of use and the perceived behavioural changes. It is possible that the periods selected for the survey did not make it possible to record the moments at which significant changes occur and/or are perceived as such by drivers (in particular, the first period of 5 months is undoubtedly too long following the initial appropriation phase of the systems). It is also possible that a longitudinal approach might be more appropriate for recording the occurrence of such changes in sufficient detail.

4 On-road study on long-term effects of FCW+LDW on driving behaviour

4.1 Introduction

According to motivational models, namely *"risk homeostasis" theory* (Wilde, 1988; 1982) and *"zero-risk" theory* (Summala, 1988), any intervention into the vehicle or driving environment that does not intend to change drivers' motives will have a limited effect in time, due to behavioural adaptation. This means that learning to drive with an ADAS, without knowing in advance the potential changes of this system in drivers' motives, there is a certain risk that drivers will adapt their driving behaviour to the opposite extreme of the desired direction.

Thus, behavioural adaptation of drivers may be expected due to the introduction of ADAS. Several studies have been carried out to investigate such effects, but they are mainly conducted on a driving simulator and do not study long-term effects, namely how driving behaviour changes with long-term use of the system. Moreover, we are not aware of any long-term study having been performed, studying the simultaneous use of two ADAS, providing both longitudinal and lateral support.

Thus, the objective of the on-road study conducted by CERTH/HIT was:

- To identify the long-term effects on driving behaviour when using stand-alone and a combination of two ADAS, namely *Forward Collision Warning* – FCW - and *Lane Departure Warning* – LDW, .
- To study the possible adaptation of driving behaviour associated with the use of stand-alone and a combination of two ADAS in long-term
- To study the possible long-term impact on mental effort, due to the use of stand-alone or a combination of ADAS.
- To study how drivers' acceptance of ADAS evolves in long-term.

4.2 Method

The method of this experiment has been presented in AIDE Deliverable 1.2.3, and is thus not repeated here. Summarising it, the duration of the experiment was 15 weeks. 24 participants were distributed in four groups, those driving with the FCW system active, those driving with LDW system active, those driving with FCW+LDW systems active and the control group, where no system was active. Each participant was asked to drive once a week the equipped vehicle along the same highway route and the same day and time, so that distance travelled and exposure time to the systems tested were similar for all drivers. Only data recorded during the highway driving were analysed. Data recorded on the roads to and from the highway were excluded from the analysis. The highway route was 79 km with a speed limit of 120 km/h. duration was around 1 hour, thus each ride in the following diagrams correspond to 79 km. Each driver was asked to drive the vehicle on this specific route once a week, at the same day and time each week, so that traffic environment was kept as much as possible similar among consecutive rides.

The short-tem horizon was defined as the first five rides, namely the first five weeks. The results of the short-term period was presented in AIDE Deliverable 1.2.3.

In this document the results of the whole period of fifteen weeks are being presented, trying to identify long-term effects of systems' use.

4.3 Results

From the four groups that took part, performance in the control group could be considered as reference to the other three groups, in the sense that, participants were driving the experimental vehicle periodically, thus the driving behaviour changes in the control group represent the possible changes that might occur due to familiarization with the vehicle and the experimental process. Instead, the driving behaviour changes in the other three experimental groups represent the possible changes that might occur due to the combined effect of vehicle familiarization and the systems used. Thus, having the control group performance as reference to the other three groups, one could possibly identify possible changes within time in the three experimental groups due to the systems used.

Considering the particular driving tasks that each system is supposed to affect, namely the FCW system is supposed to affect basically the longitudinal behaviour while the LDW system is supposed to affect mainly the lateral behaviour, the effects on the measurable driving performance parameters will be presented in respect to these two aspects.

4.3.1 Speed

Starting with a rather generic driving parameter, namely the vehicle speed (Figure 37, Table 27) the results show that the mean speed in the FCW group in the total sample (15 rides) was lower than the mean speed in the control group ($p=0.0344$). There was also a trend between the LDW group and the control group ($p=0.1071$). That is to say, within a period of 15 rides driving with only one system (either FCW or LDW) there is a positive effect in terms of speed reduction. On the other hand, no difference was found between the FCW+LDW and the control group. There was an effect of ride, only in the FCW+LDW group ($p=0.061235$). Participants in the FCW+LDW group, not only used to drive at higher speed in comparison to the other two groups, but they also tended to increase their mean speed with ride. It seems as participants in FCW+LDW group intentionally drive at higher level of risk.

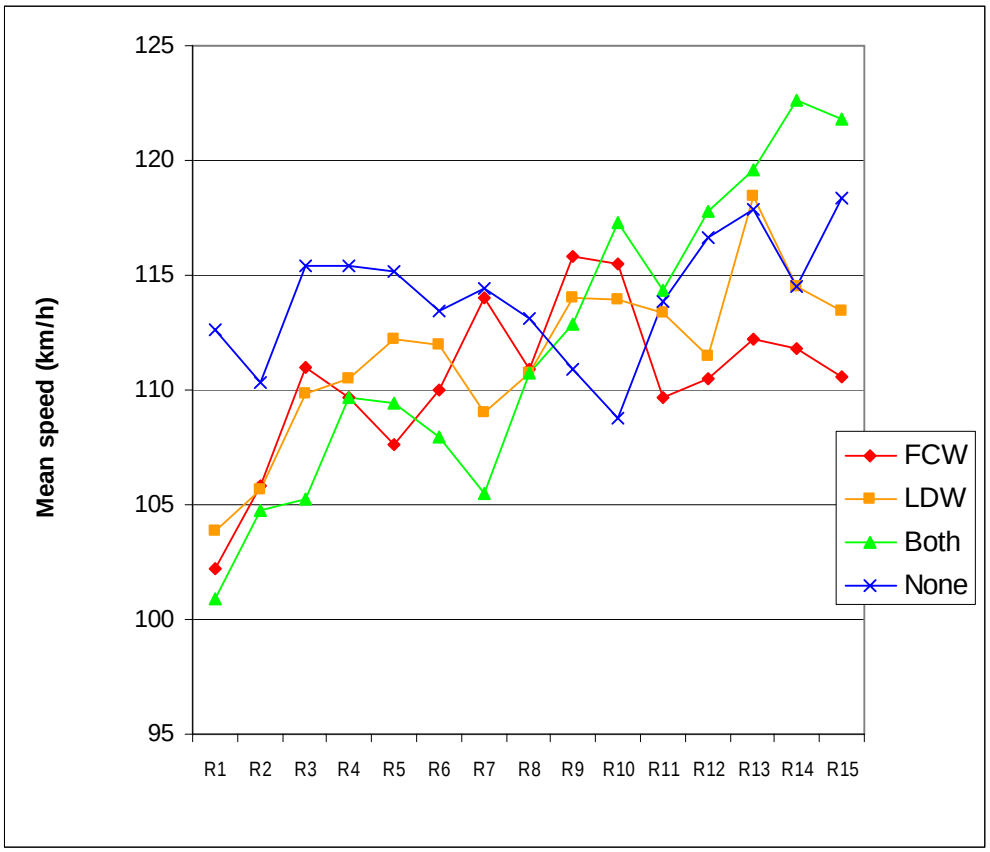


Figure 37: The mean speed for the different rides and for each group

	FCWgroup	LDW group	FCW+LDW group	Controlgroup
FCW group				
LDW group	Ns			
FCW+LDW group	Ns	Ns		
Controlgroup	0.0344	0.1071	Ns	

Table 27: Groups comparison regarding mean speed per ride

4.3.2 Longitudinal behaviour

Regarding the longitudinal behaviour two indicators were considered, the number of frontal collision warnings that each group received per ride, and the percentage of time driving at short headways (<1sec) to the lead vehicle. In the case of the LDW and control groups the number of frontal collision warnings refers to the number of warnings that would have been received, if the system was active.

4.3.2.1 Number of imminent frontal collision warnings per Ride

As can be seen in Figure 38 and Table 28, the mean number of warnings received by the FCW group per ride was significantly lower than in the case of all the other three groups. The FCW system alone had certainly a positive effect in respect to longitudinal behavior, as the participants in this group drive trying to avoid receiving warnings. An effect of ride is also found for the same group (p=0.090768). The mean number of warnings per ride, tends to rather increase in this group. It seems that as time passes by (as participants get used to the system?), the positive effect of the FCW alone, was rather more weak compared to the first rides, however it was always present compared to the other groups.

The mean number of warnings that would be generated for the LDW group per ride was significantly lower in relation to the FCW+LDW and control groups. This may indicate that participants in this group drive per se more conservatively than participants in the control group. However, the significant difference with the FCW group indicates the effect of the system itself on the behaviour of participants in the FCW group.

No difference was found between the FCW+LDW and control groups. It seems that participants in the FCW+LDW were driving without taking into account the warnings. Although no ride effect was found for this group, studying the figure below, one sees that in the first 9 rides, the means number of warnings per ride for this group is lower than for the control group. After ride 10, this is very high, higher than in the control group. It seems that in the first rides, these participants were trying to adapt somehow their behaviour to the FCW system. After this period, they start driving at shorter distances in following cases.

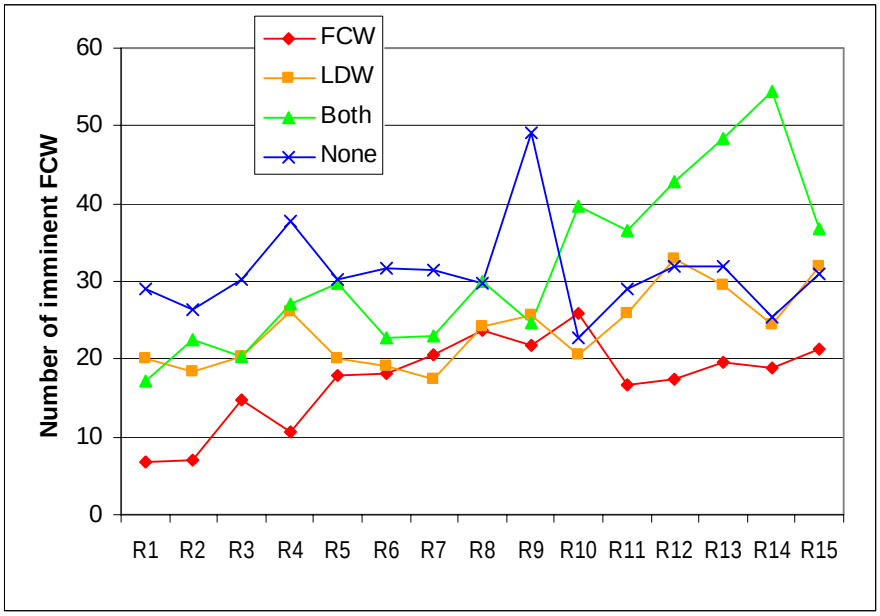


Figure 38: Mean number of imminent frontal collision warnings (visible/audible for Groups A and C).

Groups	FCW	LDW	FCW+ LDW	Control
FCW				
LDW	0.0011			
FCW+LDW	$2.063\ 10^{-7}$	0.0057		
Control	$2.559\ 10^{-8}$	0.0046	Ns	

Table 28: Groups comparison regarding mean number of imminent FCW per ride

4.3.2.2 Percentage of time driving at short headway (< 1s)

It should be noted here that the FCW warnings were not activated at a certain headway threshold. The warning distance was calculated each time as the distance corresponding to the reaction time of the driver and the difference of stopping distances of the ego and front vehicle with a deceleration of – 5m/s^2.

The indicator studied in this section is therefore not directly related to the number of warnings, studied in the previous section, as it could be the case that there was no warning given although the headway is less than 1 s. Thus, the behavioural adaptation due to the system is more related to the number of warnings. The present indicator is more meant to give an overview of impact of the system on traffic safety.

Considering the percentage of time driving at headway < 1 s, (Figure 39 and Table 29) there was a significant difference found among the FCW and FCW+LDW group and among the FCW and control group, and a trend between FCW and LDW group. The FCW system alone has a positive effect on safety, as participants in the FCW group avoid driving at short headway (< 1 s).

A significant difference was, also found between the LDW and FCW+LDW groups, but not between LDW and control group. It seems that the behaviour of the participants in the LDW group, as far as driving at short headways is concerned, is between that of the FCW group and that of the control group, as no significant differences are found with any of these groups.

Significant differences are found between FCW+LDW and all other groups. As of ride 5 (with the exception of ride 9), participants in this group drove more time at short headways (<1 s) compared to all other groups.

Some effects of ride were found for the FCW+LDW group (p=0.097683). The percentage of time driving at short headway rather increases with ride, possibly due to driver's familiarisation with the system.

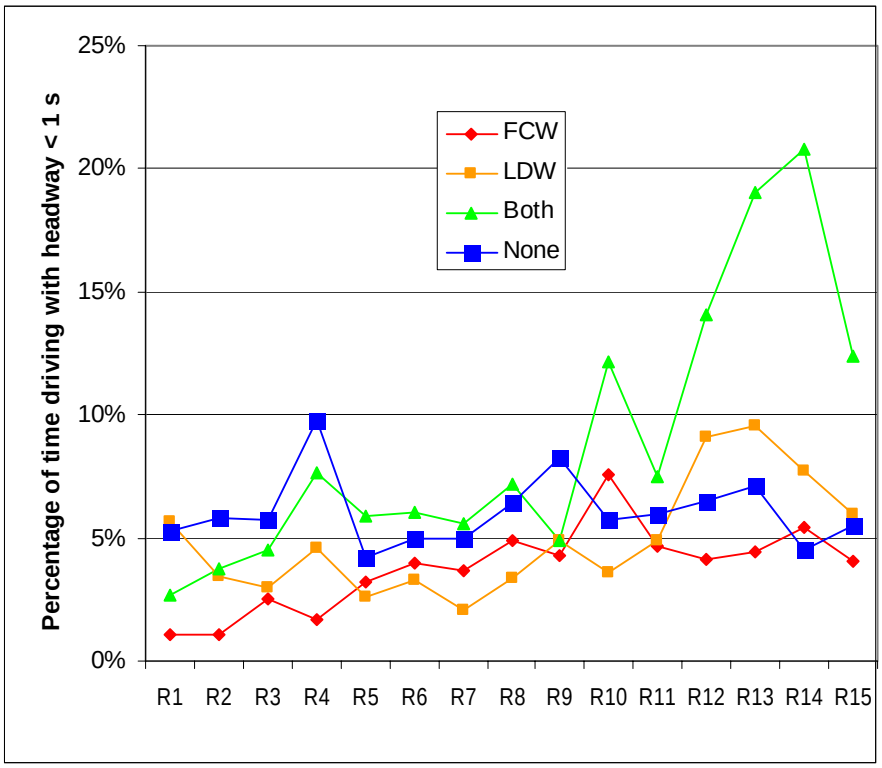


Figure 39: Mean percentage of driving time where headway is shorter than 1 s

	FCW	LDW	FCW+LDW	Control
FCW				
LDW	0.0981			
FCW+LDW	$2.382\ 10^{-5}$	0.0018		
Control	0.0005	Ns	0.0229	

Table 29: Groups comparison regarding percentage of time driving at headway < 1 s per ride

4.3.3 Lateral Behaviour

Regarding the lateral behaviour three indicators were taken into account, namely the mean number of lane departure warnings that each group received, the standard deviation of lateral position per ride, and the percentage of lane changes per ride (in the total number of lane changes per ride) that were performed with the use of direction lights.

For the FCW group and the control group the number of lane departure warnings refers to the number of warnings that would have been received, if the system was active.

4.3.3.1 Number of lane departure warnings per ride

As it can be seen in Figure 40 and Table 30, the mean number of lane departure warnings was significantly lower in the LDW group than in all other groups.

No difference was found among the other three groups.

Considering that the warnings from the LDW system were only audible in the LDW and FCW+LDW groups, the above finding implies that the participants in the LDW group were driving, so as to avoid receiving warnings from the system.

In the FCW+LDW group, which received warnings from both systems, the participants did now make any effort to drive so as to avoid receiving warnings from the system. This is the case even from the first ride.

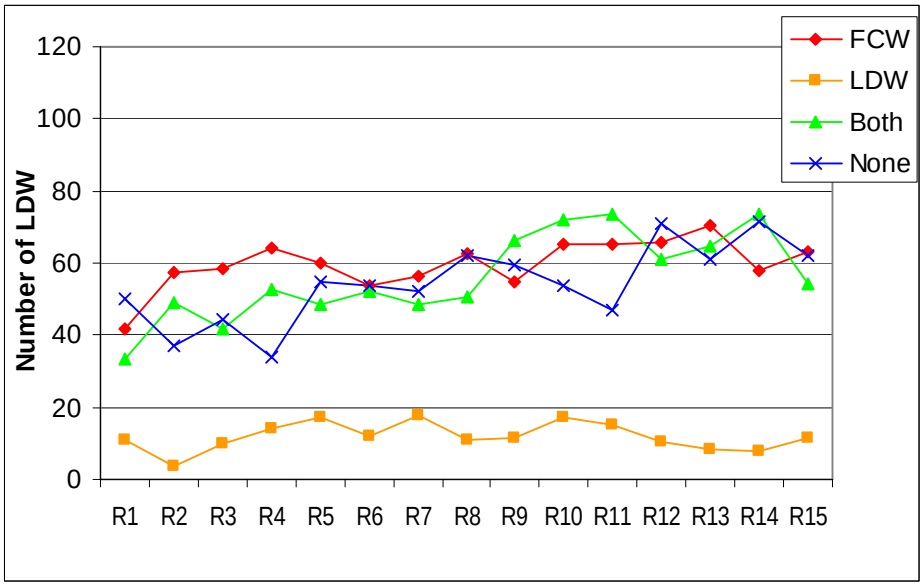


Figure 40: Mean number of lane departure warnings (audible for LDW and FCW+LDW groups only).

Groups	FCW	LDW	FCW+LDW	Control
FCW				
LDW	$3.91\ 10^{-33}$			
FCW+LDW	Ns	$7.238\ 10^{-13}$		
Control	Ns	$4.79\ 10^{-16}$	Ns	

Table 30: Groups comparison regarding mean number of LDW per ride

4.3.3.2 Standard deviation of lateral position

In order to calculate the standard deviation of lateral position per ride, the recordings during lane changes have been excluded from the analysis. As explained in AIDE Deliverable 1.2.3, the high values of standard deviation of lateral position found in this study compared to the ones in the literature should be attributed to the fact that in the present study, participants were asked to drive normally and were not instructed to maintain their position in the lane.

Significant differences were found among the LDW group and all the other groups. The standard deviation of lateral position per ride is always lower in the case of the LDW group compared to the other groups. This suggests that the LDW system in the LDW group did have a positive effect on lane keeping performance.

Significant differences were found among the FCW group and all the other groups. The standard deviation of lateral position per ride is always (except for ride 1) higher in the FCW group than in the other groups. This may possibly indicate a negative side-effect of the FCW system in lane keeping performance, in the sense that participants in the FCW group might be more concentrated into the longitudinal behaviour, trying to avoid FCW warnings, and put less effort into lane keeping.

No difference was found among the FCW+LDW group and the control group.

Looking at the figure below, one sees that in the first ride, the standard deviation of lateral position in the FCW+LDW group were as low as that of the LDW group. After the second ride however, this has increased and became comparable to that of the control group. The lane keeping performance of the participants in the FCW+LDW group was not affected by the LDW warnings, as they seem to completely ignore them, since their lane keeping performance is not different from that of the control group.

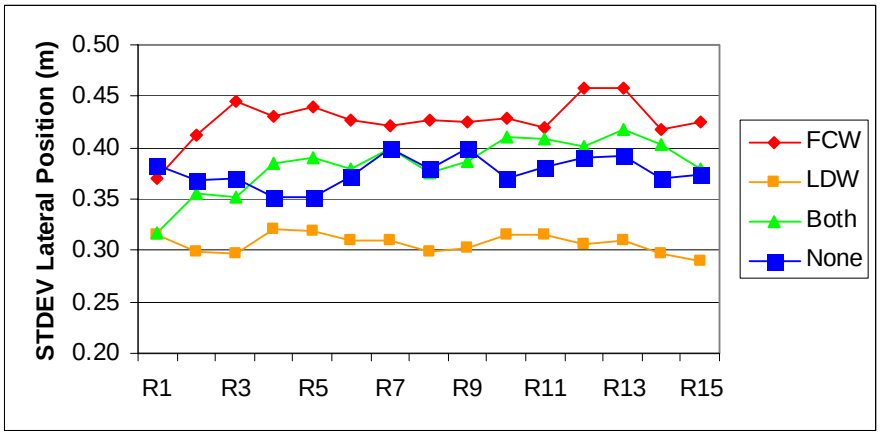


Figure 41: Standard deviation of lateral position (distance from lane centre)

	FCW	LDW	FCW+LDW	Control
FCW				
LDW	$1.048\ 10^{-22}$			
FCW+LDW	0.00335	$5.687\ 10^{-8}$		
Control	$2.285\ 10^{-6}$	$7.564\ 10^{-11}$	Ns	

Table 31: Groups comparison regarding standard deviation of lateral position per ride

4.3.3.3 Number of lane changes per ride

In an attempt to clarify the possible strategies that each group adopted in order either to avoid close-following situations or to reduce the time of driving at short headway, the number of lane changes per ride was taken into account.

No effect of group or ride on total number of lane changes per ride was found. This implies, that the lower time percentage of driving at short headway that was found for the FCW group was not due to a different strategy that participants in the FCW group might have adopted, namely more frequent lane changing. This in turn, suggests that the FCW system alone had certainly a positive effect in longitudinal behavior without inducing potential unwanted driving behavior changes (e.g. increased number of lane changes in order to avoid FCW activation).

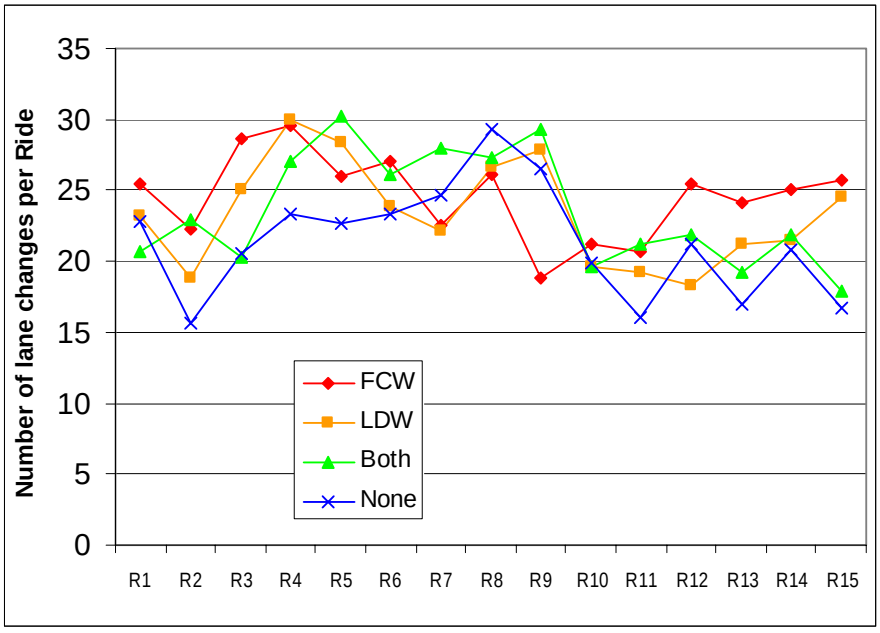


Figure 42: Number of lane changes per ride

4.3.3.4 Number of lane changes with use of direction lights

In order to review the secondary effects of LDW system, namely the encouragement of participants to use the direction light when changing lane, in order to avoid warnings' activation, the lane changes performed with the use of direction lights as a percentage of total number of lane changes per ride was calculated.

There were significant differences among the LDW group and all other groups regarding the percentage of lane changes performed with the use of direction lights.

No difference was found among the FCW+LDW group and the other groups.

In other words, the use of the LDW alone has clearly increased the use of direction lights during lane changes. This is not true for the FCW+LDW group, where the use of direction lights is similar to that of the rest groups, namely it is not affected by the LDW warnings.

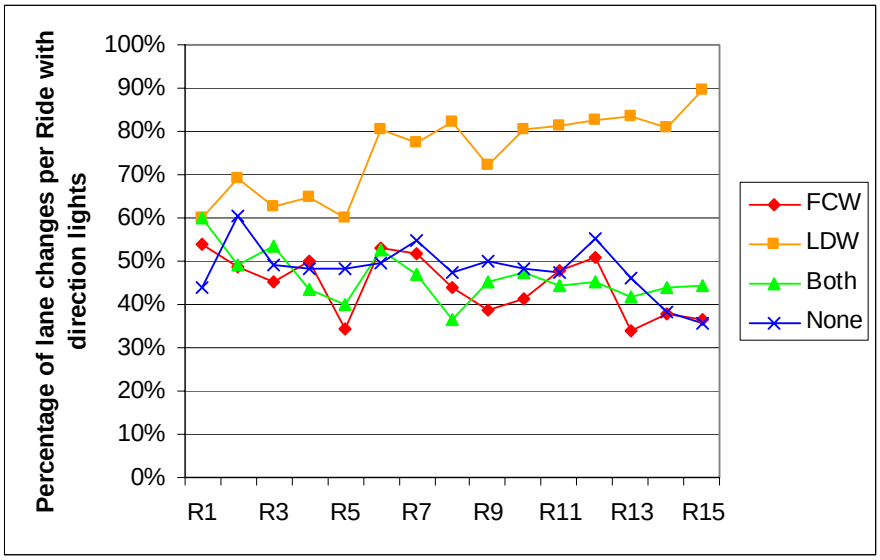


Figure 43: Percentage of lane changes per ride with the use of direction lights

	FCW	LDW	FCW+LDW	Control
FCW				
LDW	$1.0245\ 10^{-15}$			
FCW+LDW	Ns	$2.527\ 10^{-9}$		
Control	Ns	$8.74\ 10^{-9}$	Ns	

Table 32: Groups comparison regarding percentage of lane changes with the use of direction lights per ride

4.3.4 Subjective ratings

Beyond the above mentioned effects of the two ADAS systems into longitudinal and lateral behaviour based on objective measurements of driving performance, in the following section the subjective ratings of the participants about the ADAS systems that they used is considered, in terms of systems' acceptance and resulting mental effort. Both issues have been questioned by means of questionnaires that were filled by participants after each ride.

4.3.4.1 Acceptance

System acceptance is referred to participants' subjective evaluation about the ADAS system(s) that they used, in the following two dimensions: *system usefulness*, namely how useful the system(s) was in terms of traffic safety, and *system satisfaction*, namely how pleasant was driving with the system(s) on.

Regarding the FCW system, both the FCW and FCW+LDW groups rated it as useful, but only the FCW group rated it as satisfactory. The usefulness scores from the FCW+LDW group are lower than those from the FCW group. The participants in the FCW+LDW have always negatively rated the FCW system as far as satisfaction is concerned, implying that the FCW system in combination with another ADAS system causes feelings of irritation.

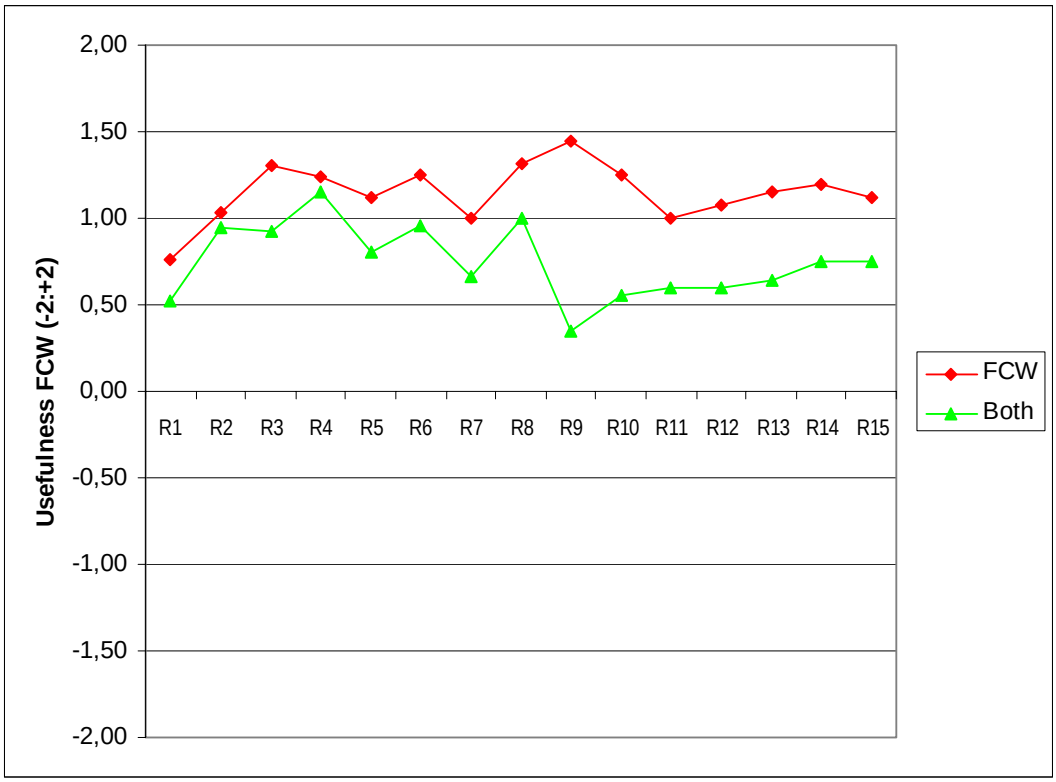


Figure 44: The usefulness score for FCW system (audible to FCW and FCW+LDW groups).

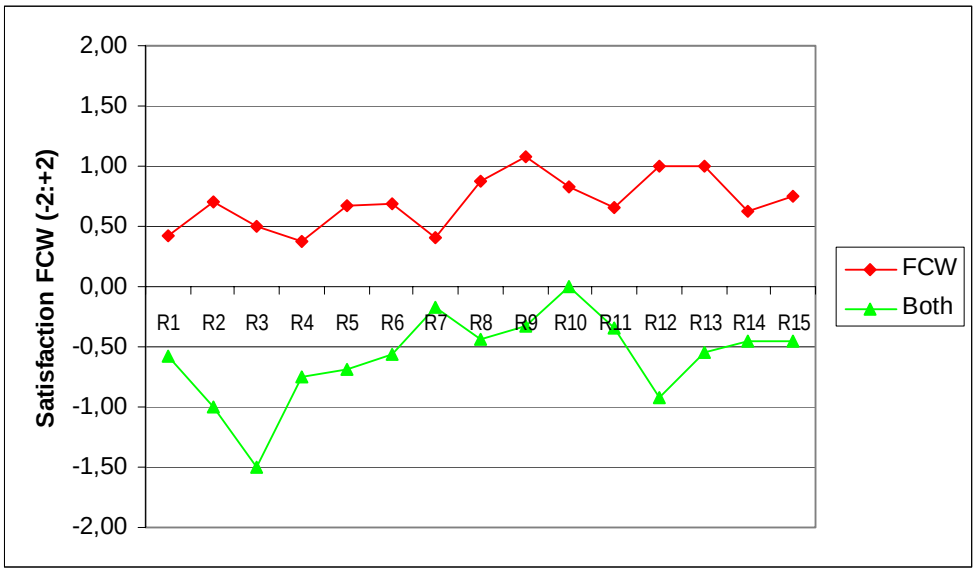


Figure 45: The satisfaction score for FCW system (audible to FCW and FCW+LDW groups).

The same pattern was also found in regard to the LDW system evaluation. Both the participants in the LDW and the FCW+LDW groups rated it as useful, but only participants from the LDW group rated it as satisfactory. The usefulness scores from the FCW+LDW group are most of the times lower than those from the LDW group. The participants in the FCW+LDW group have always (except from ride 10) rated it negatively regarding the satisfaction.

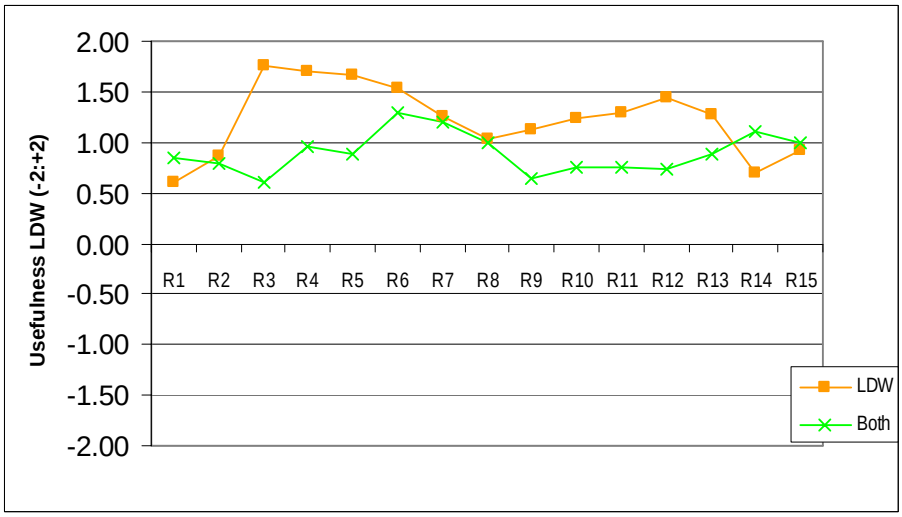


Figure 46: The usefulness score for LDW system (audible to LDW and FCW+LDW groups).

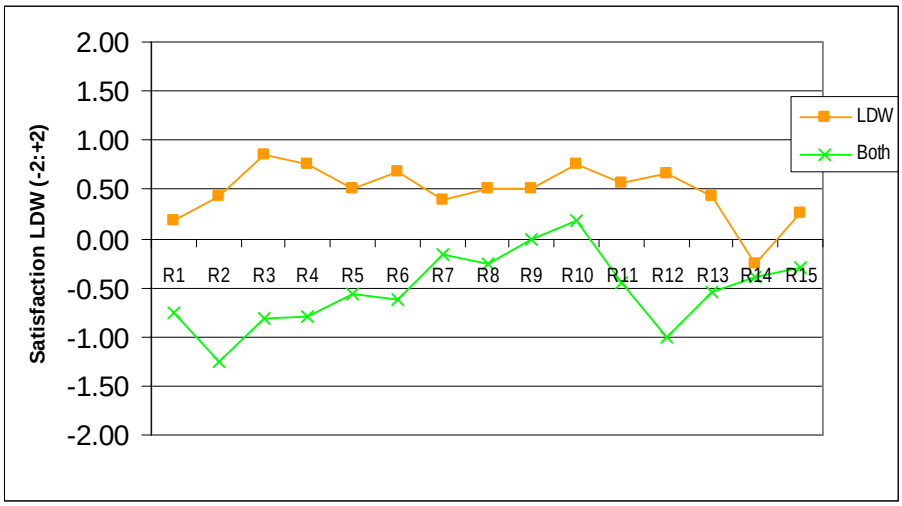


Figure 47: The satisfaction score for LDW system (audible to LDW and FCW+LDWgroups).

In other words, FCW and LDW systems are considered as both useful and pleasant by those who participated in the groups where only one system was active. However, the participants who received warnings from both systems concurrently (group FCW+LDW) rated both systems as useful in terms of traffic safety, but unsatisfactory.

4.3.4.2 Mental effort

Participants were asked to rate the mental effort devoted to driving after each ride using the RSME scale.

Participants from the FCW and LDW groups have given much higher ratings than the control group. Participants from FCW+LDW group have given ratings similar to that of the control group.

The use of stand-alone systems has led to increased mental effort. The concurrent functioning of both systems has rather led participants to ignore them, as the ratings of mental effort indicate.

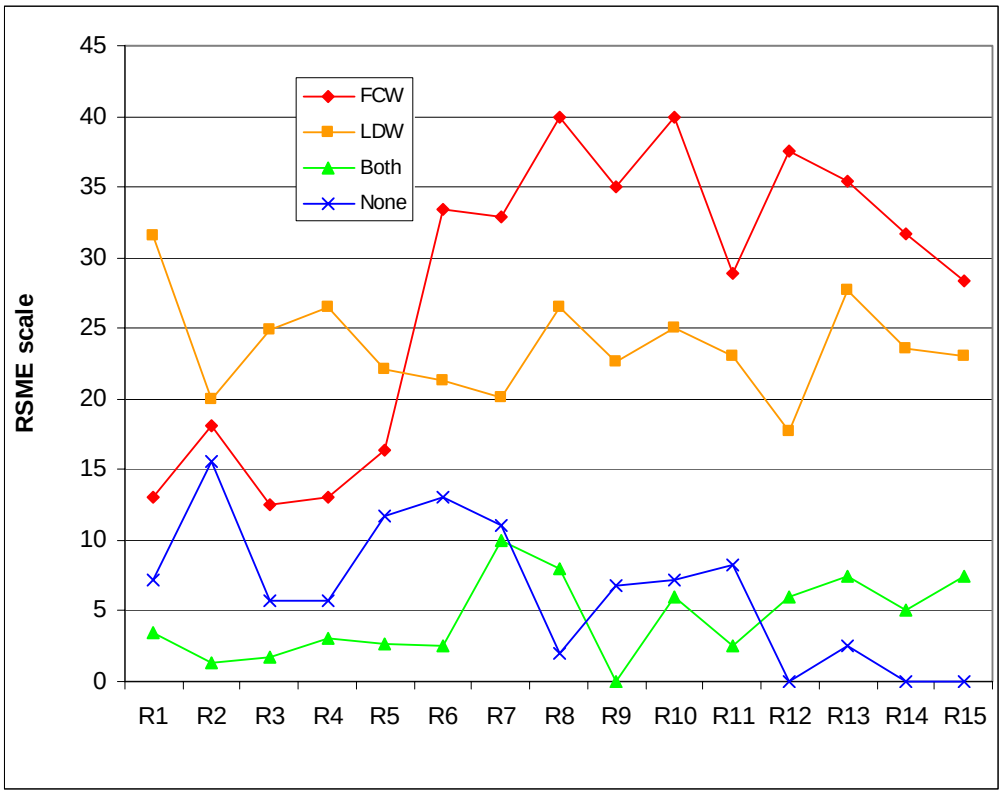


Figure 48: Mean subjective ratings of mental effort.

In total, the participants' subjective evaluation of the two ADAS tested in this particular study, show that the use of a stand-alone system (either FCW or LDW system) had a positive impact on drivers' acceptance, even though driving with such a system induces a much higher mental effort. Alternatively, the results could be explained by the fact that due to the high level of acceptance of each stand-alone system, participants were putting more effort, in an attempt to integrate the provided information to their driving behavior.

On the other hand, when the same systems were functioning concurrently and independently of each other, the participants' ratings are negative, not in terms of the potential usefulness of the systems but in terms of satisfaction. This could be simply, because the two concurrent functioning systems produced a rather noisy environment, causing a lot of irritation to drivers that has actually led the drivers to ignore both of the systems. This is reflected not only through the subjective measurements but also through the objective measurements. The performance of participants in the FCW+LDW group in respect to longitudinal/ lateral behavior, shows no improvement compared to the control group in the long-term.

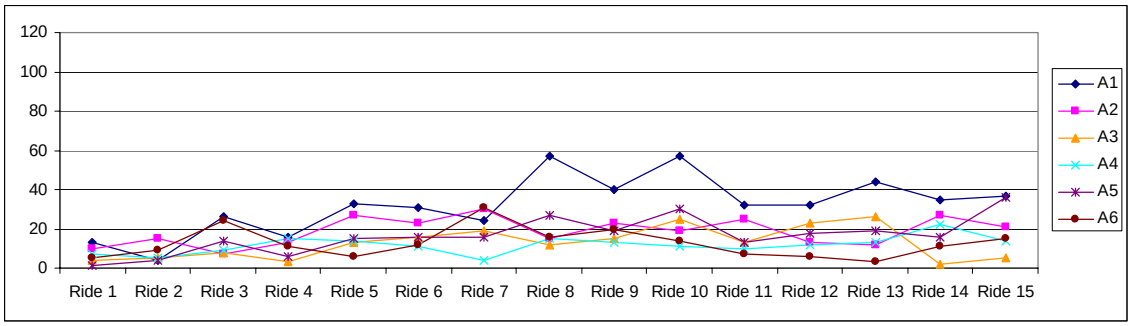
A raising question, however, is if the intention of participants in the FCW+LDW group to ignore both systems could be caused by their irritation due to the two concurrent and independently functioning systems. An open issue is why participants did not attempt to reduce the number of warnings by changing their driving behaviour, in order to minimize the source of irritation.

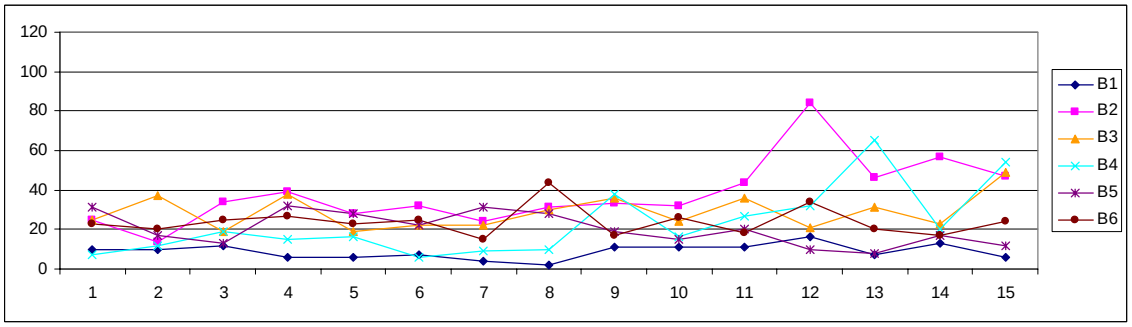
4.3.4.3 Follow-up interviews

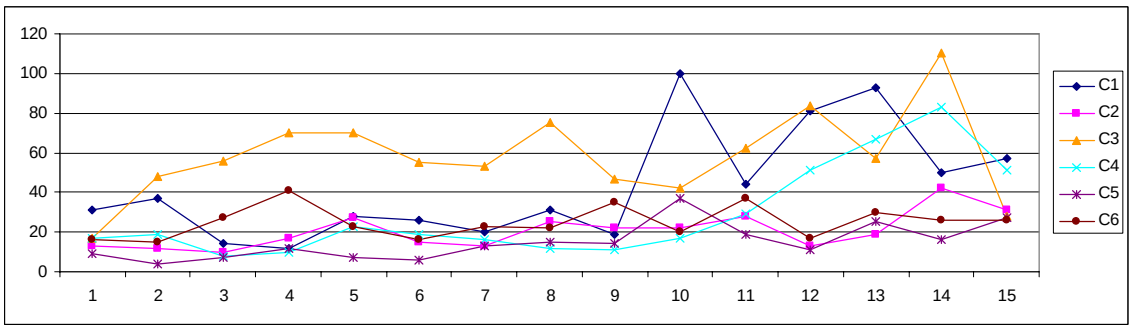
From the subjective measurements it was impossible to come up with a definite answer to the above question. To answer it, we have conducted a follow-up telephone interview in order to clarify this issue. The asked questions were:

"Do you remember which system you used during the experiment?"
"Was the system(s) reliable?"
"Did you always drive in compliance to the system(s) thresholds?"
"In case of two systems, did you pay the same level of attention to both systems?"

The participants that took part in these telephone interviews were selected on the basis of the number of warnings that they received. In specific, comparing the number of frontal collision warnings received per ride among participants in each group, it can be seen in the following diagrams, that, the number of warnings for all participants in FCW group (named as Group A) are of the same order, except for participant A1. This particular participant seems to start ignoring the system warnings as of ride 8.







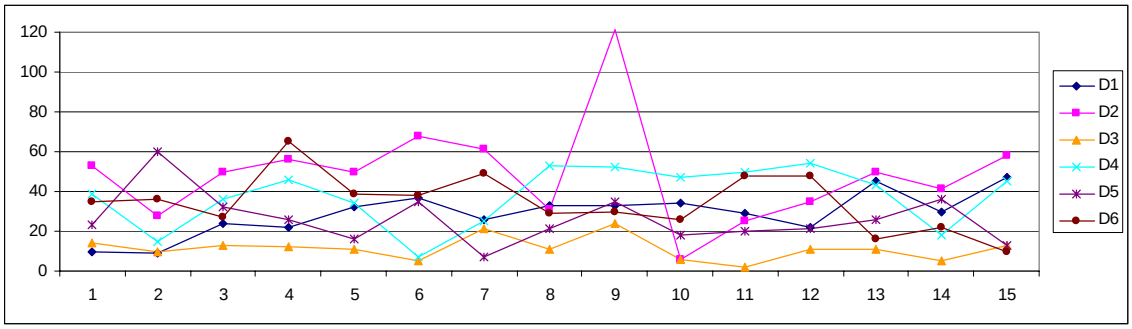
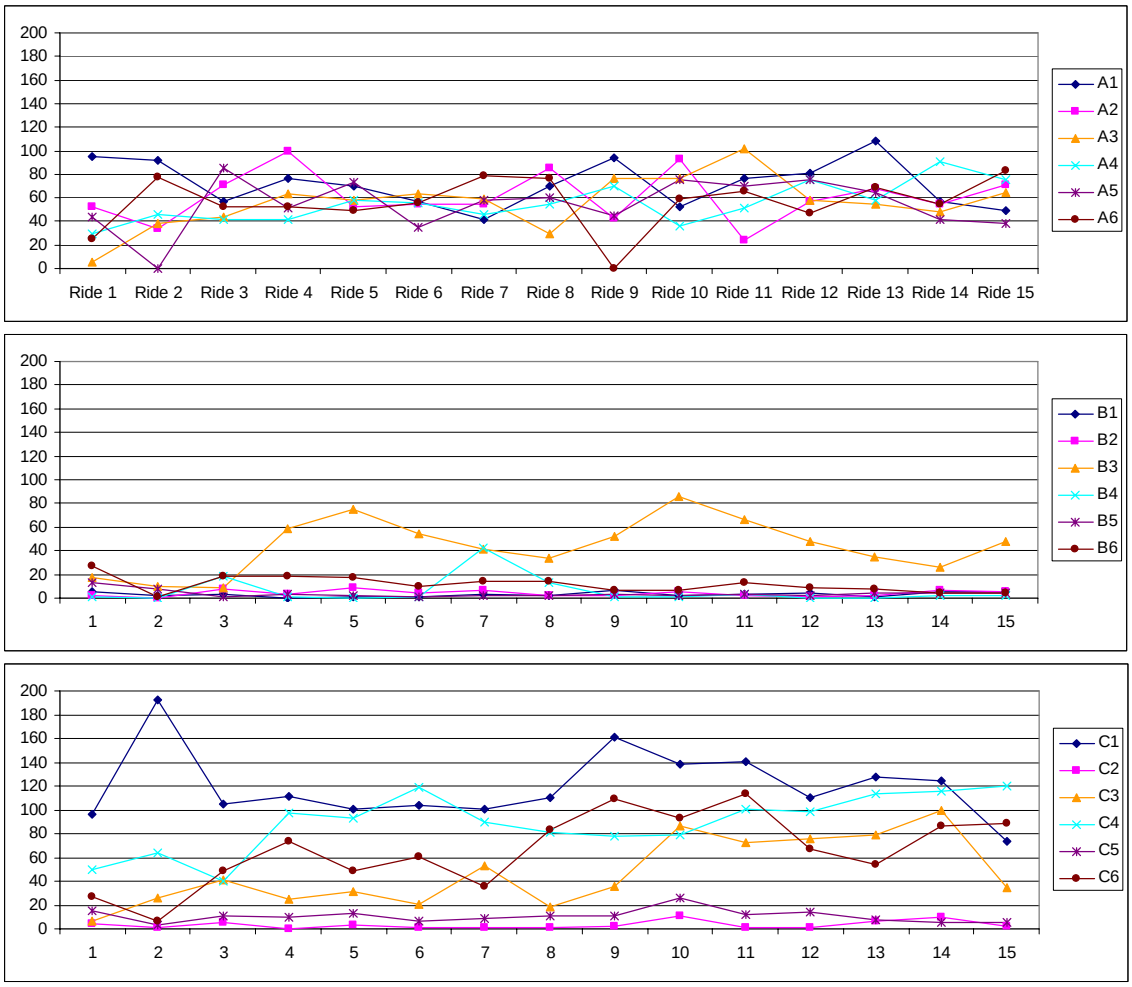


Figure 49: Number of frontal collision warnings received per ride among participants in each group.

Accordingly, comparing the number of lane departure warnings received per ride among participants in each group, it can be seen in the following diagrams that the number of warnings for all participants in LDW group (named as Group B) are of the same order, except for participant B3. This participant seems to start ignoring the system warnings as of ride 4.



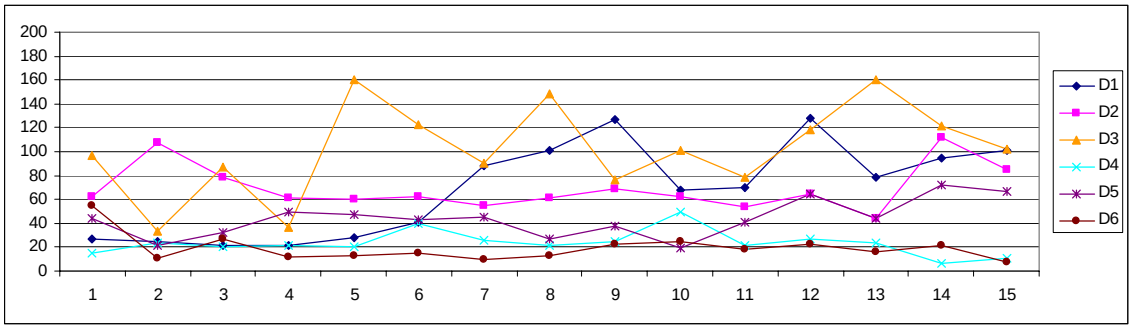


Figure 50: Number of lane departure warnings received per ride among participants in each group.

Comparing the number of warnings among participants in the FCW+LDW group (named as Group C), it can be seen that there is more variance among participants than in the FCW or LDW groups. In specific:

- Participants C2 and C5 seem to drive in all rides in accordance to both the FCW and LDW, as the number of warnings received indicate.
- Participant C6 seems to drive according to FCW but ignores LDW warnings as of ride 3.
- Participants C1 and C4 seem to ignore the LDW warnings as of the first ride (ride 1). However, these two participants seem to have initially tried to drive according to the FCW warnings, but they start ignoring them as of ride 9 and 11 respectively.
- Participant C3 seems to ignore the warnings of both systems as of ride 2.

All the above observations that led to the identification of the participants who received a considerable high number of warnings (marked with X) are summarized in the following table. These participants were finally selected for the telephone interviews.

Group A		Group B		Group C		
Participant	Compliance to FCW system	Participant	Compliance to LDW system	Participant	Compliance to FCW system	Compliance to LDW system
A1	X as of ride 8	B1	✓	C1	X as of ride 9	X
A2	✓	B2	✓	C2	✓	✓
A3	✓	B3	X as of ride 4	C3	X as of ride 2	X as of ride 2
A4	✓	B4	✓	C4	X as of ride 11	X
A5	✓	B5	✓	C5	✓	✓
A6	✓	B6	✓	C6	✓	X as of ride 3

Table 33: Participants selected for the telephone interview

Below is the reasoning for non-compliance to the provided warnings according to the answers of each participant through the telephone interviews.

Participant A1

The system was reliable, but depending on the level of traffic (and consequently, the frequency of lane changes that I was able to do), in heavy traffic conditions the number of warnings was high whereas in low traffic conditions the number of warnings was minimal.

Participant B3

The system was reliable but I could not avoid LDWs, because I usually do not use the indicator light when I change lane. Despite that I tried to respect it, most of the time I was forgotten and did not use the indicator. In general the number of warnings was not so high and I could stand them.

Participant C4
I never paid attention to LDW. In the beginning, I tried to respect FCW in order to avoid warnings, but it was not adapted to my preferences. Thus, after the third-fourth trial, it was easier to ignore warnings than to try to avoid them by changing my driving behaviour. In contrast, the number of LDW was high, because I am not used to use indicator light.
In general sound warnings were irritating and after a while I purposefully ignored them.

Participant C6
I never paid attention to LDW. To some extent, I tried to respect FCW but the forward distances were not in accordance to my perception of imminent danger. That is why I decided to drive not in compliance to it. On the other hand, I could not avoid LDWs, because I usually drive on the lane marking, so in case of no other traffic I was earnest to ignore received warnings, than to change my habitual driving behaviour.
In general sound warnings were irritating and I purposefully ignored them almost from the beginning, especially the LDW.

Participant C1
I was purposefully driving rather aggressive (e.g. close-following, high speeding, driving on lane markers) in order to test systems' reliability. I found out that both systems worked well, even at high speeding, and the warnings were reliable. That is why, the number of warnings were not similar within each trial. It was depending on the system that I was tested more, each time.
After the ninth trial, I have learned how the systems work and I tried to harmonise my driving behaviour with them. But it was rather stressful to drive in compliance with both systems during the whole trial. It was relative easy to drive in compliance with the systems only for a while, about 10min.
In general I would prefer visual than acoustic warnings, but the system was reliable.

Participant C3
I never paid attention to warnings, because the thresholds for warnings' activation did not match to my driving style. My driving behaviour style could be described rather as aggressive (close-following, high-speeding) and warnings thresholds were too conservative. Comparing the two, I found out that LDW was more reliable than FCW, so in the very beginning I tried to respect, to some extent, only the LDW. But none of the systems were close to my driving safety criteria, so it was easier to ignore sound warnings rather than to be in compliance to them.

As it was made clear from the interviews, for the two participants in FCW and LDW group, the main reason of ignoring the provided warnings was their reluctance to change in long-term, their habitual driving style. The same also holds true for participants in FCW+LDW group.

Participants in the FCW+LDW group first came up with a dilemma of choosing which system could be more feasible to comply with. Most of them have chosen to comply with the system

that they considered as most easy to comply with, i.e. they were not paying attention to LDW, since they are not using direction lights or are driving on the lane marking.

Quite interesting is the case of participant C1, who purposefully drove aggressively in order to test and learn the systems functionality. Following this strategy he did actually manage to learn or to predict the timing for warnings' activation but he was not able to follow these for the whole ride.

Clearly, the concurrent functioning of the two systems that were tested in this particular study generated a lot of warnings, so that ignoring them became inevitable in order to lower the level of frustration that participants felt as they were trying to cope with both systems.

4.4 Overview of results

The main findings for longitudinal behaviour are given in Table 34.

	Group A	**Group B**	**Group C**	**Group D**
Group A				
Group B	✓ Imm_FCW (A<B)			
Group C	✓ Per_Time_1 (A<C) ✓ Imm_FCW (A<C)	✓ Per_Time_1 (B<C) ✓ Imm_FCW (B<C)		
Group D	✓ Per_Time_1 (A<D) ✓ Imm_FCW (A<D)	✓ Imm_FCW (B<D)	✓ Per_Time_1 (C>D)	

Table 34: Significant group effects regarding longitudinal behaviour.

The main findings for lateral behaviour are given in Table 35.

	Group A	**Group B**	**Group C**	**Group D**
Group A				
Group B	✓ Per_LC_with flash (B>A) ✓ StDevLP (A>B) ✓ LDW (B<A)			
Group C	✓ StDevLP (A>C)	✓ Per_LC_with flash (B>C) ✓ StDevLP (B<C) ✓ LDW (B<C)		
Group D	✓ StDevLP (A>D)	✓ Per_LC_with flash (B>D) ✓ StDevLP (B<D) ✓ LDW (B<D)		

Table 35: Significant group effects regarding lateral behaviour.

The results are short listed below.

FCW alone (Group A)

- ***Positive effect:*** Reduction of time driving in short headways compared to control group. However, this increases with ride, possibly due to driver's familiarisation with the system.
- ***Side effect:*** Increase of standard deviation of lateral position compared to control group.

LDW alone (Group B)

- ***Positive effect:*** Reduction of standard deviation of lateral position compared to control group.
- ***Positive effect:*** More frequent use of directions lights in lane changes compared to control group.

FCW+LDW in combination (Group C)

- ***Negative effect:*** Increase of time driving in short headways compared to control group. Time percentage of short headways increases with ride, possibly due to driver's familiarisation with the system.
- No difference from control group on standard deviation of lateral position or on use of direction lights.

4.5 Discussion

Results from the on-road study conducted with the experimental vehicle along a period of 15 weeks (one ride per week), show that there is a clear difference regarding to the driving behaviour effects of the two ADAS that were tested, namely the frontal collision warning (FCW) and the lane departure warning (LDW), when these systems are used as stand alone or are functioning in parallel but independently of each other.

According to the above, when the systems are used as stand alone, the FCW and the LDW system have improved the longitudinal and lateral behaviour, respectively, and this is in accordance to the primary goal that each system has been designed for. However, a slight difference between the two groups was found in respect to the magnitude of the behavioural effects that each system induced.

In specific, in the FCW group, the participants were driving so as to receive less warnings due to close-following and were driving less time at short headways (< 1 s). This effect was more strong during the first rides, whereas during the last five rides the percentage of time of driving at short headways (<1s) becomes higher than in the first rides. This effect of ride was statistically significant.

On the other hand, in the LDW group, participants showed better lane keeping performance (as standard deviation of lane position and number of LDW warnings indicate) and were using more systematically the direction lights during lane changes. These behavioural changes remained unaffected through rides.

Moreover, the number of FCW warnings in the LDW group was less than in the control group. In the FCW group the standard deviation of lane position was higher than in all other groups.

Considering the differences between the two groups, it is rather difficult to attribute them as systems' side-effects into driving behaviour alone or as the result of individual differences. Maybe the answer is somewhere in the middle, in the sense that participants in the LDW group seem to drive more conservative in relation to FCW group and this explains to some extent why the differences in the lateral and longitudinal behaviour of this group from the control group remain unaffected through time. On the other hand, it could be the case that in

order to maintain steady lane position and thus avoid LDW warnings, they were driving in greater distances from the lead vehicle, so as to have a better view of the lane markings ahead and not being influenced by the lane position of the lead vehicle.

Similarly, participants in the FCW group basically attempted to avoid warnings from FCW system. The increased standard deviation of lane position might be the inevitable side effect of participants' concentration on longitudinal behaviour, thus reducing the effort of maintaining the vehicle position in the middle of the lane.

In conclusion, either system has produced in long-term, a positive effect in accordance to the primary goal it that has been designed for, namely longitudinal and lateral behaviour, expressed with less warnings, less time driving at short headways and better lane keeping respectively. But, for the given road infrastructure that the experiment took place, the FCW system may produce a negative side-effect in terms of lane keeping as a strategy to minimise the effort needed to maintain vehicle in the middle of the lane, whereas, the LDW system may produce a positive side-effect in terms of following at short time distances as a strategy to keep concentration on the lane-keeping task.

In contrast, considering participants' performance when the two ADAS are functioning concurrently, there was essentially no positive effect either in respect to longitudinal behaviour or in respect to lateral behaviour, in terms of number of warnings, driving at short headways and lane keeping. It seems that participants in the FCW+LDW group paid no attention to the provided warnings. Their lane keeping performance was similar to the control group. They drove at short distances more often than the control group. Considering, the double number of warnings that they were receiving compared to the other two groups, and the resulting noise polluted environment that participants had to live, it was inexplicable why participants did nothing in order to avoid the warnings. To answer this question, a follow-up telephone interview was conducted. From the answers of these interviews, it was found that trying to cope with both systems generated a lot of frustration to participants, because driving became too restricted compared to their usual driving style.

Considering the usual habits of the interviewees, of not using direction lights while changing lane or of driving on the lane marking, could explain why two out of six participants stated that they never paid attention to the LDW system. Thus, selecting to pay attention only to one of the two systems was one strategy used for copying with the two particular ADAS. However, this strategy was not effective in long term neither to longitudinal nor to lateral behaviour, as after some rides participants started ignoring both systems.

Trying to learn how the two ADAS behave under various traffic situations and under different travelling speeds (as one participant stated), so that driving with the two ADAS becomes feasible in the long-term, was a second strategy used for copying with the two ADAS systems. However, even though this strategy seems more promising than the first one, the practical value of this learning process is limited because driving in compliance to both the safety thresholds that have been defined for the systems warnings' activation makes actually driving too restricted to be respected during 1h journey.

Therefore, from the results of the FCW+LDW group two different aspects have to be considered for the evaluation of the long-term effects of the two particular ADAS into the driving behaviour.

The first is related to the learning process that is necessary, so that drivers can control both systems. In contrast to the other two groups, in the FCW+LDW group there is evidence that a phased introduction of the two systems might be a more appropriate method in order to give to drivers the opportunity to learn how the systems behave and to integrate them in driving.

The second aspect is related to the safety thresholds that have been defined for systems warnings' activation. Clearly, these safety thresholds have been defined having in mind only one particular driving task (e.g. lane-keeping). In the LDW or in the FCW group where participants were asked to drive in compliance to these safety thresholds, it was relatively easy for them to do so, because they had to consider one particular driving task. However, when two driving tasks have to considered, as was the case in the FCW+LDW group, these safety thresholds should be revised in the view of the antagonism produced between the two driving tasks.

Comparing the results of this study (long-term horizon), with the results of the analysis of the 5 first rides only (short-term horizon), the following differences are found.

Regarding longitudinal behaviour, the percentage of time driving at short headways increases in the long-term for Group A, compared to the findings in the short-term range. In the long term, Group C drives at shorter headways, compared to all other groups.

	Short-term (5 rides)	Long-term (15 rides)
A-B: Per_Time_1	A<B	ns
B-C: Per_Time_1	Ns	B<C
B-D: Per_Time_1	B<D	ns
C-D: Per_Time_1	Ns	C>D

Table 36: Differences in results regarding longitudinal behaviour among short- and long-term

Regarding the lateral behaviour, there are no significant changes among the findings of the analysis of the short-term and the ones of the long-term. The only differences are that the trend found in the short-term for the percentage of lane changes with indicator lights among groups B and C becomes true significant in the long-term (B>C). There is also a significant difference for the same parameter among groups B and D (B>D), which was not found in the short-term.

5 Effect of LDWS on driving behaviour

5.1 Introduction

The Lane Departure Warning System (LDWS; in French: Alerte de Franchissement Involontaire de Ligne – AFIL) is an informative lateral support system. Since October 2004 this system is installed in the Citroën C4 and C5. When the speed exceeds 80 km/h, six pairs of infra-red sensors detect the (continuous or discontinuous) edge and /or lane markings. If the driver crosses a marking without using the indicator (e.g., during lane changing or lane deviation without manoeuvres), the system warns the driver by means of vibration of the seat. The vibration simulates the effect rumble strips. Moreover, the warning indicates at which side the marking is crossed. If the driver crosses the left marking, the vibration is felt at the left side of the seat and when the right marking is crossed the right side of the seat vibrates.

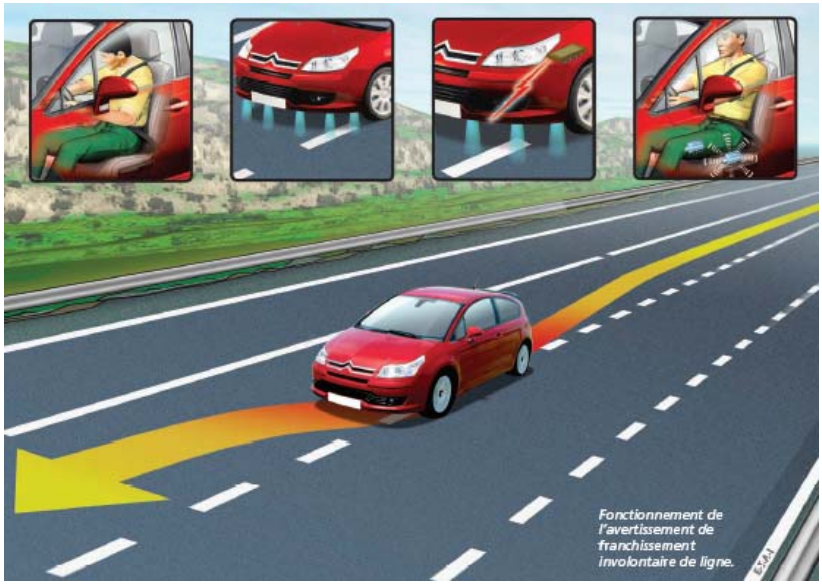


Figure 51: Citroen LDWS

In the present study PSA and TNO investigated the effect of LDWS on driving behaviour by means of interviews and questionnaires. We were interested whether drivers change their behaviour over time while driving with such a system and in which way. More specifically, the aims of the present study are:

- To define a set of safety critical parameters that describe long-term behavioural effects (direct or indirect) when using the LDWS. This is obtained from how drivers describe their adaptation to the system.
- To determine critical parameters that sustain a modelling architecture: the results will provide the DVE model with inputs on drivers' experience with the system, in particular for elderly drivers, and its integration in the whole driving activity

5.2 Expected long term effects of LDWS

The driving task can be divided into three different levels: the strategic level, the tactical level, and the operational level (see, e.g., Janssen, 1979). On the strategic level drivers make decisions about, for example, the route and the mode of transport. At the tactical level decision are made about manoeuvres such as, speed and overtaking. The operational level is quite often seen as the real driving task. At this level drivers brake, steer, gear shift, etc. With respect to these different task levels we expect different long-term effects of LDWS. These are presented in the Table 37.

	Driving task level		
	Strategical	**Tactical**	**Operational**
Positive long-term effects	Increased mobility: with increased feeling of safety, elderly people drive more frequently at night or have more long trips	Less lane changes without indicators Avoidance of crossing the continuous line Avoidance of driving on the "striped zone" Better lane positioning	Better use of indicators Smaller and less steering corrections
Negative long-term effects	Increased mobility: more driven kilometres probably results in more accidents	Keep indicators on longer to avoid warnings Less amplitude of deviation when motorcyclists are passing Keep close to the lane (night, curve) Longer driving by using LDWS as a fatigue warning system	More abrupt steering corrections

Table 37: Expected long-term effects of LDWS

The long-term effects may also be influenced by age, driving experience and driving style. Driving style was difficult to infer from verbal data obtained from the interviews. So, only age and driving experience are taken into account in this study.

5.3 Method

The procedure for data collection consisted of interviewing participants and filling out a questionnaire by the same participants. The interview was more related to driving behaviour and the questionnaire focussed on personal information, for example, driving habits, use of equipment, motivation of car/system purchase, etc.
Most interviews were conducted by phone and most questionnaires were sent to the participants. Occasionally, both interview and questionnaire were obtained at the same time (either by phone or in person).

5.3.1 Questionnaire

The questionnaire had 58 questions dealing with ten different topics (see Table 38). The questionnaire is presented in Annex 2.

Questionnaire on participants' characteristics	Total number of administered questions	Total number of selected questions for analysis
Personal information	8	3
Personal vehicle	4	3
New techonologies	2	0
Car	4	2
Car driving	3	0
The driver	8	3
Daytime driving	6	3
Night time driving	8	5
Position on the road	8	4
System purchase and use	7	2
TOTAL	58	25

Table 38: Summary of topics in questionnaire

It was agreed not to analyse more than half of the questions (57%) for the following reasons :

- Too few participants answered the question,
- the content of collected responses was difficult to exploit.

However, the questions left (25 of the 58) were judged as most relevant to obtain all the necessary information for interpreting long-term effects and give input to the DVE model.

5.3.2 Interview's guide content

The interview consisted of 29 questions dealing with nine topics (see Table 39). The interview's guide is presented in Annex 2.

Questions of interview	Total number of questions	Total number of selected questions for analysis
System understanding	2	2
Warning perception	2	2
Perceived reliability	2	2
Reaction to warning	8	3
System use	2	0
System usefulness	5	5
Driving modification	5	4
Comfort	2	0
Satisfaction	1	1
TOTAL	29	19

Table 39: Summary of Interview's questions

It was agreed to analyse 19 of the 29 questions (66%). The other questions were not analysed for the following reasons:

- Some questions had some overlap with other questions: For example, the topic of changing driving behaviour is covered by several questions.
- Some questions related to system's use were difficult to understand by most participants: e.g., "*do you try to anticipate to the warnings*"
- Some questions did not have any link with long-term effects: e.g., *"do you find the vibration pleasant or not*" or "*were you startled the first time the warning occurred ?"*

5.3.3 Participants

Participants were end-users of the LDWS: buyers of vehicles Citroën C4 and C5 equipped with the LDWS. No pre-selection of participants on age and driving experience could be made since this information was not available in the participants' file.

5.3.3.1 Pre-selection of participants to contact

French participants

From the French side, two criteria have been taken into account:

- From the date of purchase in the participants' file, participants were selected to fit with a minimum 11 months of duration of LDWS possession. This criterion was chosen to exclude any potential learning or short-term effects.
- Then participants were selected from the towns around Paris (PSA site) for practical reasons (the time dedicated to the survey and cost). However, a few participants lived in country side and were questioned by phone, to avoid travel time.

All participants were contacted by phone. Participants who lived near Paris were given the choice to fill in the questionnaire and to achieve the interview face to face or by phone.

Dutch participants

All private owner addresses were extracted from a sales list of both the Citroën C4 and C5 with LDWS sold in the Netherlands. These people were requested by phone to cooperate in the study. If they were willing to comply, the main goal was to make an appointment for a personal meeting. During this meeting the interview would be conducted and the respondent would fill in the questionnaire.

If people didn't want to make an appointment but were willing to cooperate in the study, the interview was done by phone and the questionnaire was send to them. The questionnaire included a letter with a short explanation of the study. The participants lived in both urban and rural areas across the Netherlands. The selection criterion with respect to date of purchase was used as for the French participants (11 months or more).

5.3.3.2 Summary of participants

French participants
29 participants aged from 34 to 81 years old participated in the survey: the participants are representative of Citroën C4 and C5 participants and it seems that the variability in age between the participants is high considering the range.

Participants had their driving licence for 11 years to 61 years, and covered from 8 000 km up to 40 000 km a year. All can be considered as experienced drivers.

All participants (11) with a Citroën C4 drove with manual gearbox and 18 participants had a Citroën C5 with manual gearbox (11) or automatic gearbox (7). The shortest date of purchase was 12 months before the interview, the longest 17 months. All cars were equipped with other systems such as navigation system, conventional cruise control, and speed limiter. All participants reported that most equipment was used.

Dutch participants
20 participants (aged between 41 and 77 years) participated in the study. These participants are considered to be a representative sample of the Dutch Citroën C4 and C5 drivers.

The participants obtained their drivers license at least 24 years ago. On this account they can be considered experienced drivers. They drove a total of 2500 up to 35000 km a year. The lesser amount of kilometres were mainly due to retirement. Since the retired participants drove more kilometres when employed, they can still be considered as experienced drivers.

Four participants drove a Citroën C4, of which one had an automatic gearshift. Most participants owning a Citroën C5 drove with an automatic gearbox (12/16).

Some general background information of the participants is presented in Table 40.

	French participants	Dutch participants
Total number of participants	29	20
Gender	28 males and 1 female	unknown[2]
Age range	34 – 81 years	41 – 77 years
Duration of driving licence owning	11 – 61 years	24 – 56 years
Total km/year	8 000 – 40 000 km	2 500 – 35 000

Table 40: Background information on French and Dutch participants

5.3.4 Exposure Groups

To acquire knowledge on long-term effects, it is necessary to investigate possible effects of LDWS at different points in time. However, with the present methodology (questionnaire and interview) "exposure to LDWS" is difficult to collect. The best way (although far from ideal) for the present study to have an indication of the exposure to the LDWS is the duration of

[2] The question with respect to gender was not asked to the Dutch participants.

LDWS possession (period between the date of purchase and the date of interview in April – July 2006). This is not ideal since warnings occur according to situations met by drivers and the way of driving. Some drivers may have had the system for a long time and do not encounter a lot of warnings while others may have had the system only for a while and encounter a lot of warnings. So, the purchase date does not give a reliable, objective indication of exposure. It is nevertheless the best indicator within the present method.

18 months is the maximum duration of LDWS possession considering the LDWS marketing date, but no participant had the car for 18 months. The groups were constructed in order to know long-term effect at around one year and at more than one year.

The participants were divided into two groups (called "*exposure groups*") depending on the duration of LDWS possession:

- 11 – 13 months (Exposure group 1).
- 14 – 17 months (Exposure group 2).

5.3.5 Age Groups

In order to identify an effect of age on driving (which is of interest for the DVE modelling) participants were divided into the following three age groups.

- < 56 years ('young' drivers)
- 56 – 65 years (middle-aged drivers)
- > 65 years (senior drivers)

5.4 Results

5.4.1 Description of exposure groups

As shown in Table 41 most participants both in France and the Netherlands owned their car with LDWS for more than 13 months.

Exposure group	French participants	Dutch participants
11 – 13 months	7 (24%)	8 (40%)
14 – 17 months	22 (76%)	12 (60%)
TOTAL	29	20

Table 41: Summary of exposure groups

5.4.1.1 Gender, age and visual acuity

French participants

Most participants were male and were older than 56 years (see Table 42). The majority reported they could see the road markings, even if they reported vision defaults. Both exposure groups are comparable in terms of age: about half of the participants were middle-aged drivers and around one third of the participants were elderly drivers (> 65 years).

Dutch participants

The different age groups were not evenly distributed over exposure groups (see Table 42 and **Figure 52**). The group of middle-aged drivers (56 – 65 years) was the lowest in Exposure group 1 while it was the highest in the in Exposure group 2. All drivers reported that they could see the road marking (one did not respond).

		French participants		Dutch participants	
		11 – 13 months n=7	**14 – 17 months n=22**	**11 – 13 months n=8**	**14 – 17 months n=12**
Gender	Female	0	1	Unknown	Unknown
	Male	7	21	Unknown	Unknown
Age	range	35 – 68 years	34 – 81 years	41 – 72 years	45 – 77 years
	< 56	1 (14%)	5 (23%)	3 (37%)	4 (33%)
	56 – 65	4 (57%)	11 (50%)	1 (12%)	5 (41%)
	> 65	2 (29%)	6 (27%)	4 (50%)	3 (25%)
Perception road marking	yes	6 (86%)	16 (72%)	7 (78%)	12 (100%)
	No response	1 (14%)	6 (28%)	1 (12%)	0 (0%)

Table 42: Gender, age and perception

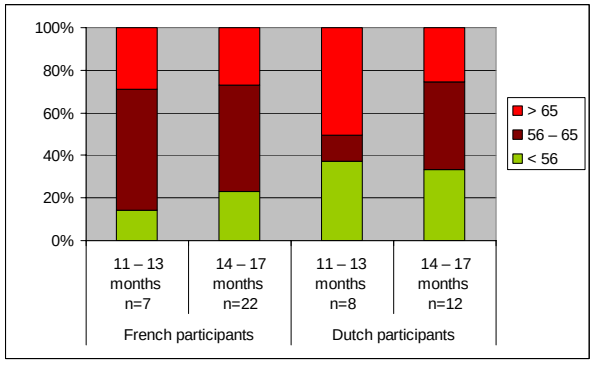


Figure 52 : Age of customers for each exposure group

5.4.1.2 Car possession and equipment use

French participants

In both exposure groups, most participants owned a Citroën C5 equipped with a manual gearbox (see Table 43). The average duration the participants owned the LDWS was 12.7 months for the Exposure group 1 and 15.2 months for Exposure group 2.

Dutch customers

In the least experienced group, the C4 was more abundant. In the 14-17 month group most customers drove a C5. The participants owned the LDWS for an average of 12 months in the 11-13 exposure group and 15 months in the 14-17 months exposure group.

		French participants		Dutch participants	
		11 – 13 months n=7	**14 – 17 months n=22**	**11 – 13 months n=8**	**14 – 17 months n=12**
Vehicle model and Gearbox	C4 manual gearbox	2 (29%)	9 (41%)	2 (25%)	1 (8%)
	C4 automatic gearbox	0 (0%)	0 (0%)	1 (12%)	0
	C5 manual gearbox	4 (57%)	7 (32%)	1 (12%)	3 (25%)
	C5 automatic gearbox	1 (14%)	6 (27%)	4 (50%)	8 (67%)
Duration of LDWS possession	Range	12 – 13 months	14 – 17 months	11 – 13 months	14 – 16 months
	mean	12.7 months	15.2 months	12 months	15 months

Table 43:Vehicle and equipment

5.4.1.3 Attitude in equipments use after buying a car

French participants

All participants purchased a car equipped with different types of equipment (e.g., navigation, speed limiter, cruise control, hands-free phone) because they bought a pack of options including the LDWS. Most frequently used by all participants were: the parking assistance, the multifunction system, and the navigation system.

No customer reported any lack of interest in the equipment (see Table 44). Very few differences were observed between both exposure groups. The majority of participants reported to read the user manual before operating the equipment and/or trying the equipment the first time while driving (many types of equipment did not work while standing still), and a part of them mentioned they were the first to try all equipments.

Dutch customers

Lack of interest in the equipment has not been reported by either exposure group. Most customers (regardless of exposure group) first read the instruction manual before they operated new equipment. In the 14 – 17 month group this was a large majority but in the 11 – 13 months group half of the customers reported no to read the instructions first.

In Exposure group 1 the “in stationary” and “while driving” answers concerning the trial of new equipment were equal. In Exposure group 2, however, 33% of the customers stated that they tried new equipment while standing still and only 8% during driving. This leaves an unaccounted for percentage which might be due to these customers not using all equipment as in the first exposure group. This, because some of the equipment only works while driving and therefore cannot be tried out during standstill.

	French participants		Dutch participants	
	11 – 13 months n=7	**14 – 17 months n=22**	**11-13 months n=8**	**14-17 months n=12**
Not interested in equipment	0	0	0	0
Try all equipment	2 (29%)	7 (39%)	6(67%)	1(8%)
Try equipment while driving	5 (71%)	13 (59%)	3 (50%)	1 (8%)
Try equipment in stationary	7 (100%)	7 (39%)	3 (50%)	7 (33%)
Read instructions before use	4 (57%)	15 (68%)	3 (50%)	9 (75%)

Table 44: Attitudes in equipment use

5.4.1.4 Driving experience

French participants

Most participants were experienced drivers considering their age and total number of kilometres driven per year (see Table 45). However, important variability between participants in the driving experience is found, according to the exposure group. The differences can reach two times or five times the total number of kilometres covered over a year. In both exposure groups, few participants reported a daily use of the car. Many participants were retired and did not need to drive everyday.

Dutch participants

All customers are experienced drivers based on the criteria of "amount of years since obtaining of drivers license" and the total amount of driven kilometres per year.

There's a large variability in the amount of driven kilometres due to retirement of some participants. This also accounts for the large amount of people that reported not to drive to work.

	French participants		Dutch participants	
	11 – 13 months n=7	**14 – 17 months n=22**	**11 – 13 months n=8**	**14 – 17 months n=12**
Duration of driving licence owning	15 – 48 years	11 – 61years	28 – 52 years	24 – 56 years
Total km/year	15 000 – 30 000	8 000 – 40 000	8 000 – 35 000	2 500 – 25 000
Everyday driving - Go to work by car	1 (14%)	5 (23%)	24 (50%)	4 (33%)

Table 45: Driving experience

5.4.1.5 Knowledge and motivation for purchase

French participants
About half of the participants knew about the LDWS before the purchase in both "exposure groups". Of those who knew about the system in the first exposure group (11 – 13 months) for all of them the system motivated them to buy the car. In the second exposure group this was for about half of the participants who knew about the system (seeTable 46).

Dutch customers
In the 11-13 months exposure group more than half the customers knew about the system, two of them claimed to be motivated to buy the car because of the system. The others with prior knowledge in the 11-13 month group reported no influence on their decision to purchase the car. Of the customers in the first exposure group that did not have prior knowledge two left a blank answer.

The second exposure group only had one person with prior knowledge and this person was motivated to purchase the car because of the system. Five people with no knowledge about the system refrained from answering the motivation question.

		French participants		Dutch participants	
		11 – 13 months n=7	**14 – 17 months n=22**	**11 – 13 months n=8**	**14 – 17 months n=12**
Knowledge of the system before purchase	Yes	4 (57%)	11 (50%)	5 (62%)	1 (8%)
	No	3 (43%)	11 (50%)	3 (28%)	11 (92%)
Did the system motivate the car's purchase	Yes	3 (100%)	5 (45%)	2 (33%)	1 (14%)
	No	0	6 (55%)	4 (67%)	6 (86 %)

Table 46: Knowledge of the LDWS and motivation of car purchase

5.4.1.6 Use of LDWS: first activation

There were too many responses missing in both exposure groups to analyse these results.

5.4.1.7 Use of LDWS : perceived reliability and warnings occurrence

French participants
All participants who had the LDWS for 11 – 13 months judged the system as reliable. Nevertheless 71% participants of this exposure group met false alarms or non detections. For participants of Exposure group 2, 82% judged the LDWS as reliable. Of the participants in this exposure group 50% of them reported they met false alarms or non detections, the other half did not give a response.

Dutch participants
All customers deemed the LDWS reliable, the small number of reported false alarms are due to old and redundant or faded previous road markings. The occurrence of non-detections is also because of faded road markings according to the customer that reported it. These

occurrences have no influence on the perceived reliability of the system which is a hundred percent in both exposure groups.

	French customers		Dutch customers	
	11 – 13 months n=7	**14 – 17 months n=22**	**11 – 13 months n=8**	**14 – 17 months n=12**
LDWS judged reliable	7 (100%)	18 (82%)	8 (100%)	12 (100%)
Occurrence of false alarms only	2 (29%)	2 (9%)	3 (37%)	0
Occurrence of non-detections only	2 (29%)	3 (14%)	0	1 (8%)
Occurrence of false alarms and non-detections	1 (13%)	6 (27%)	0	0
No response	2 (29%)	11 (50%)	5 (63%)	11 (92%)

Table 47: Reliability of LDWS

5.4.2 Long-term effects

In this section we describe the answers to questions that in someway related to long term effects. In the subsections that follow the question that is analysed is first presented.

5.4.2.1 System's understanding

In your mind, do you know how the system works? Do you know at which speed the system is activated?

French Participants

All participants reported they knew how the system worked (situations with warning occurrence). The knowledge of the minimum speed of LDWS activation was not known by only six participants. Five of them were of Exposure group 2. The duration of LDWS possession did not seem to influence the understanding of the LDWS as most people got this information.

Dutch Participants

Three out of eight participants of Exposure group 1 claimed they did not understand how the system worked. In Exposure group 2, three out of twelve participants reported they did not know how the system worked. When asked if they could anticipate to the warnings of the LDWS all customers answered positively. Therefore it can be assumed they understand the basic working of the system.

5.4.2.2 Warnings' perception

Can you easily detect the vibrations in the seat?(seat vibration)? Do you easily feel if the vibration is on the left or on the right?

French participants
The duration of LDWS possession does not influence perception of the alarm vibrations: all participants reported they could perceive them.
There were two participants who could not distinguish the locations of the seat vibrations. They were 63 and 71 years old.

Dutch participants
All participants in both exposure groups could easily detect the vibrations and assign them left or right**.**

5.4.2.3 Reaction to warnings

How do you react to the warnings of the system? Describe your reaction: brake, deceleration, turn the steering wheel… Could you clarify your response?
Do you sometime not react to an alarm? If yes, in which situations?
Do you think your reactions (steering wheel movements) changed over time? Why/and how?

French participants
Most participants reported that their reactions to warnings depended on the manoeuvres. If a warning occurred during lane changing without activating the indicator light, participants said they continued the manoeuvres with or without indicator activation, no one stopped changing lane. If a warning did not occur during a lane change, they said they noticed the lane deviation and corrected their heading.
Duration of LDWS possession did not have any impact on reaction. Participants made a diagnosis of the situation when warnings occurred; they did not report any "automatic" behaviour, their reaction depended on context of driving.
Reactions to warnings did not change over time, as they depended on the driving situation.

Dutch participants
All customers reported their first reaction to a warning was a steering wheel adjustment. As the French participants their reaction depended upon the situation. A voluntary lane change without indicator use was the main reason for not responding to the system. The exposure time to LDWS did not influence the reaction**.**

5.4.2.4 Feeling of safety

Globally, do you feel safer when the system is active? If you feel a safety benefit, do you think the benefit is low or notable? Why?

French participants
Almost all participants mentioned they felt safer since they had the LDWS and most of the participants found the safety benefit as notable (see Table 48, Figure 53 and Figure 54). Reasons given by most of the elderly participants (13) who found the benefit notable were that the LDWS warned them about lane deviations during episodes of drowsiness, inattention or fatigue.

Difference between exposure groups is on the level of judged benefit induced by the LDWS. There were more participants in Exposure group 2 who found the benefit of the LDWS notable.

Four participants found the benefit low. One of them mentioned that the LDWS was only useful at night while he/she did not drive often at night. Consequently, the benefit was minimal. The others gave no reason.

Dutch participants

In both exposure groups the majority of the customers felt a safety benefit when the LDWS was activated. The specific situation during which this occurred is during long journeys when drivers get tired. There were no big differences between the age groups.

Exposure groups differ on the perceived benefit of LDWS. Participants in Exposure group 2 more often report a low benefit.

Overall, most participants feel a notable benefit when the LDWS was activated. No reasons were given by the participants who reported a low benefit

	French customers			**Dutch customers**		
Globally, do you feel safer or not when the system is active	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**	**11 – 13 months n=8**	**14 – 17 months n=12**	**Total**
Feel Safer	6 (86%)	21 (95%)	27(93%)	6 (75%)	8 (67%)	14(70%)
Feel Less safe	0	0	0	0	0	0
Feel unchanged	1 (14%)	1 (5%)	2 (7%)	2 (25%)	4 (33%)	6 (30%)
Benefit of the LDWS	**11-13 months n=6**	**14-17 months n=21**	**Total**	**11-13 months n=6**	**14-17 months n=8**	**Total**
Notable	4 (67%)	18 (85%)	23(82%)	3 (50%)	3 (37%)	6 (43%)
Moderate	0	1 (5%)	1 (4%)	2 (33%)	1(12%)	3 (21%)
Low	2 (33%)	2 (10%)	4 (14%)	1 (17%)	4 (50%)	5 (36%)

Table 48: Feeling of safety and safety benefit

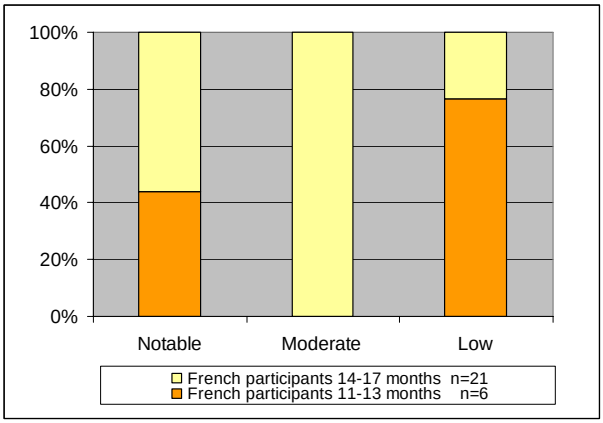


Figure 53 : Experienced benefit of LDWS (French)

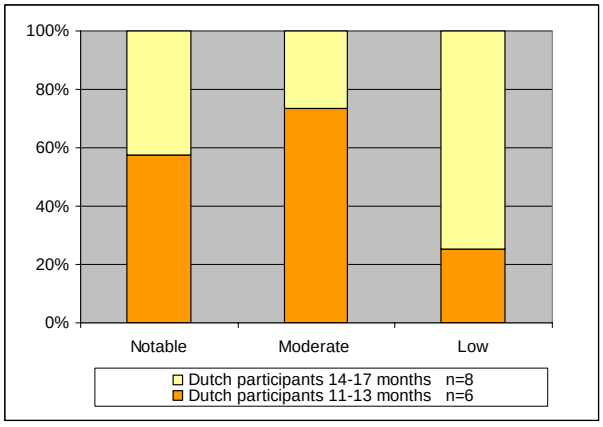


Figure 54: Experienced benefit of LDWS (Dutch)

5.4.2.5 Long-term effects on operational level of driving task

In this section we will present the answers to the questions that are related to the driving task itself. Two subsections will be distinguished with respect to the lateral and longitudinal part of the driving task.

Lateral position

Globally, do you think the system is useful or useless? Does the system help you to have a better position within the lane?

French participants
All participants found the LDWS useful. The majority of participants (86%) mentioned that the LDWS helped them to adopt a better position within the lane (see Table 49 and Figure 55).

Results showed that the longer participants had the LDWS the more they found the LDWS useful to adopt a better position in the lane. Of the few participants that reported the LDWS did not help, all considered they were already well positioned in the lane.

Dutch participants
Except for one participants, all found the system useful. In both exposure groups most participants reported a better lane position because of the system. In contrast with the French participants, longer exposure to LDWS did not result in a better road position because of LDWS. Participants who reported no better road position because of LDWS did find the system useful. Although they did not give a clear reason why LDWS did not help them to have a better road position they did state that the system was useful in certain situations (e.g., drivers fatigue during long journeys and during driving when tired in general.

	French participants			Dutch participants		
Better position within the lane?	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**	**11 – 13 months n=8**	**14 – 17 months n=12**	**Total**
Yes	**4 (57%)**	**21(95%)**	**25 (86%)**	**5 (62%)**	**7(58%)**	**12 (60%)**
No	3 (43%)	1 (5%)	4 (14%)	3 (38%)	5(42%)	8(40%)

Table 49: LDWS usefulness for lane position

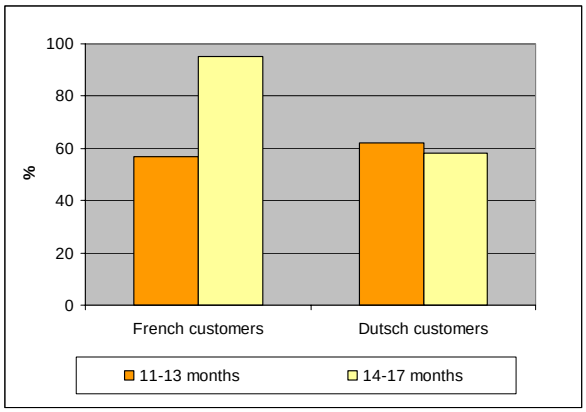


Figure 55 : Percentage of Customers indicating that LDWS helps to adopt a better position in the lane

With the system, do you think you pay more (or less) attention to your position in the lane?

French participants

The majority of participants (76%) reported that they paid more attention to the lane position (see Table 50 and Figure 56). The other 24% did not mention any changes, because they were already concentrated. The longer participants had the LDWS the more they mentioned increased attention to the lateral position. However, some negative effects were reported. One participant reported that increased attention paid to lane position lead to more effort, so lateral control demands increase with LDWS. Another participant mentioned explicitly over reliance on the LDWS: "I paid less attention to the lane position, as I relied completely on the system to warn me if I left the lane".

Dutch Participants

In the Exposure group 2 less participants reported more attention to lane position because of the system. The majority of the people claiming the system did not affect the attention paid to the lateral position said this was because they were very experienced drivers and already paid close attention to their driving behaviour.

	French participants			Dutch participants		
Attention to your position in the lane?	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**
Yes – more attention	4 (57%)	18 (82%)	22 (76%)	3 (43%)	4 (34%)	7(35%)
No- more attention	3 (43%)	4 (18%)	7 (24%)	5 (57%)	8 (66%)	13(65%)

Table 50: Attention paid to lane position

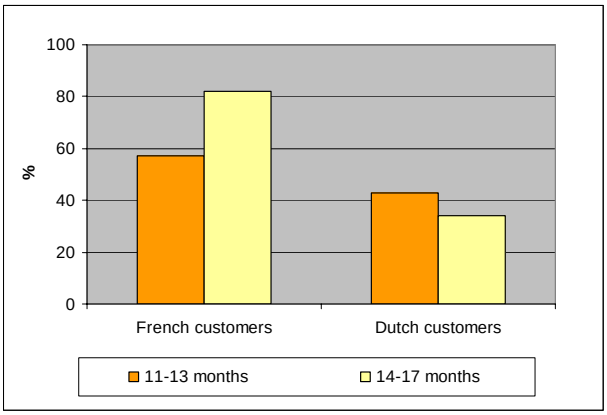


Figure 56 : Percentage of customers who reported to pay more attention to lane position with LDWS

When the system is activated: do you think you change your position within the lane?

French participants

Most of participants reported no adaptation in lane position, as they considered they were already well positioned (Table 51 and Figure 57). The participants in Exposure group 2 reported more changes in lane positioning and they adopted a better position within the lane ("more in the centre"), compared to participants in Exposure group 1. Among participants who mentioned to adopt a better lane position, some specified that it mainly occurred during curves and one customer mentioned that it especially had a beneficial influence when driving at night. Four participants confused lane number (right, left, middle lane) and position in the lane.

Dutch participants

Most participants reported no change in lane position because of the system. The participants in Exposure group 2 reported less influence on their lane position compared to the Exposure group 1. No direct clarification was given for the negative answers although it can be linked to the fact that most of these participants reported they already drove well and concentrated on their driving behaviour.

	French participants			Dutch participants		
Change in lane position	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**	**11 – 13 months n=8**	**14 – 17 months n=12**	**Total**
Yes	1(14%)	9(41%)	10(34%)	3(37%)	4(33%)	7(35%)
No	6(86%)	9(41%)	15(52%)	5 (62%)	8(67%)	13(65%)
No response	0	4(18%)	4(14%)	0	0	0

Table 51: Change in lane position

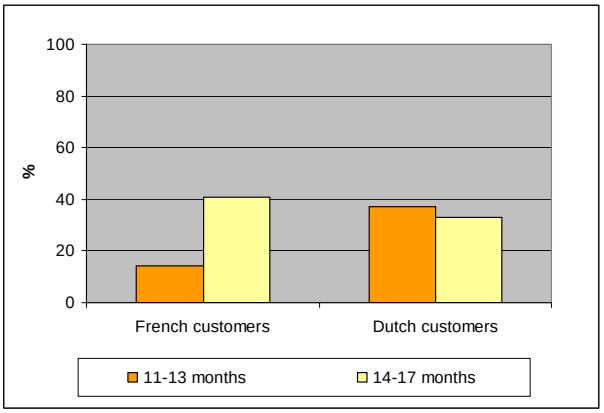


Figure 57 : Percentage of customers who changed the position in the lane

Do you sometimes touch lane markings? Do you sometimes drive on broken line (overtaking excluded)?

French Participants

Most participants mentioned they touched lane markings, but they specified that it occurred rarely. With the LDWS, all participants mentioned that they either rarely touched the lane markings (broken or continuous lines) or, they never did. The duration of LDWS possession did not influence frequency of line crossing.

		French participants		Dutch participants	
		11 – 13 months n=7	**14 – 17 months n=22**	**11 – 13 months n=8**	**14 – 17 months n=12**
Touch the lane marking (lane boundaries)	Yes - rarely	3 (42%)	14 (64%)	4 (50%)	4 (33%)
	No	2 (29%)	7 (32%)	4 (50%)	8 (67%)
	No response	2 (29%)	1 (4%)	0	0
Touch broken line (overtaking excluded)	Yes - rarely	5 (71%)	14 (64%)	2 (25%)	3 (25%)
	No	2 (29%)	7 (32%)	6 (75%)	9 (75%)
	No response	0	1 (4%)	0	0

Table 52: White line crossing

Dutch Participants
More experienced drivers touch the lane markings less. The customers that did touch the lane markings mentioned that this was infrequent and happened because of carelessness and distractions. The crossing of the broken line (excluding overtaking) happens rarely in both exposure groups and the proportions are the same in both groups.

Speed management

When the system is activated: do you think you change your speed? If yes: how (faster or slower) and in which situations

Neither French nor Dutch participants reported and changes in speed management; the assistance in lateral control did not impact the longitudinal control.

5.4.2.6 Long-term effect on tactical level of driving task

Lane changing with Indicator use

- *Do you think your use of the direction indicator changed? If yes: do you use it less or more frequently? Why? If not: why didn't it change?*

French participants
66% of the participants mentioned that they used the direction indicator more systematically, that is, frequently or always with LDWS (see Table 53 and Figure 58). The other participants did not change their behaviour. They stated that they used the indicators already sufficiently enough. Few differences can be observed between both exposure groups. A slightly higher percentage of participants of Exposure group 2 mentioned a change and more frequent use of the indicator.

Dutch Participants
Most participants used their direction indicator very frequently before the use of LDWS and therefore their behaviour has not changed. Compared to Exposure Group 2 participants in Exposure group 1 used the indicator not as frequently and report more use because of the system.

	French customers			Dutch customers		
Do you think you changed the use of the direction indicator?	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**	**11 – 13 months n=8**	**14 – 17 months n=12**	**Total**
Change - more use than before LDWS	4 (57%)	15 (68%)	19 (66%)	3 (37%)	2 (17%)	5 (25%)
No change – frequent use	3 (43%)	7 (32%)	10 (34%)	5 (62%)	10 (83%)	15 (75%)

	French customers			Dutch customers		
Frequency of indicator lights use with LDWS	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**	**11 – 13 months n=8**	**14 – 17 months n=12**	**Total**
Always	4 (57%)	16 (72%)	20 (69%)	5 (62%)	12 (100%)	17 (85%)
frequently	3 (43%)	5 (23%)	8 (28%)	3 (37%)	0	3 (15%)
No response	0	1 (5%)	1 (3%)	0	0	0

Table 53: Change in direction indicator use/frequency of indicator use

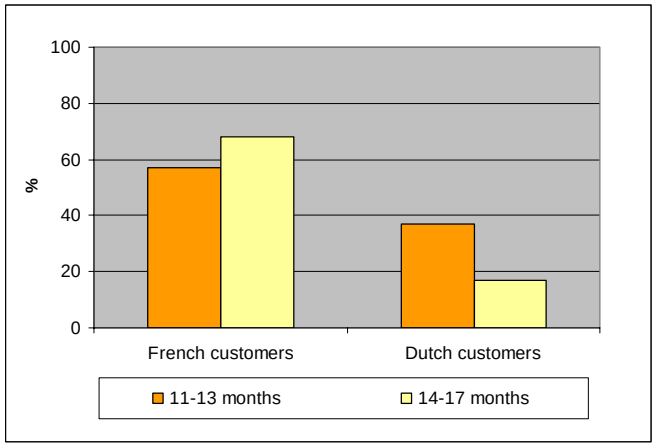


Figure 58: Percentage of customers who indicated to use the indicators more often

Spontaneous comments by French drivers

Interactions with motorcyclist

Around a third of participants explicitly mentioned the use of indicators to warn other vehicles. Since they got the LDWS, they reported that they still deviated to let motorcyclist pass and they did not change the amplitude of lane deviation. Duration of LDWS possession did not affect the behaviour**.**

Mobility

Independent of the duration of LDWS possession, most participants mentioned they did not change their mobility by car since they had the LDWS. They did not plan more frequent short or long trips neither more trips at night, even if they felt safer when driving with the LDWS. Among people that took long trips, only one reported that he changed his travel plan and

management of breaks. He tended to postpone breaks and drove longer since he had the LDWS, even when he got tired.

5.4.2.7 System's use and deactivation

Have you ever switched off the system? If yes, how often and in which situations?

French participants
Participants in Exposure group 2 turned it of less often than in Exposure group 1.
Participants reported they deactivated the LDWS for different reasons:

- Risk of disturbing frequent false alarms (rain, work road, bad coating…)
- Risk of voluntary line crossing when avoiding line crossing is a demanding task due to road geometry (curves, narrow road…)
- No risk of drivers fatigue during short trips
- No necessity to use direction indicator to warn other road users, when there are few users for example
- In urban area when the LDWS is not activated because the speed is lower than 80km/h (limits of system functioning).

Differences between both exposure groups are observed in deactivation of LDWS during these circumstances. Around a third of the participants in Exposure group 2 deactivated the LDWS often when false alarms occurred, while none of the participants of Exposure group 1. Among participants who reported they met false alarms the longer the participants had the LDWS the more they tended to deactivate the LDWS when false alarms occurred. Participants in the Exposure group 1 deactivated the LDWS especially when they thougt the system was useless, which was under the following circumstances:

- When they felt alert and they thought that line crossing would not occur,
- in urban area as they will probably not drive at more than 80km/h considering the speed limit

Participants in Exposure group 2 did not consider deactivating the LDWS, as they state the LDWS did not have any impact on driving. Independent to duration of LDWS possession, half of participants deactivated the LDWS when they made voluntary line crossing (they did not want to avoid line crossing when the curve is tight or the road is narrow). They anticipated the LDWS alarm and switched it off

Dutch participants
Participants of Exposure group 2 tend to switch it off a bit more often compared Exposure group 1 in which the answers where equally parted (50-50)
Participants reported they deactivated the LDWS for different reasons:

- During short trips when the system seemed useless. Short trips are a common reason to switch the system off because people do not get tired and the risk of involuntary lane crossing is minimal. Also when driving on local urban roads the speed rarely exceeds 80 km/hour.

	French participants			Dutch participants		
Have you ever switched off the system?	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**	**11 – 13 months n=7**	**14 – 17 months n=22**	**Total**
Yes	6 (86%)	14 (64%)	20 (69%)	4 (50%)	7 (58%)	11 (55%)
No	1 (14%)	8 (36%)	9 (31%)	4 (50%)	5 (42%)	9 (45%)

Table 54: LDWS deactivation

5.4.2.8 Global satisfaction

Do you want to have this system in your next car? Or do you want it in another current car you have?

French Participants
The majority of participants are satisfied with the LDWS, and they reported that they would like to have the LDWS in their next car.

Dutch participants
Also a majority of the Dutch participants would like to have the LDWS installed in their next car. Although for most participants in Exposure group 2 this depends whether the system comes in a package deal. If so then they are willing to buy it.

5.4.2.9 Summary of long-term effects

Table 55 summarises the results of this study with respect to the long term effects. Table 56 presents the effects on the different levels of the driving task. In this table there an effect of the system is indicated and a change of the system. The last indicates whether there was an effect between exposure groups. The first indicates whether there was an effect of the system which was the same over exposure groups.

	Effect exposure time on LDWS usage	
	French participants	**Dutch participants**
Understanding of LDWS	All participants understood LDWS functioning group 1 = group 2	All participants understood LDWS functioning group 1 = group 2
Perception of warnings	All participants perceived warnings group 1 = group 2	All participants perceived warnings group 1 = group 2
Reaction to warnings	All participants had same reaction depending on manoeuvres or not group 1 = group 2	All participants had same reaction depending on manoeuvres or not group 1 = group 2
Feeling of safety	Increased feeling of safety for all participants but notable feeling for more participants who had the LDWS for longer group 1 < group 2	Majority feels an increase in safety, but more notable for less experienced groups. group 1 > group 2
Deactivation of LDWS	group 1 > group 2 Voluntary line crossing	group 1 < group 2 During short trips
Global satisfaction	High satisfaction group 1 = group 2	High satisfaction group 1 = group 2

Table 55: Summary of exposure time on LDWS use (group 1 (2) = Exposure group 1 (2))

Effect on driving		Effect of duration of LDWS possession	
		French participants	**Dutch participants**
Operational level	**Lateral position**	LDWS helps to have a better lane position for most participants, and the longer they had the LDWS and the more they found the system helps in lane positioning. group 1 < group 2	No change
		LDWS helps to pay more attention to lane position for most participants, and the longer they had the LDWS and the more they paid attention to lane position group 1 < group 2	No change
		Lateral position: the longer participants had the LDWS and the more they changed the lane position (more in the centre) group 1 < group 2	The low exposure group reports more influence of the system group 1 > group 2
		Avoid line crossing: all participants did it rarely or never since they had the LDWS. group 1 = group 2	More experienced drivers touch the white boundaries less. The customers that did touch the white line mentioned this was infrequent and happened because of carelessness and distractions. group 1 < group 2 The crossing of the dotted line (excluding overtaking) happens rarely in both exposure groups and the proportions are the same in both groups group 1 = group 2
	Speed management	no effect	no effect
Tactical level	**Use of indicators**	an effect, no change group 1 = group 2	no effect

Table 56: Summary of long-term effect of LDWS on driving

5.4.3 Results for DVE modelling

An important part of the work performed in AIDE is the Driver-Vehicle-Environment modelling. The present study not only provides information for this modelling with respect to long term effects of an LDWS but also with respect to driving behaviour and age. To this end the participants were divided into three different age groups (see Table 57). This section describes the results of the different questions with respect to driver behaviour and age groups.

age	Number of French participants	Number of Dutch participants
< 56	6 (21%)	7 (35%)
56 – 65	15 (52%)	6 (30%)
> 65	8 (27%)	7 (35%)
TOTAL	29 (100%)	20 (100%)

Table 57: Summary of age groups

5.4.3.1 Driving experience

French participants

In each age group, there is important variability in total number of kilometres covered over a year, independent from the duration of driving licence. However, considering the minimum of kilometres covered over a year and the minimum of years with driving licence, it seems that most participants are experienced drivers. The majority of participants mentioned they can see the white lines.

Age did not affect the mobility by car (total number of kilometres covered over a year).

Dutch participants

Within the outer two age groups there's a large variability in the amount of driven kilometres per year. The middle group does not deviate much from 20.000 km/year.

	French participants			Dutch participants		
Age group	**< 56**	**56 – 65**	**> 65**	**< 56**	**56 – 65**	**> 65**
Total number	6 (21%)	15 (52%)	8 (27%)	7 (35%)	6 (30%)	7 (35%)
Age	34 – 55 Mean = 44.6	57 – 65 Mean = 61.3	66 – 81 Mean = 72	41 – 54 Mean = 48	56 – 65 Mean = 61	66 – 77 Mean = 69.7
Driving licence	11 – 36 years	39 – 46 years	45 – 61 years	24 – 35 years	27 – 47 years	40 – 56 years
km/year	15000 – 28000	10000 – 40000	8000 – 22000	6000 – 28000	20000 – 25000	2500 – 35000
Perception of marking ('yes')	4 (67%)	11 (73%)	7 (87%)	100%	100%	100%

Table 58: Age groups and driving experience

5.4.3.2 Lane position: line crossing

French participants
The majority of participants mentioned they rarely touched the lane markings, or they never did it, since they had the LDWS. Age did not affect the position in the lane.

Dutch participants
As age increases less people touch the white line boundaries**.**
Road positioning during daytime driving was proclaimed to be the same in all age groups (middle)

5.4.3.3 Manoeuvres during daytime driving

During daytime, do you have tendency to - Overtake and change lane as soon as you can or stay in the same lane independently from traffic?

Results are different between French and Dutch customers (see Table 59 and Figure 59)

French participants
French participants did not mention any changes in the frequency of manoeuvres: they reported they overtook as allowed; they did not have any tactical behaviour to avoid changing lane. Age did not affect frequency of manoeuvres and lane changing. There is no compensatory behaviour potentially linked with feeling of stress or apprehension which may increase with age

Dutch participants
Customers that reported to avoid lane changing stated this was because of a relaxed way of driving without haste. Lane changing is not effected by age, almost all customers claim to be relaxed when driving and stated no particular stressful situations (except for restlessness due to traffic jams)

	French participants			**Dutch participants**		
Manoeuvres during daytime	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**	**< 56 n=7**	**56 – 65 n=6**	**> 65 n=7**
Overtake when possible	5 (83%)	13 (87%)	6 (75%)	0	6 (100 %)	3 (43%)
Avoid lane changing	0	2 (13%)	2 (25%)	5 (71 %)	0	4 (57 %)
No response	1 (17%)	0	0	1(14 %)	0	0
Both				1(14 %)	0	0

Table 59: Effect of age in manoeuvres during daytime driving

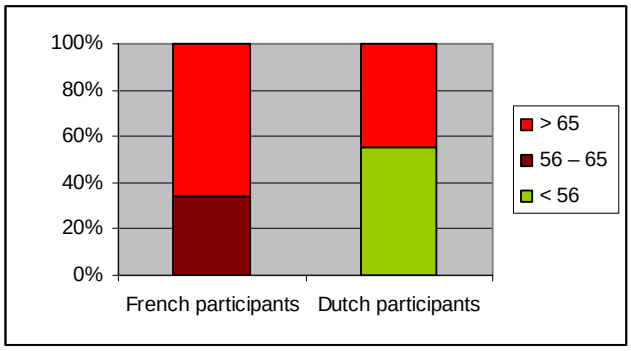


Figure 59: percentage of customers who reported to avoid lane changing during daytime driving

5.4.3.4 Time headway during daytime driving

During daytime, at which distance are you used to drive from the vehicle ahead?

French participants
The majority of participants in each age group reported they drove far enough from the front vehicle, within a judged "safe headway" (see Table 60, Figure 60 and Figure 61).

Dutch participants
All except for one customer report to drive within a safe distance to the cars ahead.
When age increases people tend to have more headway distance beyond the safety limits.
None of the age groups drive predominantly close to the vehicles ahead

	French participants			**Dutch participants**		
Time headway during daytime driving	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**	**< 56 n=7**	**56 – 65 n=6**	**> 65 n=7**
Rather close	1	3	0	0	1 (17 %)	0
Far enough	5 (83%)	12 (80%)	8 (100%)	6 (86 %)	5 (83 %)	4 (57%)
Very far	0	0	0	1 (14 %)	0	3 (43 %)

Table 60: Effect of age in time headway during daytime driving

.

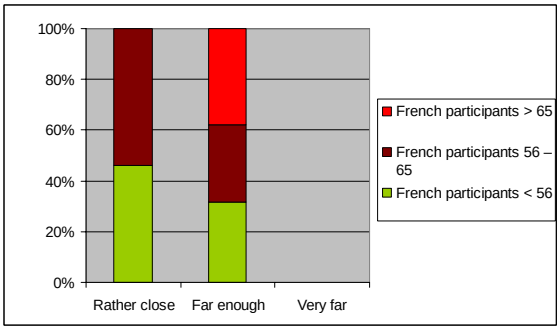


Figure 60 : Time headway management during daytime driving (French)

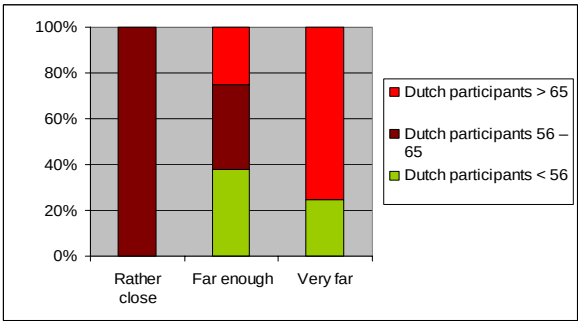


Figure 61 : Time headway management during daytime driving (Dutch

5.4.3.5 Feeling of stress during daytime driving

During daytime, how do you usually feel about driving and at which usual and comfortable speed do you drive on different types of road.

French participants

All participants felt comfortable on highways, on A-roads and secondary roads: age did not affect apprehension of driving . However, it seems that with age (>56 years), more drivers felt stressed on ring roads and on urban roads, where driving task demands are higher (traffic density). Age affects driving task's demands in urban road and ring road, and the feeling of stress.

Dutch participants

On highways nobody reported feelings of stress :age does not effect apprehension on highways. Younger people reported more stress when driving on ring roads or bypasses Age doesn't seem to affect apprehension much on any type of road.

Feel stressed at daytime		French participants			Dutch participants		
		< 56 n=6	**56 – 65 n=15**	**> 65 n=8**	**< 56 n=7**	**56 – 65 n=6**	**> 65 n=7**
Highways	stressed	0	0	0	0	0	0
	No response	0	0	1 (12%)	0	0	1(14%)
A-Roads	stressed	0	1 (7%)	0	-	-	-
	No response	0	0	1 (12%)	-	-	-
Secondary roads	stressed	0	1 (7%)	0	0	1 (17 %)	0
	No response	0	0	1 (12%)	0	0	0
Urban road	stressed	1 (17%)	4 (27%)	1 (12%)	1 (14%)	0	0
	No response	0	0	1 (12%)	0	0	0
Ring road - bypass	stressed	0	4 (27%)	2 (24%)	2 (28 %)	1 (17%)	1 (14%)
	No response	1 (17%)	0	1 (12%)	1 (14 %)	0	0

Table 61: Effect of age in feeling of stress during daytime driving

5.4.3.6 Exceeding speed limit during daytime driving

For each type of road, put a cross either in "rather comfortable" or "rather stressed", and indicate the speed at which you feel comfortable.

French participants
Half of the younger participants (< 56 years) tended to exceed speed limit when driving on highways and on ring road or bypasses. A part of the middle-aged participants (56 – 65 years) mentioned exceeding the speed limit on ring road-bypass, urban road and highways. The senior drivers (> 65) hardly ever exceeded the speed limit, with a small exception for ring roads (see Table 62).

Dutch participants
No participants reported exceeding the speed limit on any type of road.

Type of road	**Exceeding speed limit**	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**
Highways	speed > 130km/h	3 (50%)	3 (20%)	0
	No response	0	5 (33%)	2 (25%)
A-Roads	speed > 110 km/h	0	0	0
	No response	0	0	2 (25%)
Secondary roads	speed > 90 km/h	0	1 (7%)	0
	No response	0	3 (20%)	2 (25%)
Urban road	speed > 50 km/h	0	4 (27%)	0
	No response	0	1 (7%)	2 (25%)
Ring road – bypass	speed > 80 km/h	3 (50%)	6 (40%)	2 (25%)
	No response	0	5 (33%)	3 (37%)

Table 62: Effect of age on exceeding speed limit during daytime driving (French participants only)

5.4.3.7 Frequency of night driving

Excluding the itinerary from home to work, how often do you drive during night time ?

French participants
There were only a few drivers of all participants who avoided driving at night (see Table 63) and these were evenly distributed over age groups. Although there seem to be some differences between age groups in night time driving this probably depend more upon whether they still work and how far they have to commute.

Dutch participants
More frequent driving at night occurs more in the younger age groups. However it is again important to note that hardly anybody avoided driving at night. The 56 – 65 group tends to drive the most at night but this is probably due to other factors related to age (like employment). The most common answer in all age groups is that night driving occurs occasionally.

	French participants			Dutch participants		
Frequency of night driving	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**	**< 56 n=7**	**56 – 65 n=6**	**> 65 n=7**
Several times over a week	0	4 (27%)	0	1(14%)	2 (33%)	0
Several times over a month	5 (83%)	3 (20%)	3 (37%)	0	0	0
occasionally	0	4 (27%)	1 (12%)	2 (28%)	3 (50%)	2 (28%)
Rarely	0	2 (13%)	2 (25%)	2 (28%)	1 (17%)	2 (28%)
Never	0	0	0	2 (28%)	0	2 (28%)
Avoid driving at night	1 (16%)	1 (7%)	2 (25%)	0	0	1 (14%)
No response	0	1 (7%)	0	0	0	0

Table 63: Effect of age in frequency of night driving

5.4.3.8 Manoeuvres during night driving

During night time, do you have tendency to avoid lane changing or overtaking

French participants

Compared to daytime driving, all participants reported changes in frequency of manoeuvres at night. The reasons for participants who mentioned that they would avoided lane changes were the decrease in visibility, the glare and the difficulty to evaluate distances.

The results as presented in Table 64 and Figure 62 suggest a difference between age groups: 50% of youngest participants reported avoiding lane changes while 20% of middle-aged participants and 38¨% elderly participants avoided lane changes.

Dutch participants

In comparison to daytime driving all age groups reported a change in driving manoeuvres at night. Almost all younger participants (< 56 years) avoided lane changes at night, while most middle-aged participants overtook another car when possible. Most senior drivers (> 665 years) avoided lane changes.

	French participants			Dutch participants		
Manoeuvres	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**	**< 56 n=7**	**56 – 65 n=6**	**> 65 n=7**
Overtake when possible	2 (33%)	11 (73%)	5 (62%)	0	4 (66 %)	2 (28 %)
Avoid lane changing	**3 (50%)**	**3 (20%)**	**3 (38%)**	**6 (86 %)**	**2 (34%)**	**3 (44%)**
No response	1 (17%)	1 (7%)	0	1 (14 %)	0	2 (28 %)

Table 64: Effect of age on lane changes and overtaking during night driving

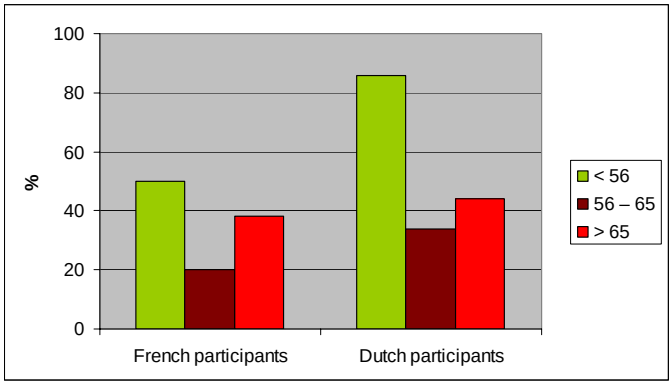


Figure 62 : Percentage of customers who reported to avoid lane changing during night driving

5.4.3.9 Time headway during night driving

During night time driving, how much distance do you keep to the vehicle ahead?

Results are presented in Table 65 and Figure 63 and Figure 64)

French participants
Most participants in all age groups reported to drive "far enough" during night time, the same as during daytime driving. Results did not show any difference with age in headway management during night driving.

Dutch participants
The majority of the participants reported to drive at a distance far enough of leading vehicles.

None reported driving rather close as some did during the daytime. All age groups tend to drive at least at a safe distance at night, the elderly drive at the largest distance from vehicles in front of them.

	French participants			**Dutch participants**		
Time headway during night time	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**	**< 56 n=7**	**56 – 65 n=6**	**> 65 n=7**
Rather close	1 (16.5%)	0	0	0	0	0
Far enough	4 (67%)	14 (93%)	8 (100%)	6 (86%)	6 (100%)	3 (43 %)
Very far	1 (16.5%)	0	0	1 (14%)	0	2 (28 %)
No response	0	1 (7%)	0	0	0	2 (28%)

Table 65 : Effect of age on time headway during night time driving

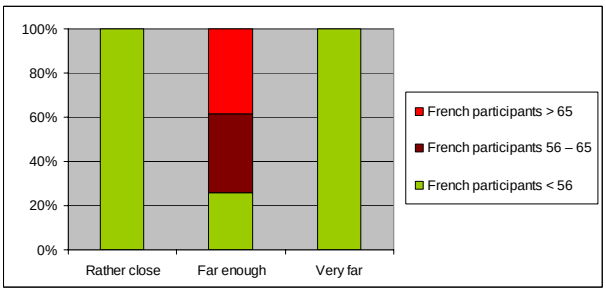


Figure 63 : Time Headway management during night time driving (French)

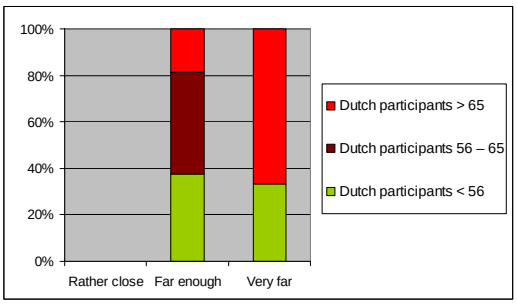


Figure 64 : Time Headway management during night time driving (Dutch)

5.4.3.10 Feeling of stress during night driving

During night time driving, how do you feel when driving on the different types of road?

French participants

On the highways no participants reported any stress while driving during night time. Especially more middle-aged drivers reported stress on the other roads. However, as Table 66 shows most participants did not report any stress on any type of road. On secondary roads, urban roads and ring roads, more elderly participants (> 56 years) reported to be rather stressed than younger drivers.

Dutch participants

On highways and urban roads nobody reported any stress when driving at night, a small percentage showed stress on secondary roads. Ring roads and by passes show the most stress, just like when driving during the daytime. However the majority of participants in all age groups did report any stress while driving at night on any type of road.

		French participants			**Dutch participants**		
Feel stressed during night time driving		**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**	**< 56 n=7**	**56 – 65 n=6**	**> 65 n=7**
Highways	Stressed	0	0	0	0	0	0
	No response	1 (17%)	1 (7%)	2 (28%)	0	2 (28%)	1(14%)
A-Roads	Stressed	1 (17%)	3 (20%)	1 (12%)	-	-	-
	No response	1 (17%)	1 (7%)	2 (25%)	-	-	-
Secondary roads	Stressed	1 (17%)	3 (20%)	2 (25%)	1 (14%)	0	0
	No response	2 (33%)	1 (7%)	1 (12%)	2 (28%)	0	2 (28%)
Urban roads	Stressed	0	3 (20%)	3 (37%)	0	0	0
	No response	1 (17%)	3 (20%)	2 (25%)	2 (28%)	0	2 (28%)
Ring roads - bypasses	Stressed	0	3 (20%)	2 (25%)	0	2 (33%)	1 (14%)
	No response	2 (33%)	2 (13%)	2 (25%)	2 (28%)	0	2 (28%)

Table 66: Effect of age in feeling of stress during night driving

5.4.3.11 Exceeding speed limit during night driving

For each type of road, put a cross either in "rather comfortable" or "rather stressed", and indicate the usual speed you feel comfortable with.

French participants
When driving at night on highways, A-roads or secondary roads, only two participants reported to exceed the speed limit. However, more participants reported exceeding the speed limits on urban roads, and especially on ring roads (almost half of participants). On urban roads more middle aged drivers exceeded the speed limit than in any of the other age groups. On ring roads less senior drivers drove above the speed limit than the other two age groups.

Dutch participants
All customers report to drive the exact speed limit.

Type of road	**Exceeding speed limit**	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**
Highways	speed > 130 km/h	1 (17%)	1 (7%)	0
	No response	2 (33%)	1 (7%)	3 (37%)
A-Roads	speed > 110 km/h	0	0	0
	No response	2 (33%)	1 (7%)	2 (25%)
Secondary roads	Speed > 90 km/h	0	0	0
	No response	3 (50%)	2 (13%)	2 (25%)
Urban road	Speed > 50 km/h	0	4 (27%)	0
	No response	2 (33%)	3 (20%)	3 (37%)
Ring road – bypass	Speed > 80 km/h	3 (50%)	8 (53%)	1 (12%)
	No response	3 (50%)	3 (20%)	3 (37%)

Table 67: Effect of age in exceeding the speed limit during night driving (French participants only)

5.4.3.12 Comparison between daytime and night time driving

During night time, do you think you change the way of driving?

French participants
Results did not suggest any age effect. Participants who reported changes between night and day time driving, mentioned speed reduction, time to headway increase, decrease of overtaking frequency**.**

Dutch participants
The results did not suggest an effect of age on changes in driving between day and night time. Participants all stated that their position within the lane was the same irrespective of daytime or night time driving.

Driving changes between day and night	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**
Changes	2 (34%)	8 (53%)	3 (37%)
No changes	4 (66%)	6 (40%)	5 (63%)
No response	0	1 (7%)	0

Table 68: Effect of age in driving changes between day and night time driving (French participants only)

Is your position in the lane, the same during daytime and night time?

Driving changes between day and night	**< 56 n=6**	**56 – 65 n=15**	**> 65 n=8**
Changes	0	4 (37%)	1 (23%)
No changes	5 (83%)	11 (73%)	7 (87%)
No response	1 (17%)	0	0

Table 69: Effect of age on changes in lane position between day and night driving (French participants only

5.4.3.13 Summary of input DVE model

	Effect of age of French participants	**Effect of age of Dutch participants**
Lane position: line crossing	No effect of age	No effect of age
Manoeuvres during daytime driving	No effect of age	No effect of age
Time headway during daytime driving	No effect of age	Positive correlation only at very far distance
Feeling of stress during daytime driving	with age (>56 years), more drivers felt stressed on ring roads and on urban roads	No effect of age
Exceeding speed limit during daytime driving	youngest drivers more often exceeded speed limit than elderly drivers on highways and ring roads	No effect of age
Frequency of night time driving	No effect of age	No effect of age
Manoeuvres during night time driving	With age, more drivers reported lane changing when traffic allowed it, when driving at night.	Elderly people overtake less when driving at night
Time headway during night time driving	No effect of age	Positive correlation only at very far distance
Feeling of stress during night time driving	With age drivers feel more stressed when driving at night on non-lighted roads or on roads with potentially high traffic density (ring roads).	No effect of age
Exceeding speed limit during night driving	No effect of age	No effect of age
Comparison between daytime and night time driving	No effect of age	No effect of age

Table 70: Summary of age effects on driving

5.5 Discussion

5.5.1 Long term effect of LDWS

French Participants
No major differences were found between exposure groups, that is, between participants who had the LDWS for around one year or close to one year and a half.
Long-term effects on driving depended more on the "attitude of participants": behavioural adaptation is effective for people who considered the LDWS as an educative support system, while adaptation is lower for people who considered the LDWS as a "bring back to order " or "respect of law or highway code" and were not ready to change their behaviour.

Behavioural adaptation reported by participants also depended on the management of driving task demands: for example, some participants reported that they did not care about LDWS system when the traffic density is very low, as the lane deviation or indicator omission did not have any impact on safety.

A large part of participants said they bought the LDWS exclusively because they tended to feel asleep when they drove for long time during daytime or night time, while the LDWS was not designed for this goal: the LDWS was not designed to detect hypo vigilance or inattention episodes even if these parameters can be the causes of lane deviation or manoeuvres without indicators, but the LDWS was designed to assist the driver to adopt a better lateral lane position or to use the indicators more frequently during lane changing.

Dutch Participants
Exposure time did not influence the understanding of the systems functioning. All participants think it's a useful system and the satisfaction levels are high and do not differ with exposure time.

The practical use of the LDWS is different when comparing less experienced users with more experienced users: participants that have had the system for about a year claim to be more influenced in their driving style. They pay more attention to their road position and use the indicators more often because of the LDWS. This change in driving behaviour is possibly not due to the exposure time to the system. Most of the participants think the system is mainly useful when drivers are fatigued or the driving task becomes more demanding, for instance during heavy rainfall.

When these circumstances do not occur some people tend to switch the system off or ignore the alarms. Customers that portrayed this behaviour where more numerous in the group with longer LDWS experience. These customers had more rigid driving behaviour patterns, be it because of old age or intensive driving experience and therefore were less likely to be influenced in their behaviour.

5.6 Conclusion

This study investigated the possible long term effects of driving with a LDWS (Lane Departure Warning System). The study was performed with French and Dutch customers of the Citroen C4 and C5, who owned the system for either 11 - 13 months or for 14 - 17 months.

In general it can be concluded that drivers feel safer when driving with LDWS (both French and Dutch customers). A majority of the drivers also found the system useful. For the Dutch drivers this experience of usefulness does not change with duration of LDWS possession. The French drivers that owned the system for 14 months or longer experienced a higher usefulness than the drivers that owned the system less long.

The results are divided in effects on the operational, tactical and strategical level.
On the operational level it can be concluded that the French drivers indicated that they had a better position within the lanes as a result of driving with LDWS. The longer exposed to LDWS the more they indicated this to be true. Of the Dutch participants, however, about half of the drivers indicated a better position within the lanes and half did not. The French drivers also state that they pay more attention to their position in the lane with LDWS. The longer exposed to LDWS the more they indicated this to be true. The Dutch participants indicate that their attention to the position in the lane has not changed because of LDWS, because they already paid enough attention before they had the system. None of the drivers reported a change in driving speed as a result of LDWS.

On the tactical level, the French reported that they used the indicators more often when driving with LDWS. The Dutch report no change in frequency of indicator use.
Overall the introduction of the LDWS in the Citroen c4 and C5 shows promise for further development of ADAS in cars; people understand the functioning of the system and a majority feel saver because of it regardless of the way they use it. Most participants trust in the systems reliability and use it to their advantage. The way people use the LDWS in their driving routine differs from intrusive to more global use.
The highest reported benefit of the LDWS is when driving task demands are higher and people can rely on the system as a safety backup, the subjective reckoning of the difficulty of the driving task is dependant on driving experience and age.

Although the system has not been designed only to be used during strenuous driving conditions the appreciation of LDWS in this particular way by it's users shows a positive attitude towards ADAS which allows further integration in regular car usage and thus further enhancement of road safety.

6 Discussion and conclusions

The results of the reported studies on long-term effects of different support systems into driving behaviour are summarised below following the COCOM/ECOM model in compliance to SP1 modelling architecture (D1.1.1a, D1.1.3). according to this model driving activity is described in terms of multiple simultaneous control loops, namely tracking, regulating, monitoring and targeting loop, with *the joint driver-vehicle system (JDVS)* as a unit (Hollnagel, 2003).

As mentioned into the introduction, depending on the method used in each study the focus on the various aspects of behaviour adaptation is different. The studies that are based on participants' description of behavioural adaptation (namely the SL-CC and LDWS studies) are more focused at the higher level of *the joint driver-vehicle system (JDVS)* , namely the targeting level. On the other hand, the studies that are based on objective measurements of driving behaviour (namely the ISA and FCW+LDW) studies) are more focused at the lower levels, namely tracking and regulating levels, whereas the possible changes at the targeting level are only implicit. The possible changes at monitoring level were not possible to be evaluated through these studies.

Moreover, depending on the system functionality and its relation to traffic context the behavioural changes due to each system at the different levels of *the joint driver-vehicle system (JDVS)* are presented separately, below.

6.1 Results from the ISA study

Targeting level:

- ISA may have effect on route choice or set-off time for regular trips (e.g. work, or school run), but these were not investigated in the current analyses.

Regulating level:

- ISA would have effect on overtaking behaviour and maybe lane choice and use of indicator etc, but these were not investigated in the current analyses.

Regulating/ tracking level:

- ISA would have effect on throttle input and maybe freq of braking, but these were not investigated in the current analyses.

6.2 Results from the SL-CC study

Targeting level: Decision to use (or not to use) driver support systems available on the vehicle

- Having ones vehicle equipped with driver support systems does not imply using them.
- Gender and age seem to influence the decision to use the systems. Women seem less likely to use the systems than men; younger drivers seem more likely to use a cruise control than older ones.

- The motives for owning the systems as well as the "image" drivers have of the systems (positive or negative) influence the use (or non-use) of the systems.

Monitoring level:
- For a large minority of drivers driving with SL have an impact on managing interaction with other road users.

Regulating level:
- Decisions to activate driver support systems in driving situation and frequency of use closely depend on the situational context (type of roads, traffic condition, weather and visibility conditions). These conditions are more or less discriminative depending of the type of assistance provided (situational conditions are more discriminative for CC than for SL)
- Gender seems to influence the frequency of use for SL: women tend to use SL less frequently than men on urban roads and motorways.

Tracking level:
- Using the systems has beneficial effects as regards speed control (less need to look at the speedometer, lower driving speed, more control over driving speed, avoiding speeding fines) and effort, especially when driving with the CC. SL has a greater effect on speed than CC. Young drivers report less adopting lower speed with SL than older ones

6.3 Results from the FCW/LDW study

LDW long-term effects

Targeting level (implicit):
- People would be eager to adapt driving behaviour according to the LDW, as the subjective ratings of mental effort, system usefulness and satisfaction suggest. Concerns about strategic decisions mentioned should be taken into account.

Regulating level:
- LDW would encourage the more systematic use of direction indicator for lane changes.

Tracking level:
- LDW would result in better lane positioning (lower sd of lateral position and fewer warnings).
- *Longitudinal behaviour* (speed, time-headway): Not affected by LDW.

FCW long-term effects

Targeting level (implicit):
- People would be more concentrated in longitudinal behaviour rather to lateral, as subjective ratings of mental effort, system usefulness and satisfaction suggest.

Regulating level:
- FCW would result in higher variation of lateral position, due to attempts to overtake the lead vehicle, so as to avoid warnings.

Tracking level:
- FCW would result in lower speed and lower percentage of driving with short headways (<1s).

Concurrent LDW + FCW long-term effects

Targeting level:
- At long-term there will be no attempt of people to adapt their driving behaviour, drivers would intentionally ignore the systems, as objective data, subjective ratings of mental effort, system usefulness and satisfaction implicitly suggest, as well as interviews.

Regulating level:
- The concurrent use of FCW and LDW systems would not result in driving at longer distances from the lead vehicle.
- The concurrent use of FCW and LDW systems would not result in increased use of direction indicators for lane changes.

Tracking level:
- The concurrent use of FCW and LDW systems would result in increase of speed with exposure.
- The concurrent use of FCW and LDW would result in increase of time driving in short headways.
- The concurrent use of FCW and LDW systems would have no effect on the lane positioning behaviour.

6.4 Results from the LDWS study

Targeting level:
- Most participants trust in the system reliability.
- The highest reported benefit of the system is when driving task demands are higher and people can rely on the system as a safety backup.

Regulating level:
- Increased use of direction indicators (especially in case of participants who habitually did not use direction lights).

Tracking level:
- Better lane position within lanes, which increases with longer exposure.
- No effect on driving speed due to LDWS.

Based on the above summary of results, the first issue that needs to be mentioned is that the long-term behavioural changes due to the use of a particular support system is highly

influenced by the number of the systems used. In the FCW+LDW study, there was a clear difference in regard to participants' behaviour when these systems were used alone and when these systems concurrently functioned. In the latter case participants intentionally ignored the systems, whereas in the former case, participants attempted to adapt their behaviour in accordance to the support system. Although it is difficult to generalise this result on the basis of only one study, it is certainly an issue that needs to be further investigated in future research.

A second related issue is that not only the number but also the systems' compatibility in terms of systems' functionality seems to play an important role in regard to their long-term effect(s) into driving behaviour. In contrast to the FCW+LDW study, in the SL/CC study where the two support systems were compatible to each other in terms of systems' functionality, no detrimental effects in regard to participants' interaction with the support systems were reported.

On the other hand, considering the long-term effects of stand alone support system there are certainly positive effects, in accordance to the driving assistance function that a system has been designed for. Occasionally, some side-effects either related to system use (e.g. reported side-effect of FCW in lateral behaviour) or to wrong interpretation of system use (e.g. in LDWS study, a large part of participants said they bought the system because they tended to feel sleepy, while the LDWS was not designed for this goal) have to be considered into the systems' design. However, the reported results support the idea either implicitly or explicitly that a stand alone support system could have a positive effect in relation to driving behaviour but the magnitude of long-term effects is more dependent on the "attitudes of participants".

In specific, in the LDWS study behavioural adaptation is effective for people who considered the LDWS as an educative support system, while adaptation is lower for people who considered the LDWS as a "bring back to order " or "respect of law or highway code" and were not ready to change their behaviour. Also, in the SL/CC study it was found that the "image" of the system is an important dimension for understanding the use and acceptance of support systems. Non-users consider that the systems result into "loss of control over the vehicle" and "monotony", whereas users agree with the idea that they afford "peace of mind when driving". More implicit, in ISA studies system compliance data demonstrated a concommittal increase in overriding behaviour and exposure, implying that prolonged use of the ISA system caused frustration amongst participants which manifested itself as increased overriding behaviour. Finally in the FCW+LDW study, when the systems were used as stand alone, there was a slight difference in the behavioural effects that each system induced. The FCW had a negative effect in terms of lane keeping, possibly as a result of individual differences as well as a strategy to minimize the effort needed to maintain the vehicle in the middle of the lane.

A further issue is the length of period needed for perceiving these behavioural changes. For all studied systems there are indications either implicit or explicit that the systems are easy to learn and use, requiring little time to adapt. However the interaction between the driver and a support system increases in line with an increase in system exposure. Thus, time exposure is the most critical parameter for further developing the system "image", and this process cannot be confined in strict time terms, since it is influenced by differences among individual drivers and the characteristics of the driving environment.

7 Contribution to the DVE model

7.1 Contribution from the ISA study

The analysis results demonstrate that drivers adapt their usage of an ADAS system along an increase in system exposure. This has provided implications to different elements of the DVE model.

The **Driver** element: the analyses suggest that the pattern of interaction between the driver and the ADAS system depends on characteristics of individual drivers. Variables tested in the analysis were intention to break speed limit (subjective assessment) and observed speed choice (objective assessment). It was found that intenders and fast drivers overrode the ISA system more than their counterparts, which demonstrates that individuals' characteristics (e.g. attitude) need to be considered in the DVE model.

The **Vehicle** element:
Speed was tested in the analysis but was proven to be insensitive to system exposure. However speed may be a sensitive variable to other ADAS systems.

The **Environment** element: the analyses suggest that the pattern of interaction between the driver and the ADAS system depends on characteristics of the driving environment. Variables tested in the analysis were complexity of road conditions (e.g. road infrastructure and geometry) and traffic conditions (e.g. speed limits and time of week). It was found that drivers overrode the ISA system more frequently in complex environments or denser traffic conditions, which indicates that complexity of driving environments needs to be taken into account in the DVE model.

It is however worth noting that the ISA system used to generate the data for analysis was activated by default but was overridable. If an ADAS system required user activation upon ignition (e.g. most navigation systems), the behavioural adaptation pattern may vary. System functionality (e.g. positive or negative systems) may also affect motivation which would further interact with individuals' characteristics and environment complexity and leads to variations in behavioural adaptation.

7.2 Contribution from the SL-CC study

<u>Generic</u>

- Situational context (type of roads, traffic condition, weather and visibility conditions) influences decisions to use and frequency of use of the systems.

<u>Static parameters</u>

- Age and gender influence the decision to use and the frequency of use of the system. Women seem less likely to use the systems (SL and CC) than men; younger drivers seem more likely to use CC than older ones. Women tend to use less frequently SL on urban roads and motorways.

– The motives for owning the systems as well as the "image" drivers have of the systems influence the use (or non-use) of the systems.

Task demand
– Using a system dedicated for a specific sub-task (speed control for example) may increase the task demand for other sub-task (for example managing interactions with other road user).

7.3 Contribution from the FCW/LDW study

Attitudes
Headway: Use of FCW influences behaviour inducing less following at short time headways (< 1 s)
Lane keeping: Use of LDW influences behaviour inducing steadier lane keeping and more often use of direction lights while changing lane
If own driving style much different than thresholds used for warning, then warnings are ignored as not reliable

Situation awareness
Headway: Use of FCW in long-term: Following at short time headways (< 1 s) is higher than in the first rides, but always less than without the system

Task demand
Use of FCW+LDW, providing audible warnings concurrently and independently, does not influence behaviour, as it creates frustration

7.4 Contribution from the LDWS study

French Participants
Elderly drivers presented differences in driving compared to young drivers: feeling of stress increased in some types of road.
Differences between day and night driving are well-known and are quite close for elderly and young drivers. The differences in mobility depending on age are more linked to the way of life and less to a real apprehension of driving.

Dutch Participants
Although it has been speculated in the hypotheses, age does not have a large impact on the driving behaviour of these participants. Elderly people do tend to drive more cautiously with regard to headway and driving manoeuvres at night.

8 Guidelines to other AIDE SPs

8.1 Input to SP2

8.1.1 Guidelines from the ISA study

The analysis demonstrated that distance was a robust and reliable measure of exposure to an ISA system, as opposite to duration of owning the system.

8.1.2 Guidelines from the SL-CC study

Surveys based on extended questionnaires are important tools for identifying in a quantitative manner the relevant variables likely to influence the use of support systems and behavioural changes associated with their use. Their relevance depends on the theoretical framework used when designing the questionnaires as well as on the previous knowledge about the factors likely to play a role, acquired through previous studies of drivers behaviour in real situations or in driving simulators (for example, critical situations identified in such studies can be included in the questionnaire).

8.1.3 Guidelines from the FCW/LDW study

Interpersonal differences are very significant among drivers, thus distribution of participants among groups should be based on their characteristics, according to the driving task to be studied. For example, when studying a FCW system, participants should be distributed among groups, so that equal percentages of close-followers and non close-followers are in each group. For a LDW system, participants should be distributed according to their lane keeping performance, so that equal percentages of "good" and "bad" lane keepers are in each group.

8.1.4 Guidelines from the LDWS study

Many concerns have been met with interviews with elderly customers, leading to unexploitable verbal data. These issues are already known by SP2.

The only thing new we can bring to SP2 is that if we want to evaluate long-term effects, transversal study presents a constraint as system exposure is difficult to rebuilt (memory of everyday life): results are very approximate, and duration of car possession may not reflect "exposure to the system", especially if the case study is a warning system, as occurrence of warnings are random.

8.2 Input to SP3

8.2.1 Guidelines from the ISA study

The analysis results demonstrated that the existence of long-term behavioural adaptation in the presence of an ADAS system is prominent. However, the evidence for supporting stabilised behaviour is weak. This warrants the need to further extend the investigation

duration of driver behavioural changes in order to fully understand the pattern of long-term behavioural adaptation.

8.2.2 Guidelines from the SL-CC study

Inrets-Renault survey confirms that most drivers do not use the manual for learning to use the system. Furthermore, the result emphasises the important role of the salesman explanation. Women more often than men state that they do not use the systems because they do not how to use them.

8.2.3 Guidelines from the FCW/LDW study

Unless warnings are considered as reliable by the drivers, when compared to their own driving style, they will not be respected. Some kind of "soft" adaptation of warning thresholds should be available. For example, the system could monitor the driving behaviour in the beginning, and allow for some relaxation of the warning thresholds, always of course within safety limits.

Multiple audio warnings are not easily accepted, as they are considered as intrusive and irritating.

8.3 Input to SP4

8.3.1 Guidelines from the ISA study

Better understanding of long-term behavioural adaptation is essential to ensure appropriate guidelines are developed and robust assessment and training procedure are designed.

9 References

Abric, J-C. (2003). Méthode d'étude des représentations sociales. Eres, Toulouse, Saint Agne.

Almqvist, S. & Nygård, M. (1997) Dynamic Speed Adaptation. Field Trials With Automatic Speed Adaptation In An Urban Area. Lund, Department Of Traffic Planning And Engineering, Lth, Lund University.

Almqvist, S., Hydén, C. & Risser, R. (1991) Hastighetsbegränsare I Bil. Effekter På Förares Beteende Och Interaktion. Lund, Institutionen För Trafikteknik, Lth, Lunds Universitet.

Ben-Yaacov, A., Maltz, M., & Shinar, D. (2002). Effects Of An In-Vehicle Collision Avoidance Warning System On Short- And Long-Term Driving Performance. Human Factors, 44(2), 335-342.

Biding, T. & Lind, G. (2002) Intelligent Speed Adaptation (Isa), Results Of Large-Scale Trials In Borlänge, Lidköping, Lund And Umeå During The Period 1999-2002. Borlänge, Vägverket.

Brookhuis, K. & De Waard, D. (1999) Limiting Speed, Towards An Intelligent Speed Adapter (Isa). Transportation Research Part F: Traffic Psychology And Behaviour, 2, 81-90.

Carsten, O. & Fowkes, M. (2000) External Vehicle Speed Control. Executive Summary Of Project Results. Leeds, University Of Leeds.

Carsten, O. & Fowkes, M. (2000). External vehicle speed control. Executive summary of project results. University of Leeds, Leeds, UK.

Comte (1999) On Road Study. Evsc (External Vehicle Speed Control) Project Deliverable 10. Institite For Transport Studies, University Of Leeds, Leeds, Uk.

Cowley, J. E. (1983) Characteristics Of The Speeding Driver. Hawthorn, Victoria, Road Traffic Authority.

Elliott, M. A., Armitage, C. J., & Baughan, C.J. (In Press). Using The Theory Of Planned Behaviour To Predict Observed Driving Behaviour. British Journal Of Social Psychology

Fairclough, S.H., May, A.J., & Carter, C. (1997). The Effect Of Time Headway Feedback On Following Behavior. Accident Analysis And Prevention, 29(3), 387-397.

Falk, E., Hjälmdahl, M., Risser, R. & Várhelyi, A. (2002) Testförarnas Attityd Till Isa : Resultat Från Enkätundersökningar. Lund, Teknik Och Samhälle, Lunds Universitet.

Fields, B., Rumbold, G. & Leening, A. (1991) Speed Behaviour And Drivers' Attitude To Speeding. Melbourne, Monash University Accident Research Centre.

Hinkley, D.V. (1970) Inference About The Change-Point In A Sequence Of Random Variables, Biometrika, 57, 1-17.

Hjälmdahl, M. (2004) In-Vehicle Speed Adaptation - On The Effectiveness Of A Voluntary System. Department Of Technology And Society. Lund, Lund University.

Hoedemaeker, M. (1999). Behavioral Reactions To Advanced Cruise Control: Results Of A Driving Simulator Experiment. In R.E.C.M. Van Der Heijden & M. Wiethoff (Eds.) Automation Of Car Driving – Exploring Societal Impacts And Conditions (Delft: Delft University Press)

Holm, S. (1979) A Simple Sequentially Rejective Multiple Test Procedure, Scandinavian Journal Of Statistics, 6, 65-70.

IMPROVER (2005). Impact of cruise control on traffic, safety, energy consumption and environmental pollution. Interim report Subproject 3. BAST, TNO, TRL, VTI and VUB. TREN-04-ST-S07.37022.

Janssen, W.H. (1979). Routeplanning En –Geleiding: Een Literatuurstudie. (Route Planning And Guidance: A Literature Survey. Report Izf 1979 C-13). Instituut Voor Zintuigfysiologie Tno, Soesterberg, The Netherlands.

Kaufmann, C. (2002) Behaviour Of Car Drivers On Austrian Motorways On Weekends. Ictct Workshop. Nagoya, Japan.

Land, M.F., & Tatler, B.W. (2001). Steering With The Head: The Visual Strategy Of A Racing Driver. Current Biology, 11, 1215-1220.

Michon, J.A. (1985). A Critical View Of Driver Behavior Models: What We Know, What Should We Do? In L.Evans And R.C. Schwing (Eds.) Human Behavior And Traffic Safety (New York: Plenum Press), Pp. 485-524.

Neisser, U. (1976). Cognition And Reality: Principles And Implications Of Cognitive Psychology (San Francisco: W.H. Freeman And Company).

Parker, D., Lajunen, T, S., & Stradling, S. G. (1998). Attitudinal Predictors Of Interpersonally Aggressive Violations On The Road. Transportation Research Part F, 1, 11-24.

Parker, D., Manstead, A. S. R., & Stradling, S. G. (1995). Extending The Theory Of Planned Behaviour: The Role Of Personal Norm. British Journal Of Social Psychology, 34, 127-137.

Parker, D., Manstead, A.S.R., Stradling, S.G., Reason, J. T., & Baxter, J. S. (1992a). Intention To Commit Driving Violations: An Application Of The Theory Of Planned Behavior. Journal Of Applied Psychology, 77, 94-101.

Persson, H., Towliat, M., Almqvist, S., Risser, R. & Magdeburg, M. (1993) Hastighetsbegränsare I Bil. Fältstudie Av Hastigheter, Beteenden, Konflikter Och Förarkommentarer Vid Körning I Tätort. Lund, Institutionen För Trafikteknik, Lunds Universitet.

Reinforcement. Psychological Monographs: General And Applied, 80.

Rotter, J. B. And Hochreich, D. J. (1975) Personality. Glenview, Illinois: Scott Foresman.

Rotter, J.B. (1966) Generalized Expectancies For Internal Versus External Control Of

Rudin-Brown, C. M., & Parker, H. A. (2004) Behavioural Adaptation To Adaptive Cruise Control (Acc): Implications For Preventive Strategies. Transportation Research Part F, 7, 59-76.

Saad, F. & Malaterre, G. (1982) Régulation de la vitesse: aide au contrôle de la vitesse. Synthèse. Rapport ONSER.

Saad, F., Vezier, B., Dionisio, C., Arslanian, E., Collaciuri, V., and Legay, F. & Timianguel, J. (2006). Learning phase and short term behavioural effect of Speed Limiter and Cruise Control systems. In R.F.T. Brouwer, D.M. Hoedemaeker (Eds.), Driver support and information systems: Experiments on learning, appropriation and effects of adaptiveness. AIDE IST-1-507674-IP, Deliverable D1.2.3.

Shinar, D. And Compton, R. (2004) Aggressive Driving: An Observational Study Of Driver, Vehicle, And Situational Variables. Accident Analysis & Prevention, 36 (3), 429-437.

Shinar, D., & Schechtman, E. (2002). Headway Feedback Improves Intervehicular Distance: A Field Study. Human Factors, 44(3), 474-481.

Summala, H. (1988). Risk Control Is Not Risk Adjustment: The Zero-Risk Theory Of Driver Behavior And Its Implications. Ergonomics, 31(4), 491-504.

Summala, H., Lamble, D., & Laakso, M. (1998). Driving Experience And Perception Of The Lead Car's Braking When Looking At In-Car Targets. Accident Analysis And Prevention, 30(4), 401-407.

Summala, H., Nieminen, T., Punto, M. (1996). Maintaining Lane Position With Peripheral Vision During In-Vehicle Tasks. Human Factors, 38(3), 442-451.

Taieb, M., & Shinar, D. (2001). Minimum And Comfortable Driving Headways: Reality Vs. Perception. Human Factors, 43(1), 159-172.

Thomas, F. (2001) A Bayesian Approach To Retrospective Detection Of Change-Points In Road Surface Measurements, Doctoral Dissertation, Department Of Statistics, Stockholm University, Stockholm.

Van Der Laan, J., Heino, A. And De Waard, D. (1997). A Simple Procedure For The Assessment Of Acceptance Of Advanced Transport Telematics. Transportation Research, Part C, 5, 1-10.

Varhelyi, A. & Makinen, T. (2001) The Effects Of In-Car Speed Limiters: Field Studies. Transportation Research Part C: Emerging Technologies, 9, 191-211.

Várhelyi, A. (1997) Dynamic Speed Adaptation Based On Information Technology - A Theoretical Background. Department Of Traffic Planning And Engineering. Lund, Lund University.

Varhelyi, A. (2002) Speed Management Via In-Car Devices: Effects, Implications, Perspectives. Transportation, 29, 237-252.

Várhelyi, A., Hydén, C., Hjälmdahl, M., Almqvist, S., Risser, R. & Draskóczy, M. (2002) Effekterna Av Aktiv Gaspedal I Tätort. Sammanfattande Rapport Lundaisa. Lund, Sweden, Institutionen För Teknik Och Samhälle.

Webster, D. C. & Wells, P. A. (2000) The Characteristics Of Speeders. Crowthorne, Uk, Transport Research Laboratory.

Wilde, G. J. S. (1982) The Theory Of Risk Homeostasis: Implications For Safety And Health. Risk Analysis, 2, 209-225.

Wilde, G. J. S. (1988) Risk Homeostasis Theory And Traffic Accidents: Propositions, Deductions And Discussion Of Dissension In Recent Reactions. Ergonomics, 31, 441-468.

Wilde, G.J.S. (1982). The Theory Of Risk Homeostasis: Implications For Safety And Health. Risk Analysis, 2, 209-225.

Wilde, G.J.S. (1988). Risk Homeostasis Theory And Traffic Accidents: Propositions, Deductions And Discussion Of Dissension In Recent Reactions. Ergonomics, 31(4), 441-468.

Zitkovitz, D.C., & Harris, L.R. (1999). Effects Of Gravito-Inertial-Force And Vision On Head Tilt During Driving. In A.G. Gale Et Al. (Eds.) Vision In Vehicles – Vii (Amsterdam: Elsevier), Pp. 281-288.

Annex 1: The ISA-UK Project

A1.1 The ISA System

A1.1.1 Vehicles

The final selection for the ISA Phase 1 development, and subsequent fleet installation was made of the Skoda Fabia Elegance 1.4 litre estate. This vehicle was judged as the most appropriate package to address the declared needs of the ISA trial. The vehicle model is illustrated in Figure 65.

Figure 65: ISA fleet vehicle

Two computers were installed, the first to provide the information function (i.e. vehicle position and current speed limit), and the second to provide control (speed limiting) and data recording.

The overall concept was to integrate ISA system components and functionality into each vehicle so that the user would feel that the system had been installed as original equipment. In terms of user interface, the vehicles appeared much like “normal” cars. The main visible elements were:

An additional LCD which was mounted centrally within the instrument cluster. This displayed ISA system status and speed limit information. It is easily seen through the steering column and has character sizing, contrast and format to the other OEM supplied LCD displays in the cluster.

Two illuminated steering wheel mounted ISA reject (red) and ISA resume (green) buttons.

The following figure shows the steering wheel and instrument cluster. There was also a system disable button within the dashboard for use in the event of an emergency.

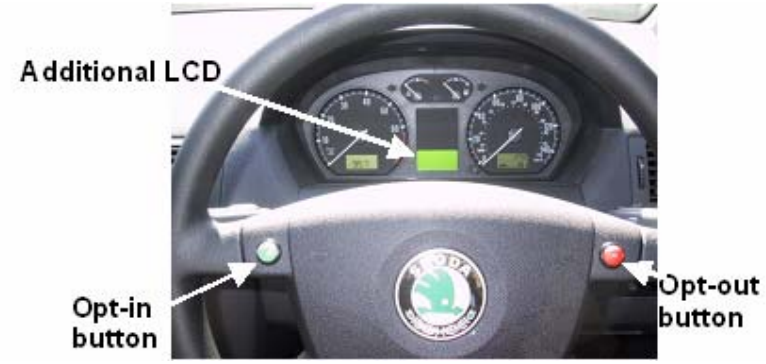


Figure 66: Steering-wheel-mounted buttons and ISA screen

Figure 67: ISA brake actuator

During the ISA active period, the system defaulted to being on and speed limit support was provided on all roads for which speed limit information was available. The LCD display indicated the speed limit. Elsewhere, the display would show "??" as the speed limit to indicate that the information was not available. Changes in speed limit were reinforced with an auditory beep. Driver demand for more throttle than required to keep within the speed limit was cancelled by the ISA system. Pushing the throttle pedal to a position substantially more than needed when cruising at or around the speed limit was discouraged through a vibration on the pedal. Mild check braking was also provided at a point roughly 10% over the speed limit. This would prevent the car speeding up too much on downhill gradients and would also slow the car if necessary on entry to lower speed zones. This braking was provided by an external actuator on the brake pedal as shown in Figure 67.

A1.1.2 Digital speed limit map

The speed limit map installed on one of the computers in the vehicle's boot provided essential information for the ISA system to function correctly.

A1.1.2.1 Coverage of the Leeds digital speed limit map

Leeds Metropolitan District covers an area illustrated in the following figure.

Figure 68: Leeds Metropolitan District

The area is run by Leeds City Council and it was their Highways Department that supplied the speed limit information in the form of paper files containing Council Speed Orders. The Leeds Metropolitan District is made up of 1890.09 miles of road. Table 1 describes the length of road for each road type with the majority road type being unclassified and the smallest type dual carriageway trunk roads.

Road Type	Total length (miles)
Motorway	42.25
Dual Trunk	8.08
Single Trunk	28.46
A Dual	38.09
A Single	109.92
B	44.12
C	93.33
Unclassified	1525.84
Total for all road types	1,890.09

Table 71: Breakdown of length of road in the Leeds Metropolitan District

Speed limits ranged from 20 mph to 70 mph within Leeds Metropolitan District. Figure 69 shows the distribution of speed zones on the digital speed map, which indicates that the majority of the roads in the Leeds trial area were 30 mph. Figure 70 is a snapshot of the digital speed map, which clearly highlights the dominance of 30 mph roads as well as six 20 mph zones.

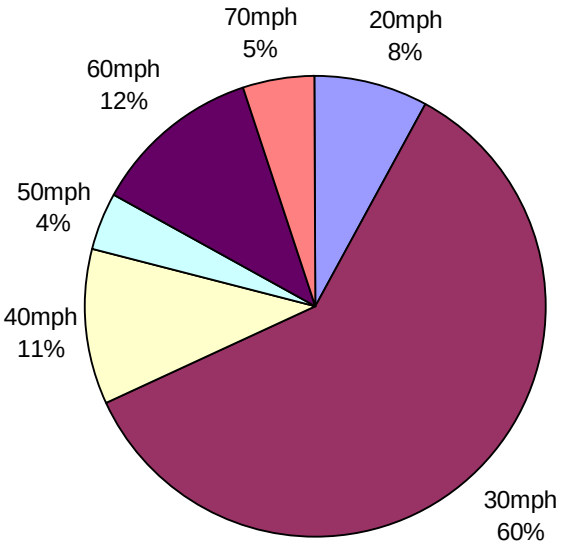


Figure 69: Distribution of speed zones in Leeds Metropolitan District

The council supplied the street data in the form of OSCAR Asset-Manager shape files containing data released in November 2001. OSCAR Asset-Manager is an Ordnance Survey data product that provides a digital representation of the Road network of Great Britain derived from the Ordnance Survey ROADS database. OSCAR Asset-Manager has centrelines of all publicly accessible and maintained roads. Private and pedestrian roads have been included where possible (Ordnance Survey, 2001). The digital street map has 1m accuracy. The Council supplied the vector data in a link and node structure – where links are road centrelines and nodes are intersections of links, with attributes attached to each feature (Burrough and McDonnell, 1998).

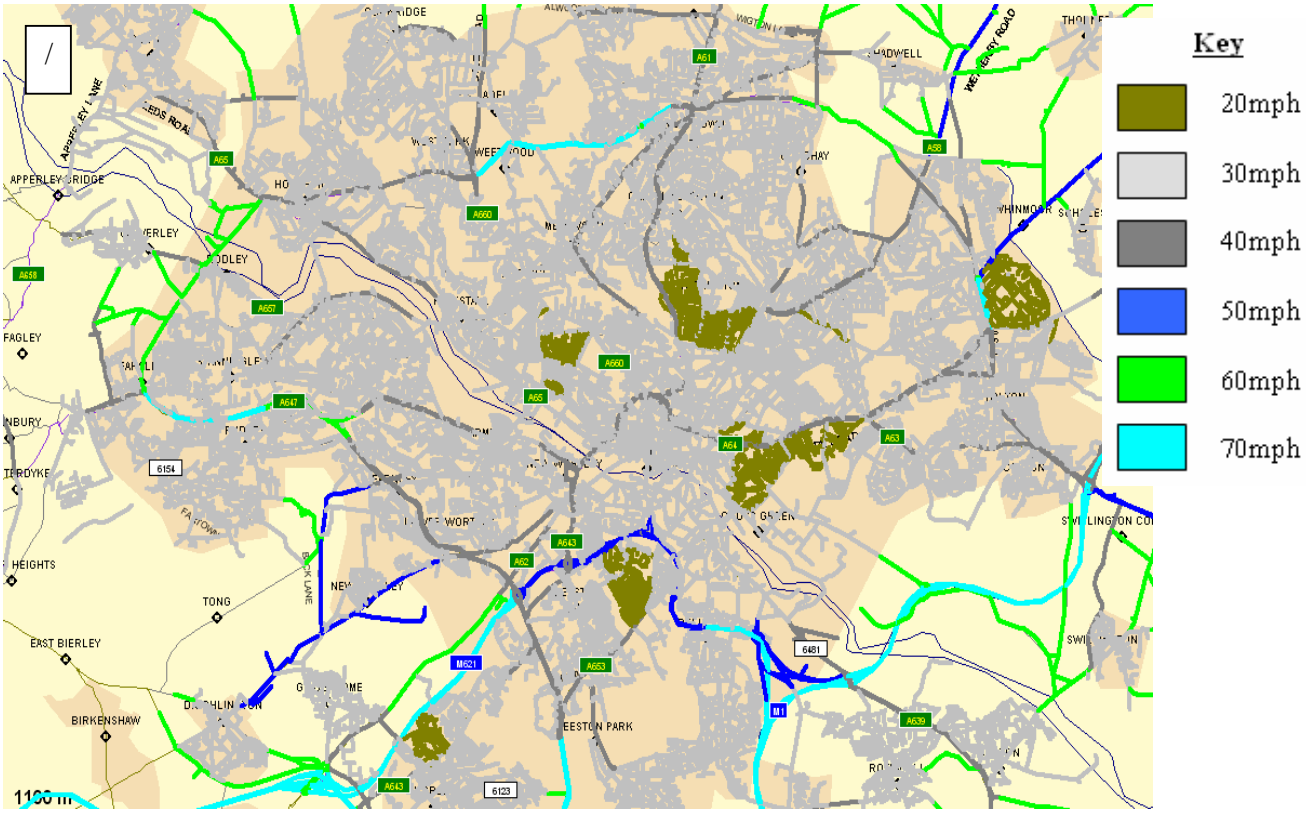


Figure 70: A map to illustrate the speed limit distribution within the Leeds Metropolitan District

A1.1.2.2 Coverage of the Leicestershire digital speed limit map

A new version of the speed limit map was developed for Trial 3 and 4 covering South West Leicestershire area. Table 72 shows the length of road for each road type, while the map boundary and distribution of speed limit zones are illustrated in Figure 71 and Figure 72.

Road Type	Total Length (miles)
Motorway	59.12
Dual Trunk	29.15
Single Trunk	17.92
A Dual	66.16
A Single	66.20
B	74.02
C and unclassified	1,161.88
Total for all Road Types	1,474.45

Table 72: Total length of road for each road type

Note: C and Unclassified Road are grouped together, as they were calculated using Ordnance Survey OSCAR Traffic-Manager data, which uses “feature code 3004 for minor or other roads…including C roads” (Ordnance Survey, 2001)

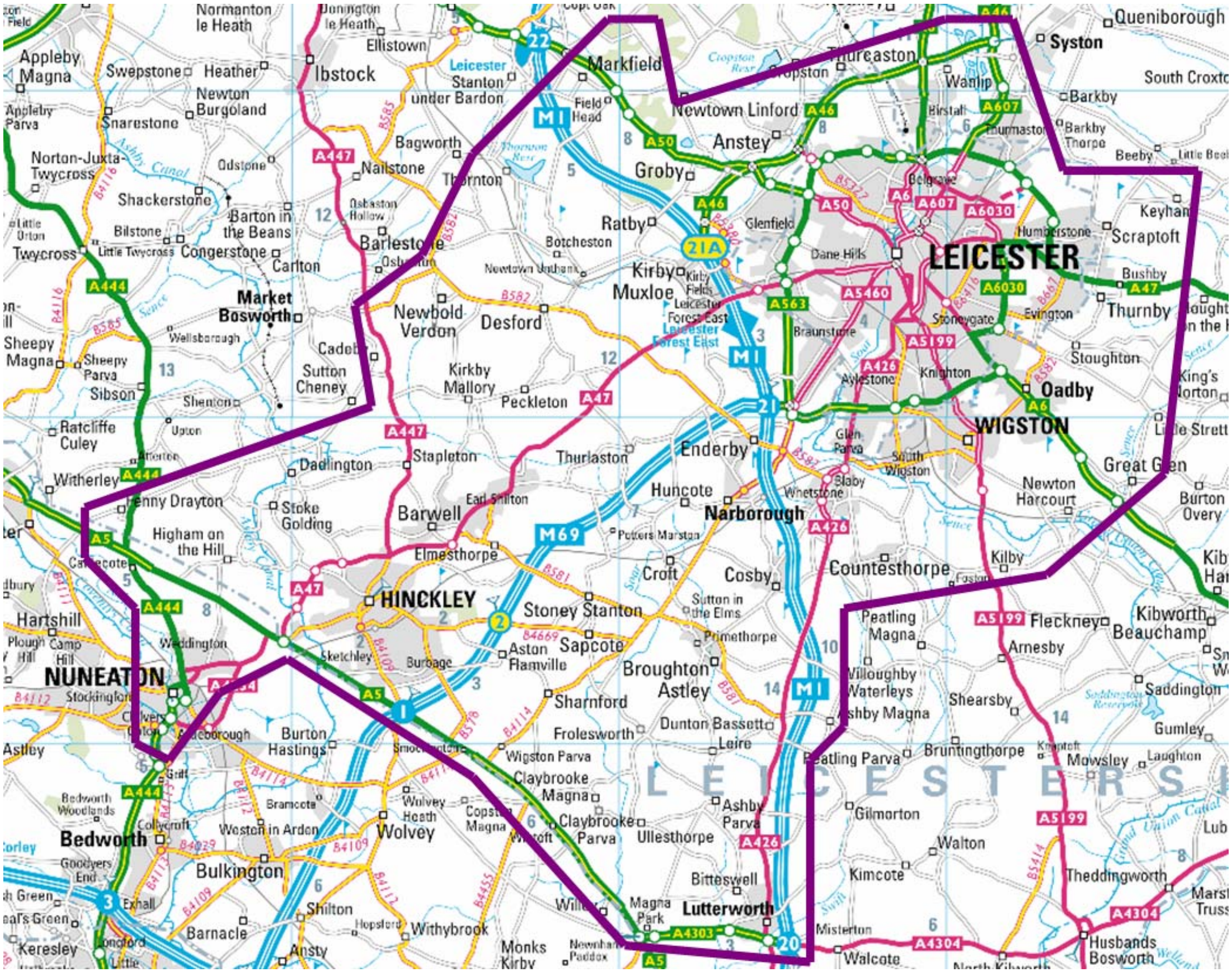


Figure 71: Boundary of the South West Leicestershire speed limit map

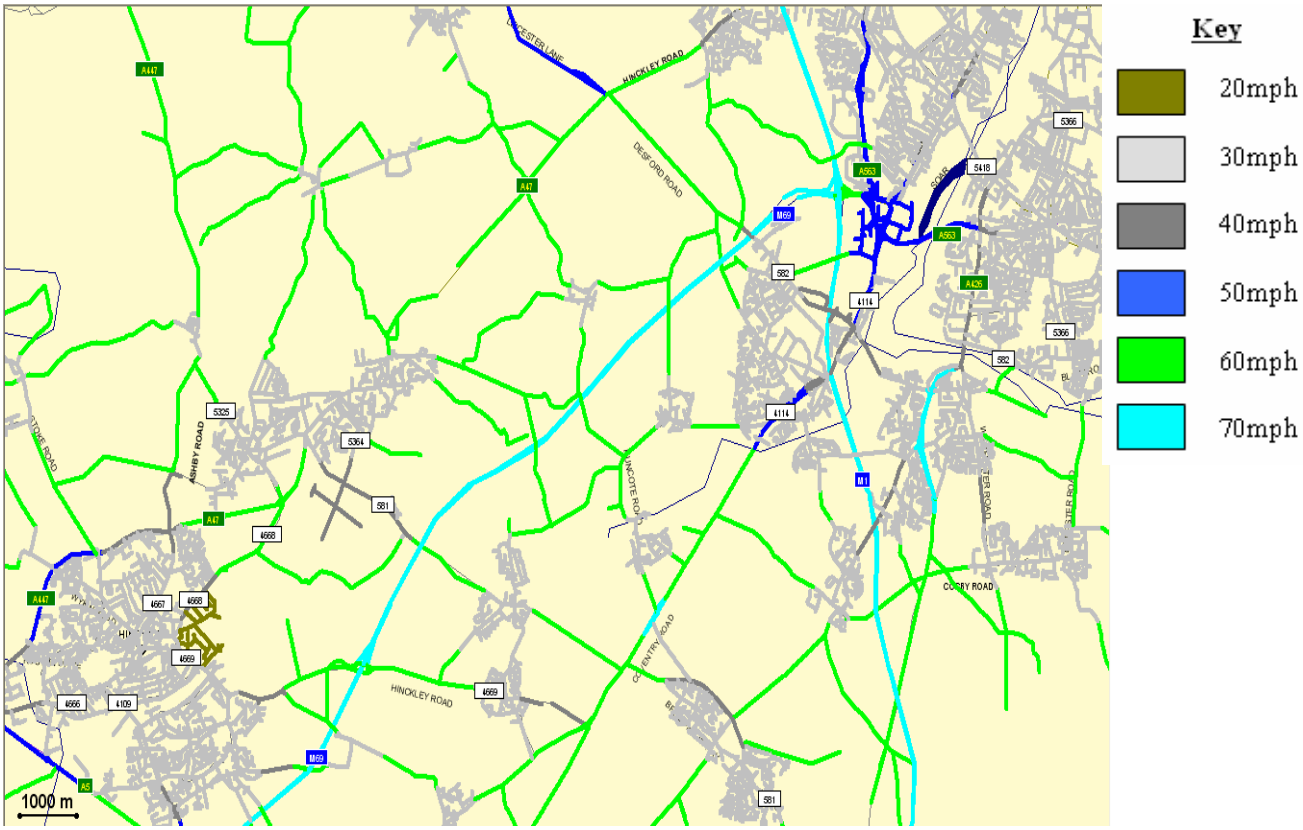


Figure 72: Illustration of speed limit distribution within the South West Leicestershire area

Figure 72 illustrates the distribution of speed zones within the map boundary (as defined in Figure 73). Speed limits ranged from 20 mph to 70 mph but the majority of the roads in the trial area were in the 30 mph zone. This is due to the inclusion of the whole Leicester City in the speed limit map, although most areas within the survey boundary were rural.

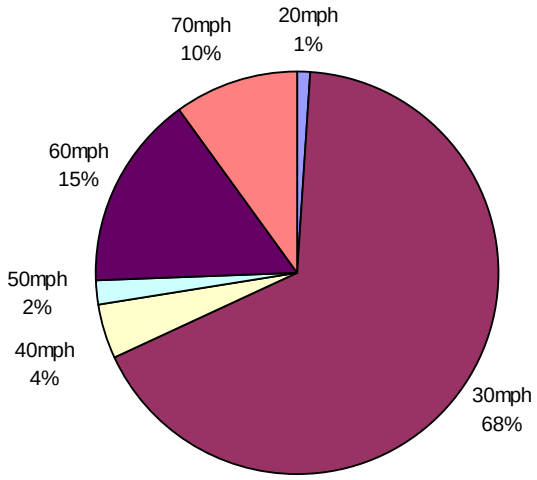


Figure 73: Distribution of speed zones in the South West Leicestershire area

A1.2 Field Trial Methodology

A1.2.1 Trial design

The field trial adopted an 'A-B-A' (i.e. ISA off, ISA on, ISA off) design with three distinct phases over 6-month trial duration, as illustrated in Figure 74.

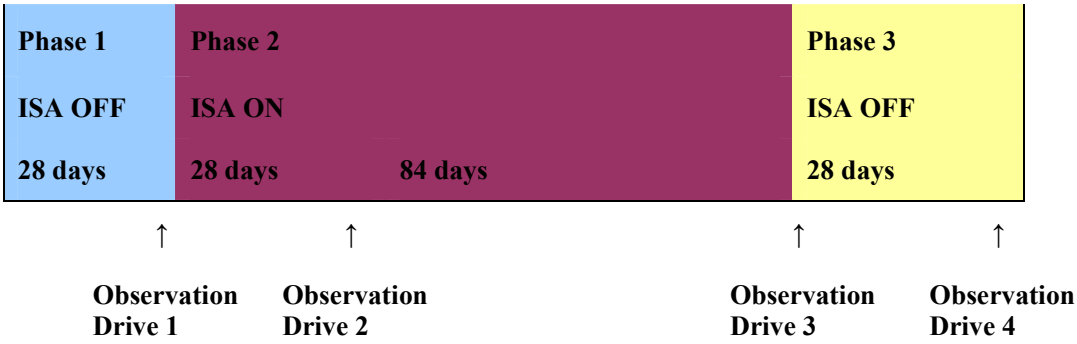


Figure 74: Field trial phases

Each participant was assigned to a vehicle and asked to undertake their normal travel behaviour for four weeks (i.e. Phase 1). This period allows the measurement of baseline driving behaviour, and therefore any changes in behaviour in the presence of ISA can be evaluated. At the end of the phase, participants attended an observation drive accompanied by two members of the research team. Upon finishing the observation drive, the ISA system was switched on, and participants subsequently started driving with ISA activated on a full-time basis (i.e. Phase 2).

When participants had driven the car with ISA activated for four weeks, they attended the second observation drive, and then carried on another 12-week driving period with ISA activated. This extended period of ISA driving over sixteen weeks provided the participants with the opportunity of experiencing all kinds of traffic scenarios and environments, and minimised the occurrence of novelty effects in the data collected.

At the end of Phase 2, participants attended the third observation drive. Upon finishing the observation drive, the ISA system was switched off. Participants subsequently started driving for another four weeks (i.e. Phase 3). When participants had completed Phase 3, they also attended the fourth observation drive. This phase of the trial was designed to assess any carry-over effects that ISA may have imposed on participants' driving style.

A1.2.2 Recruitment

All participants were recruited in response to advertisements placed in local newspapers.

A1.2.2.1 Selection criteria

Several criteria were used when selecting the participants:

Current vehicle status

Respondents were asked to describe the vehicles that they have access to in terms of vehicle make, model and its age. This information was used to ensure that those respondents who are participating in order to "drive a new car for a while" were discarded. Respondents were also asked to state the proportion of their driving spent in this car in order to exclude multi-vehicle users (as this would introduce noise into the data).

Exposure

The success of the data collection procedure depended, in part, on the amount of driving undertaken within the specified digital map area. Therefore selection was also based upon:

- Average annual mileage
- Monthly mileage within [specified map] area
- Typical weekly exposure (weekday/weekend)
- Exposure on different road types (urban/rural/motorway)
- Selected participants tended to:
- Have an average annual mileage exceeding 10,000 miles
- Undertake at least 80% of their driving within the specified map area
- Demonstrate average mileage proportions by weekday/weekend split (based on NTS data)
- Demonstrate average exposure rates to different road types (based on NTS data)

Accidents and driving convictions

A full driving history was obtained from the respondents, including details of any driving convictions they had. Respondents who had been convicted of driving under the influence of alcohol or other illicit substances and those who have been involved in more than two accidents in the previous three years were discarded. By eliminating these high-risk drivers, it was hoped that the likelihood of serious incidents would be minimal.

Attitudes

A common problem with safety studies is that samples can be skewed with regards to the types of people that volunteer for them. It was the aim of the project to include participants with a wide range of opinions relating to ISA and speeding behaviour. Participants were grouped into 'intenders' and 'non-intenders' based on participants' intention to exceed the speed limit. This classification was regarded as more reliable than the original intended grouping method which was based on participants' attitudes towards a system with which they had no experience. The respondents were asked to complete a questionnaire that identified their general intentions to exceeding the speed limit on an urban road and motorway using the Theory of Planned Behaviour. Intentions were assessed by 3 items 'I would intend to exceed the 70mph speed limit on a motorway', strongly disagree-strongly agree, scored −3 to +3. Participants were selected to reflect those who intended to speed (scores above 0) and those who did not (scores below 0).

Demographics

Attempts were also made to balance the samples for gender and age. It was intended to polarise participants into two age groups (25-39; 40-60). Due to participant drop out, we had to recruit some participants younger than 25 years.

A1.2.3 Participants

Once selected, participants were required to sign an agreement between the University of Leeds and themselves covering issues such as data collection, insurance claims and car maintenance issues. Due to participant drop out over the course of the trials, an entirely balanced sample was not achieved. On some occasions participants also lived *or* worked outside the mapped area. Although every attempt was made to recruit within the mapped area, low response rates made this unavoidable. The final selection of participants across the first three trials is shown in Table 74.

			Trial 1	Trial 2	Trial 3	Total
Male	Young	Intender	3	4	2	9
		Non Intender	2	3	1	6
	Old	Intender	2	6	4	12
		Non Intender	3	4	2	9
Female	Young	Intender	1	1	3	5
		Non Intender	5	1	2	8
	Old	Intender	2	1	1	4
		Non Intender	3	-	5	8

Table 73: Number of participants across trials by sex, age and intention group

Trial 1				Trial 2				Trial 3			
Participant	Gender	Age	Intention Group	Participant	Gender	Age	Intention Group	Participant	Gender	Age	Intention Group
1	Male	young	intender	30	male	young	intender	50	male	young	intender
2	Male	young	intender	31	male	young	intender	51	male	young	intender
3	Male	young	intender	32	male	young	intender	52	male	young	non intender
5	Male	young	non intender	33	male	young	intender	53	male	old	intender
6	Male	young	non intender	34	male	young	non intender	54	male	old	intender
7	Male	old	intender	35	male	young	non intender	55	male	old	intender
8	Male	old	intender	36	male	young	non intender	56	male	old	intender
9	Male	old	non intender	37	male	old	intender	57	male	old	non intender
10	Male	old	non intender	38	male	old	intender	58	male	old	non intender
11	Male	old	non intender	39	male	old	intender	59	female	young	intender
12	female	young	intender	40	male	old	intender	60	female	young	intender
13	female	young	non intender	41	male	old	intender	61	female	young	intender
14	female	young	non intender	42	male	old	intender	62	female	young	non intender
15	female	young	non intender	43	male	old	non intender	63	female	young	non intender
16	female	young	non intender	44	male	old	non intender	64	female	old	intender
17	female	old	intender	45	male	old	non intender	65	female	old	non intender
18	female	old	intender	46	male	old	non intender	66	female	old	non intender
21	female	old	non intender	47	female	young	intender	67	female	old	non intender
22	female	old	non intender	48	female	young	non intender	68	female	old	non intender
23	female	old	non intender	49	female	old	intender	69	female	old	non intender

Table 74: Characteristics of Participants

A1.2.4 Data completeness

As specified above, each participant was expected to generate 168 days of travelling data. Interruption to data collection was attributable to various ISA system failures. Throughout the three trials participants had to be given replacement cars following system failures which caused consequent interruption to data collection. Due to the technical difficulties, some participants were not able to contribute the full 168-day data within the sustainable time frame. The overall completion rate for each trial is shown in Table 75.

A1.2.5 Data processing

Although the data logging system in the vehicle generates data at 10Hz (i.e. 10 records per second), data used for this analysis was distance based rather than time based. While time based data is intuitively valid, it introduces undue weight to the data stream when vehicle speed is zero (e.g. the vehicle stops at junctions) or very low (e.g. the vehicle moves slowly on a congested road). Conversion algorithms were therefore developed for extracting a record per 5 metres of travelling distance from the data stream. This data processing also filtered out records without a valid speed limit attached to them, attributable to the vehicle being driven on roads which were not given speed limits by NavTech, such as private roads (e.g. supermarket car parks) or non-trunk roads outside the mapped areas.

Weighting across participants to equalise individuals' contribution of travel distance during the trials to the data was considered in order to prevent the data from being possibly distorted by participants with high annual mileage. However, it was eventually decided not to apply weights to retain a valid representation of the sample against the whole driving population, as annual mileage inherently differs from one driver to another.

Trial 1			Trial 2			Trial 3		
Participant ID	Completed days	Completion rate (%)	Participant ID	Completed days	Completion rate (%)	Participant ID	Completed days	Completion rate (%)
1	161	95.8	30	160	95.2	50	168	100.0
2	168	100	31	157	93.5	51	155	92.3
3	168	100	32	161	95.8	52	164	97.6
5	168	100	33	155	92.3	53	167	99.4
6	168	100	34	147	87.5	54	168	100.0
7	129	76.8	35	156	92.9	55	161	95.8
8	168	100	36	158	94.0	56	168	100.0
9	168	100	37	157	93.5	57	168	100.0
10	168	100	38	155	92.3	58	168	100.0
11	168	100	39	163	97.0	59	168	100.0
12	168	100	40	165	98.2	60	168	100.0
13	168	100	41	147	87.5	61	123	73.2
14	168	100	42	131	78.0	62	145	86.3
15	168	100	43	163	97.0	63	165	98.2
16	168	100	44	116	69.0	64	168	100.0
17	168	100	45	164	97.6	65	168	100.0
18	168	100	46	143	85.1	66	152	90.5
21	150	89.3	47	154	91.7	67	168	100.0
22	146	86.9	48	141	83.9	68	154	91.7
23	144	85.7	49	164	97.6	69	166	98.8
Overall completion rate		96.7	Overall completion rate		91.0	Overall completion rate		96.2

Table 75: Data completeness across trials

A1.2.6 Vehicle Kilometres

Following data processing and reduction, the final data file ready for analysis represented a total travel distance of 146,697 kilometres for trial 1, 115,937 kilometres for trial 2 and 166,509 kilometres for trial three. A breakdown of vehicle kilometres with respect to speed zones illustrated that the largest portion of vehicle kilometres was attributable to 30 mph zones, followed by 70 mph zones in both Leeds trials (trials 1 and 2). For trial three, the rural Leicestershire trial, the largest portion of vehicle kilometres was attributable to 70 mph zones, followed by 30mph zones. Unsurprising in both trials 1 and 2 most of the vehicle kilometres were recorded in urban areas (i.e. 20, 30, and 40 mph zones, which contributed to 69.2% and 52% respectively of total vehicle kilometres). Within trial 3 the majority of the travel occurred in rural areas, as the vehicle kilometres recorded in the 50, 60, and 70 mph zones accounted for 63% of the total vehicle kilometres. Even if the 50mph zone is left out, the sum of 60 and 70 mph zones was still well over 50%.

Table 76 provides a further breakdown of the proportion of vehicle kilometres across speed zones and trials. Given that the current study focuses on behavioural adaptation to the system, only data collected during ISA activation (Phase 2) is reported. As mentioned the proportion of travel across different road types varies according to trial. Adaptation to the system will therefore be examined individually within trials.

Speed zone	**Vehicle Kilometre**		
	Urban Private	**Urban Fleet**	**Rural Private**
20 mph	380	81	66
30 mph	36,617	23,728	27,147
40 mph	19,074	12,429	10,468
50 mph	5,844	4,681	6,376
60 mph	11,339	6,897	25,812
70 mph	22,451	20,651	32,688
Sum	95,705	68,467	102,556

Table 76: Vehicle Kilometres accrued during Phase 2 across trials

Annex 2: Interview of LDWS study on AFIL system

General instructions for the interviewer

To read carefully before each interview

1. Relation interviewer/person interviewed

Questions used to guide the interview will deal with AFIL system:
- its use, its efficiency– usefulness
- the safety feeling
- Behavioural changes in driving habits.

☞ Focus the speech on the AFIL system and not on the customer, in order to avoid the customer to feel judged and allow him to speak freely.
☞ Put the customer in confidence as possible
☞ Be aware and avoid to the position « dominated-dominant »
☞ Do not be prying nor pass value judgment
☞ Be aware of risk of suggestion and induction of responses
☞ Note customers' attitudes: it is possible that the customer gets defensive (induced by verbal behaviour or a non appropriated question). He can also try either to conform himself or on the contrary to be in complete opposition
☞ See the quality of answers: to try to obtain precise answers.

Observations of the customer and questions that the interviewer has to keep in mind during the interview:

- Does he show a real interest for the study?
- Is he implicated in the study or does he want to finish quickly?
- Does he show signs of impatience, irritation, and nervousness?
- Do the questions disturb him (how does he perceive the questions: too personal, useless…) ?
- Are questions understandable or badly formulated? Does he ask for more information or examples?
- Does he ask many questions? Why? Is this mistrust, apprehension, difficulty to understand questions?
- Does it tend to deviate from the topic? Is it frequent? Why?
- Are there any silences? Why?
- Does he refuse to answer? Why?

2. Relation between the person interviewed and her environment

- Does the customer agree with the choice of the interview's location?
- Does the environment disturb him?
  Did he choose it?
  If not, does he accept easily, is he constrained, does he seem to be forced to accept. Or does he refuse categorically?
- Does the customer want to speak about his environment (including car): is he expressive? Check out the body languages, postures.
- Does he express his satisfaction, criticism, try to tell about his car options

☞ Do not interfere with the customer's demonstration
☞ Ask to the customers to be as natural as possible (as usually)

Interview

System understanding

Questions asked to person interviewed	Instructions for the interviewer
1. In your mind, do you know how the system works? And do you think you could anticipate the warnings?	
2. Do you know at which speed the system is actived?	Avoid the question if the answer is in the question 1. Important to know how he collects this information, alone (note) or with another person (salesman). Interest by personal curiosity of customer. Link with the question n°62 « reading intructions ». If instructions have been read: Does the customer remember it? If instructions not read: how and in which conditions does he account for it? Link with the question n°63 « system's activation by the car dealer » and « information given by the salesman »: was the information given by the salesman (question n°61)? Link with the question n°11 « interest in new technologies » and question n°13 « interest in car innovations ».

Warnings perception

Questions asked to person interviewed	Instructions for the interviewer
3. Do you feel warnings easily or not (seat vibration)? **Why?**	Specify the intensity level of the vibration
4. Do you feel easily or not if the vibration is on the left or on the right?	

Reliability of system and situations met with alarms activation

Questions asked to person interviewed	Instructions for the interviewer
5. Do you think the system is reliable or did you meet false alarms?	If system not reliable: why? ▪ If false alarms : describe and explain situations and frequency ▪ If no alarms: which frequency and what circumstances (type of line, angle of penetration on the lane…)?
6. Can you describe situations (type of road, traffic density, night/day, weather conditions, road lighted or not…) where : ▪ **Vibrations occurred (correct alarms)** ▪ **Vibrations did not occur despite line crossing (no detection)** ▪ **Vibrations occurred without crossing (wrong alarms)**	Link with frequent or regular journey.

Reaction during alarms activation

Questions asked to person interviewed	Instructions for the interviewer
7. Have you been surprised the first time an alarm (seat vibration) occurred?	If yes, why ? (surprise, no line crossing)
8. Have you been surprised again the times after by the warning or do you get used to it ?	For which reasons ?
9. In your mind, does the seat vibration mean a warning? **Is it always right after several activations?**	
10. Did you associate easily or not, the seat vibration, with a crossed lane boundary?	If it is easy: why? If it is difficult: it is in wrongs alarms and no detections or alarms not much frequently or very spaced.
11. Did you identify easily or not if the line crossing is on the left or on the right?	For which reasons? ▪ Difficulties to feel the vibration ▪ Leisure (the customer is doing something else during driving)…
12. How do you react to warnings? **Describe your reaction: brake, deceleration, turn the steering wheel… why?**	
13. When an alarm occurred, does it happened you don't correct your position by turning the steering wheel? **If yes, in which situations?**	Ask if it's systematic (reflex behaviour) Crossing without indicator, keep out lane volontary (am : bend) or involontary (leisure, radio)
14. Do you think your reactions i.e. steering wheel movements, changed along time? **Why?**	

Use of system

Questions asked to person interviewed	Instructions for the interviewer
15. Do you try to anticipate seat vibration? **If yes, do you often do it or not?** **Is it to avoid vibrations? why?** **Is it in particular situations?** **What do you do? (put always the indicator light or switch off the system) ?**	
16. If you anticipate: how are you doing?	Pass to question 17 if answer = no Explanation on the behaviour: using indicator, more attention… Ask precision on frequency: rarely, often, always and on the road conditions (type of road, weather, night/day…)

Usefulness of system

Questions asked to person interviewed	Instructions to the interviewer
17. Globally, do you think the system is useful or useless?	If useful: why and in which situations (type of road, traffic, night/day, road lighted or not, weather conditions, long trip, type of lane…)? If useless: in relation with wrong alarms ?
18. Have you ever switched off the system? **If yes, at what frequency and in which situations?**	
19. Does the system help you to have a better position within the lane?	If yes: for what reasons (habits), what frequency (is it becoming systematic or not?) and on what type of trip (long or short) and road? Link with question n°45 « usual position in the lane ».
20. Globally, do you feel safer or not when the system is actived?	Is it in specific situations
21. If you feel a safety benefit, do you think the benefit is low or notable? Why?	Is it in specific situations

Modification of driving habits

Questions asked to person interviewed	Instructions to the interviewer
22. Globally do you think you changed the way you are driving since you experienced the system? **If driving changed :** **Why, in which situations? How did it change?** **Is it a general changing or only in specific situations, can you explain?**	
23. With the system, do you think you pay more or less attention to your position in the lane?	If more attention: why (does the warning help you as a guide, help you to care more attention…)? If less attention: what are the reasons? If no changing: in your mind, why do the system doesn't have impact on your driving? Link with questions 43 et 44 « establish driving habits».
24. When the system is activated: do you think you change your position within the lane?	Link with the question n°45 « usual position who serve to reference for estimating a behaviour changing».
25. Do you think you changed the indicator light use? **If yes: do you use it less or more frequently? Why?** **If no: what was your usage and why didn't it changed?**	Link with the question n°50 Establish driving habits
26. When the system is activated: do you think you change your speed? **If yes: how (higher or lower) and in what situations?** **If no: how (higher or lower) and in what situations?**	Link with the question n°28 et n°39 « reference to usual driving speed ».

Comfort of the system

Questions asked to person interviewed	Instructions to the interviewer
27. Do you find the vibration in the seat pleasant or unpleasant?	
Why ?	
28. Have you ever been irritated by the warnings?	
Why ?	
29. Do you want to have this system in the next car you would plan to purchased? Or do you want it in another current car you have?	