SESSION 2 :

AUTOMATED DRIVING & ADAS

COMPARING DRIVER'S SUPPORT FOR SUPERVISION AND INTERVENTION DURING PARTIALLY AUTOMATED DRIVING

Arie P. van den Beukel
Assistant Professor Human Centred Design Group University of Twente, The Netherlands

ABSTRACT: Driving automation changes the driving task from manual control to supervising automation. Supervision of partial automation requires now and then intervention. Since the automation causes low vigilance and out-of-the-loop performance problems, this changing role is not well suited for human operators. To explore how driver-vehicle interfaces can support drivers in their changing role, we evaluated five interface-concepts with regard to Situation Awareness, Accident Avoidance and Perceived Usefulness. The evaluation shows improved support for supervision with an 'illumination'-concept – providing directional cues upon the location where attention is needed. Knowing that supervision will be the dominating driver's responsibility during partially automated driving, illumination is a promising concept-direction. However, compared to the base-line, none of the concepts showed additional intervention-support. We concluded that intervention and supervision benefit from different interface- features and identified a concern to use detailed graphical information on system-state: The data show that this information might work as a distraction and then deteriorates intervention.

1 INTRODUCTION

Automotive industry has started market introduction of vehicles that allow automatically driving. The introduced vehicles combine existing driver assistance Systems for both lateral and longitudinal system control. Examples are Mercedes-Benz offering Adaptive Cruise Control with Active Lane keeping Assist [1] and Tesla enables with her software-update 'Autopilot' full automation [2]. The introduced applications are level 2 systems [3] defined as partial automation, meaning that the driver shall permanently monitor the automation and preserves final responsibility for safe driving. This definition also assumes driver's availability at any time to take over driving if required. While emphasizing drivers' final responsibility, car manufactorers promote the introduced systems as comfort enhancing. Governments and policy-makers harbour expectations that automation improves traffic efficiency and safety. The general public (currently) seems especially thrilled by technological advances. Human Factors researchers however, have time and again warned against downsides of partial automation [4-6]. These concerns can be summarized by Out-of-the-Loop (OOTL) Performance problems (like slower reaction times, misinterpretation of counter-measures and – on the long term – skill degredation). The reason behind these concerns is that partially automated driving basically changes the driving task from actively operating the vehicle to supervising – something humans are not particularly good at, due to low vigilance [7].

Despite the raised concerns, automobile interfaces are still designed with an actively operating driver in mind. Human Factors research for driving-automation mainly focusses on controllability aspects, like; intervention-performance, warning strategies, achievable reaction times and accident mitigation [8]. Looking at the changing driving task, it is noteworthy that applied research how to support drivers' supervisory role, is scarce. Available research often addresses design considerations and guidelines from a theoretical point of view. Development of praxis-based expertise is however still in its infancy. Nonetheless, supervision will during automation be the dominating driver's task. Moreover, acceptance of partially automated driving is expected to depend heavily on the appraisal whether supervision (including now and then retrieving control) is less effort taking than a human driving his or herselves [9]. Consequently, successful application of partially automated driving is in need of appropriate interfaces to support drivers with their changing role. As a first step to introduce new interface-solutions, the author developed and evaluated in two previous studies five different interface-concepts. The previous studies [10, 11] were conducted in the same over-arching research and the concepts were tested within identical scenarios representative for partially automated driving. Therefore these test- data allow comparison and this research compares findings from both studies. The aim is to collect recommendations for further directions for the development of appropriate support.

To attain this objective, section 2 will first explain the applied method to assess and compare concepts' test-results from both studies. Then, section 3 explains the concepts, before section 4 presents the results with collected data to compare the concepts. Finally, section 5 concludes with recommendations for further development.

1 METHOD

This research compares performance to support drivers in supervision and intervention, offered by five interface-concepts tested in two previous driving simulator studies [10, 11]. It also compares scores for participants' acceptance of the concepts. Both studies used the same set of measurements and driving scenarios and therefore allow comparison between concept-scores.

1.1 Scenarios

The set with six scenarios consisted of three so called hazardous scenarios and three critical scenarios. The scenarios were validated to be representable for real-road circumstances when driving partially automated, see [9]. The hazardous scenarios requested attention from the driver because of a difficult or potentially dangerous situation, like approaching a combined on/off ramp. The critical scenarios required intervention to avoid an accident, for example when a neighbouring vehicle cuts in too close and violates minimum required follow-distances.

1.2 Measurement data

Supervisory control is strongly related to driver's understanding how the system reacts to difficult situations in combination with knowledge and understanding of required human (re)actions [12]. Cognitive performance is well covered by the psychological construct Situation Awareness [5]. Intervention tasks, on the other hand, are strongly related to operational capabilities to perform fast and accurate counter-measures and undertaking actions timely and adequately to solve a critical situation [13]. Consequently, the assessment of intervention should especially address task-performance. In a previous study [11] we introduced 'Accident Avoidance' to assess this task-performance. Accident Avoidance is a combined assessment of accident avoidance by either swerving out or by braking – the latter based on Time-To-Collision (TTC) data.

In addition to cognitive performance and task- performance, our framework should also assess perceived comfort, because raising comfort is in general an important goal for the development of driving- assistance [8]. To summarize, our concept evaluation will be based on comparison of scores between concepts with regard to: Accident Avoidance, gained Situation Awareness (SA) and Concept Acceptance.

1.3 Material & Procedure

Both studies took place in the same (mid-fidelity) driving simulator from University of Twente. Within both studies a trial consisted of experiencing a concept within a specific scenario. Test trails were relatively short and took between 4 to 6 minutes. After each trial the simulation was frozen to allow probe-taking to measure Situation Awareness and to take additional questionnaires. Also driving-data were collected, like Reaction Time and Time-to-Collision to measure driving performance. Within each trial participants drove directly automatically and the surrounding traffic was programmed so that participants had exactly the same chance of resolving the situation. The applied concepts will be explained in section 3.

1.4 Analysis

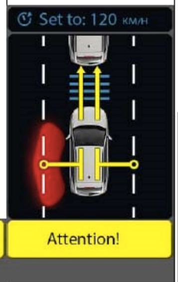
We collected data measured within both studies that allow assessment of concepts' support in supervision and intervention, i.e.: measurement of Situation Awareness, measurement of Accident Avoidance and measurement of Concept Acceptance. In both studies, measurement of SA was based on probe-taking and used so called SAGAT-technique [5]. Measurement of Concept Acceptance was based on a VanderLaan- questionnaire – of which the subscale Perceived Usefulness was most applicable. Because the data were collected from different studies, independent sample test are needed to compare results between concepts.

2 CONCEPTS

The concepts were designed to explore different kind of support for supervision and intervention. Because the changing driver's role is dominated by a demand for supervision (as explained in the introduction), most emphasis is on support in directing attention. Conventional interfaces either use single modal (audible or visual) means to direct attention, or multimodal means, like combinations of audible and visual signals. Introduction of multimodal interfaces has advantage that a signal might be picked up more effectively when there is competition from other signals using the same sensorial modus. However, multimodal interface might introduce new problems, like: distraction, spatial mismatch, raised annoyance, confusion and misinterpretation [10]. Recently, engineers and scientists have levered their attention to advanced interfaces, like using force-feedback and illumination to direct attention. Knowing that our concepts represents only a modest range of possible concepts, they do represent a relatively large spectrum of potential solutions, see table 1. For a more extensive review of design considerations interested readers are suggested to read: [10].

All concepts differentiated between so called 'soft-warning' and 'hard- warning'. The signals of a soft-warning are intended to ask for attention, because of a potentially difficult or maybe dangerous situation. If appropriately applied, soft-warnings are raised during hazardous scenarios, like approaching a combined on/off-ramp. The signals of a hard-warning are intended to urge for intervention, because of direct danger. The signals apply to critical scenarios, like a vehicle cutting in too close, violating minimally required follow-distances. The base-concept only used sound to differentiate between soft- and hard-warnings. All other concepts used the same audible alerts. The 'Instruction-concept' provided an additional textual instruction, like "attention" or "take-over now". The 'ControlRoom'-concept was based on a

Table 1: Concepts and their signals to convey ‘soft’ warnings (for supervision) and ‘hard’ warnings (for intervention)

	A: Concept “Base”	B: Concept “Instruction”	C: Concept “ControlRoom”	D: Concept “Icon”	E: Concept “Illumination”
<< Signals: SW = soft-warning, HW = hard-warning					
	Only sound warning	Text alert	Showing situational information to reflect system-state	Icon depicting driver’s role	Illumination at sides of wind-screen
		Audible warning identical to concept base-concept (A)			
SW	High-frequency beep	Text message “attention!”	Yellow-‘anchors’	Yellow arrows indicate requested attention	Yellow illumination directing at potential hazard
HW	Intermitting rattle-sound	Text message “Take over now!”	Red areas indicating location of danger	Red arrows indicating location of danger and urges for intervention	Red illumination urging for intervention + vibro-tactile signal in seat-pan

Note. The graphical displays off concepts B, C and D positioned behind the steering wheel.

control-room metaphor: Besides the audible signals it provided detailed status-information with a graphical representation of the own (“ego”) vehicle, a target-vehicle, front and side distances, recognition of target and road lines, etc. Because the detailed information of the ‘ControlRoom’-concept might work as a distraction, the ‘Icon’-concept is intended as a refined version: it presents only information that is important for the driver to understand his or her own role. Finally, the ‘illumination’-concept is intended to steer driver’s focus towards the location outside the vehicle where attention is needed. Within critical situations this concept also had a vibro-tactile signal in the front end of the seat-pan, intended as a cue for action.

3 RESULTS

The results in table 2 show that none of the concepts show a dominating superior performance over all assessment aspects and neither within both scenario-types taken together (critical and hazardous). Moreover, the dif ferences are often small. Hence, only in some occasions concepts show significant differences among one another.

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The results identify the ‘ControlRoom’-concept (C) to be ambivalent: In hazardous situations this concepts shows best SA-comprehension, however in critical situations (i.e. requiring intervention) this concept performs worst on both SA-comprehension and Accident Avoidance. For illustration: Based on SA-Comprehension (SAGAT-Level2) Concept C scores within the hazardous scenarios significantly better than base-concept A1: $t(46) = 3.36$, $p < 0.01$. But C performed significant worse than the ‘Instruction’-concept (B) within the critical scenarios, i.e. $t(46) = 2.20$, $p = 0.033$. The ‘ControlRoom’- concept (C) was designed to provide most detailed situational information that influences system state (for example road lines and relative position to surrounding traffic). Probably this information was advantageous during hazardous (i.e. non-critical) situations – requesting supervision, but worked at the same time as a distraction during critical situations.

Furthermore, the ‘illumination’-concept (E) was intended to support especially intervention. This expectation was based on its directional cue to guide focus outside the vehicle where attention was needed and at the same time conveying urgency through colour coding. Nonetheless, results do not demonstrate any advantages of this concept during scenarios which required intervention. On the contrary, it seems that the ‘illumination’-concept had a counter-productive effect on intervention-support. Possible causes of this effect are discussed in [10]. Most likely this is due to the unexpectedness of the additional vibro-tactile cue that concept C applied as additional stimulus for intervention. Probably this additional cue caused too much annoyance and then reduced performance.

Scores for Accident Avoidance in table 2 also reveals that the ‘Icon’- concept (D) is an improvement in comparison to C: $t(59) = 2.23$, $p = 0.029$. This is especially important because the ‘Icon’-concept was intended as a refinement of the ‘ControlRoom’-concept (C).

Perceived Usefulness shows highest scores for the ‘illumination’-concept (E), but the base-line concept performs almost identical. Here we need to remember that the data in this research are not based on within subjects comparison. It could be that participants’overall appraisal is dominated by experiences during hazardous scenarios because concept preference is more in line with scores during hazardous than with scores from critical scenarios.

4 CONCLUDING REMARKS

This research evaluated five interface-concepts intended to support drivers with their changing role when driving partially automated (i.e. supervision with now-and-then intervention). Concept A provided only acoustic warnings and served as a baseline. Concept B presented text-based instructions in a conventional manner. Concept C was more detailed, providing situational information with regard to the road-situation and surrounding traffic on a display behind the wheel. Concept D had similarities with C, but provided the situational information more reduced and emphasized driver’s role. Concept E was most advanced using illumination in the windscreen and haptic feedback in the seat-pan to direct attention towards the locus of a potential hazard and to create an affordance for intervention when required.

Based on measurement of Situation Awareness, the ‘illumination’- concept (E) showed superior support for supervision. (That is: within hazardous scenarios.) Knowing that supervision will be the dominating driver’s responsibility when utilizing partially automated driving, we consider the illumination-concept (E) a recommendable development-direction for support of the driver’s changing role. Nevertheless - based on Accident Avoidance scores, no concepts showed raised levels of support for intervention in comparison with the base-concept. Against expectation, the ‘illumination’-concept (E) scored comparable or worse than the baseline- concept (A). Probably, the combination of concept E’s intervention-warning, especially the unexpectedness of the vibro-tactile stimulus in addition to the acoustic and visual stimuli, caused counter-productive levels of annoyance. Moreover, the more graphically advanced the concepts are (i.e.‘ControlRoom’-concept (C) and ‘Icon’-concept D, the more it seems that graphical information has worked as a distraction during intervention. An observation that is explained by these concepts receiving lower scores on Accident Avoidance compared to the base-line. Therefore, we recommend to use graphical status-information in a reduced manner.

Based on previous considerations we conclude that intervention and supervision benefit from different interface-features. The evaluation presented in this paper contribute to further development of – and knowledge about, appropriate driver-vehicle interface while vehicle-operation advances into operating partially automated driving systems.

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Effects of intersection collision warning systems on drivers' reaction time: a hazard-based duration model

Manuel Silvestri*, Francesco Bella
Roma TRE University - Vito Volterra n. 62 - 00146 Rome (Italy)
Phone +39-06-57.33.34.16 fax +39-06-57.33.34.41
manuel.silvestri@uniroma3.it

ABSTRACT: The objective of this study was to examine the effect ICWSs on drivers' behavior, in response to a potential conflict event at the intersections; in this case, a violator vehicle from right and left that failed to stop represented the potential conflict. The ICWSs were audio warning message and visual warning. Both the audio warning message and the visual warning provided to the driver the direction of the violator vehicle. Drivers' reaction times were modeled following the survival analysis, by the use of the accelerated failure time (AFT) duration model with a Weibull distribution. The applied model identified one significant variable influencing the reaction time (V_i driver's initial speed value) and the warning signal condition; the direction of the violator vehicle did not affect significantly the reaction time of drivers. For the condition of audio message warning and visual warning, the reaction time was 43.1 % and 34.5% shorter than that for the baseline condition, respectively. In addition, the drivers' reaction time for the audio message warning was 22% shorter than that for the visual warning (statistically significant).

1 INTRODUCTION

The intersections are essential elements of the road network but constitute hazard-ous locations, because imply opportunities for conflicts among vehicles. Although intersections are a slight part of the road system, they emerge as the road sections where a remarkable portion of the accidents occurs [1, 2]. There is agreement to believe that this situation is linked to the fact that driving at intersection is one of the most dynamic and difficult task of drivers [e.g. 3,]. Such complexity often implies inadequate drivers' behavior and then occurrence of accidents. Understanding the main factors that influence the occurring of the intersection acccidents and developing systems that encourage proper drivers' behaviors and help him in the complex task of drive at the intersections, are deemed to be the keys to improve the road safety at intersections. For this reason, a lot of research were and continue to be aimed on the factors contributing to crashes at these hazardous locations and on the development of effective driving assistance systems, such as intersection collision warning systems (ICWS). The intersection collision warning systems (ICWSs) are in – vehicular warning systems, which detect obstacles with sensors in vehicles, and devices located at intersection, such as detecting radar and alert the driver of an imminent collision. These systems have an important impact on driving safety because making the potential collision at intersection predictable, by allowing the decrease of the probability and severity of accidents. [4, 5, 6]. Among the several types of alarms (auditory warnings, visual warnings, vibrotactile warnings and haptic warnings), those most used concerning the auditory and the visual stimulus. The first type of alarm consists in audio signals as beep sounds, auditory icons (i.e. car horn, skidding tires) or speech message, that are sent to the driver through a vehicle on board audio system [e.g. 7, 8]. The second type consists in a visual warning signal such as a car symbol, flashing orange warning circle, triangular warning that appears on the vehicle dashboard [e.g. 3, 4, 9,]. Several studies [3, 9, 10,] were oriented to the comparison of the effects on driver's behavior at the intersections due to different types of auditory warnings and different types of visual warnings. However, it is unclear whether is more effective an audio or a visual warning. In addition, no study compared the effects on drivers' behavior induced by an acoustic and a visual directional warning.

The main objective of the present study was to assess, in response to a potential conflict event at the intersections, the effects of directional auditory and visual warnings on driving performance.

The parameter reaction time (RT) was used for the evaluation of the effects on driving performance. Reaction time represents the time needed for the driver to react in response to a warning signal. It is a parameter of drivers' behavior that has concrete implication for road safety [e.g. 11, 12] and it is an important variable that affects traffic accidents.

Reaction time is modeled by the use of a parametric duration model, also called “survival model” or “hazard based duration model”, which is particularly indicated to provide additional information of duration effects.

Many studies demonstrated the great potential of driving simulators for the investigation of driving performances under different conditions of warnings [in addition to the already mentioned references, e.g. 13, 14, 15, 16]. Therefore, in the present study, a driving simulator experiment was carried out to analyze the effect of directional auditory and visual warnings on drivers’ behavior in response to a potential conflict event, represented by a vehicle that failed to stop at the intersection (violator vehicle).

2 METHODOLOGY

2.1 Hazard – based duration model

A hazard-based duration model is a probabilistic method that is used for analyzing data in the form of time from a well-defined time origin until the occurrence of some particular event of an end-point [17]. Such modeling is a common topic in many areas. In the transportation field, hazard-based duration models have been applied to study a number of time-related issues such as: analyzing the critical factors that affect accident duration and developing accident duration prediction models [18, 19], analyzing the crossing behavior of cyclist at signalized intersections [20], studying the effects of the phone use on the driver reaction time and on braking behavior in response to a crossing pedestrian [21, 22].

In this study, the reaction time is the duration variable. The duration variable is a continuous random variable T with a cumulative distribution function and probability density function, F(t) and f(t) respectively; conversely, the survivor function S(t) is the probability of a duration variable longer than that some specified time t.

$$F(t) = Pr(T<t) = 1-Pr(T\geq t) = 1-S(t) \quad (1)$$

The hazard function h(t) gives the conditional failure rate. More specifically, h(t) is the conditional probability that an event will end between time t and t + dt, given that the event has not ended up to time t [23].

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t + \Delta t \geq T \geq t \mid T \geq t)}{\Delta t} = \frac{f(t)}{S(t)} \quad (2)$$

The proportional hazard (PH) and the accelerated failure time (AFT) models are two alternative parametric approaches that allow incorporating the influence of covariates on a hazard function. The AFT assumption allows a simple interpretation of results because the estimated parameters quantify the corresponding effect of a covariate on the mean survival time [21, 22]. Given these features, AFT models were applied in this study. More detailed statistical presentations of hazard-based duration models can be found in [17, 23].

2.2 Driving simulator experiment

The study was conducted using the advanced driving simulator of the Department of Engineering – Roma Tre University. A multi-factorial experiment was designed to analyze the effects of the ICWSs (auditory, visual and no warning signal) on drivers' behavior in response to a vehicle that failed to stop at the intersection, both from test vehicle's right and left.

2.2.1 Road scenarios and ICWSs

A two-lane rural road approximately 38 Km long was implemented in the driving simulator. According with the Italian road design guidelines [24], the road cross-section was 9.50 m wide formed by two 3.50 m wide lanes and two 1.25 m wide paved shoulders. The design speed ranged from 60 Km/h (on curves with a radius equal to 118 m) to 100 Km/h (on tangent), and the posted limit was 90 Km/h. The radii changed from 118 m to 930 m and the lengths of the tangent ranged from 100 m to 1650 m. The vertical alignment had null longitudinal grade, to avoid conditionings on the dynamic variables, like speed or acceleration. Along to the alignment were designed several stop – controlled intersections (four-leg intersections and three-way intersections). In 6 four-leg intersections were simulated for representing the 6 combinations of the factors

ICWS and direction of the violator vehicle. In all of these 6 intersections a violator vehicle was implemented to fail the stop sign and cross the road (3 from test vehicle's right and 3 from test vehicle's left) at the speed of 70 Km/h. To ensure the same approach conditions, the approach geometry was the same for all the 6 intersections; the driver, after a curve with a radius of 450 m, traveled an approach tangent to the intersection 600 m long. During this approaching phase, the drivers also encountered a vehicle in the opposite direction. To avoid predictability and order effect 6 road scenarios with different sequences of intersections were simulated. Two types of ICWS were implemented in the scenarios.

The first ICWS was the auditory speech message, where the direction of the violator vehicle was specified: “attention, vehicle from right” or “attention, vehicle from left”. These speech messages were digitally prerecorded and saved as.wav files. Then they were reproduced into the vehicle through the audio system of the driving simulator at around 70 dB loudness level. They were fully consistent with similar auditory warnings used in literature [13, 14]. The second ICWS was a visual warning, which consisted in a red car icon (an icon of car into a red triangle). It was similar to visual warning used in previous studies in literature and appeared in the right corner of the central display, near the speedometer, to simulate its appearance on a device inside the vehicle. The visual warning provided the direction of the violator vehicle through the icon of car oriented in the direction of arrival of the violator vehicle. When activated, the visual warning remained in the screen for 7 seconds.

The triggering point of the ICWS (both auditory and visual) was when the test vehicle reached a point 100 m in advance (i.e 100 m before) of the intersection. In the same moment the violator vehicle, with the speed equal to 70km/h, was at 77.7 m from the collision point with the test vehicle. In these conditions and with the hypothesis that the test vehicle is travelling at the posted speed limit (90 Km/h), the time to collision (TTC) is equal to 4 s This value, however, is theoretical because it depends on the actual approaching speed of the driver at the intersection during the simulated drive. In other words, if the driver reaches the triggering point at 100 m from the intersection with a higher or a lower speed of 90 Km/h, the values of TTC will be lower or higher, respectively, than 4 seconds.

2.2.2 Apparatus

The driving simulator of the Department of Engineering – Roma Tre University used for this study is an interactive fixed-base driving simulator. It was previously validated [25, 26] and largely used as a reliable tool for the study of the driver's speed behavior [e.g. 27, 28, 29, 30, 31, 32, 33, 34, 35]. The hardware interfaces (wheel, pedals and gear lever) are installed on a real vehicle. The driving scene is projected onto three screens: one in front of the vehicle and one on either side, which provide a 135° field of view. The resolution of the visual scene is 1024x768 pixels with a refresh rate of 30 to 60 Hz. The system is also equipped with a sound system that reproduces the sounds of the engine and of the auditory warning during the simulation and the data recording system acquired all of the parameters at spatial intervals of 2 m.

2.2.3 Participants

Forty-two drivers (32 men and 10 women), whose ages ranged from 23 to 70 (average 31) and who had regular European driving licenses for at least three years were selected to perform the driving in the simulator. The participants were divided into 6 groups; the 6 groups drove the different 6 scenarios, which were each characterized by a specific sequence of intersections where a violator vehicle failed to stop. According to the questionnaire on perceived discomfort (see next section Procedure), 41 of 42 participants experienced null or light levels of discomfort; only one participant was not able to finish the experiment. Thus, the sample used for the analysis consisted of 41 drivers.

2.2.4 Procedure

The experiment was conducted with the free vehicle in its own driving lane. In the other driving lane, a slight amount of traffic was distributed to induce the driver to avoid driving into that lane. The participants were first briefed about the use of the hardware interface and then invited to start a training drive at the driving simulator on a specific alignment for approximately 8 minutes, to become familiar with the driving simulator. After the training, participants came out of the driving simulator for about 5-10 minutes to restore their initial condition; in this phase, also some information about the experiment were provided. In order to limit the duration of the drive and, thus, reduce the probability of sickness for driver, the experiment was divided in two steps. In the first, the participant drove the first part of one of the six road scenarios and after that, he filled in a questionnaire about his personal data and his driving experience. In the second step, the participant drove the second part of the scenario and then he filled in another questionnaire. This questionnaire consisted in two parts: perceived discomfort and effectiveness of the ICWSs.

3 DATA PROCESSING

The speed profile of each driver was plotted 150 m in advance of each one of the 6 intersections. Overall, 246 speed profiles (6 intersections x 41 drivers) were analyzed. From each speed profile the following variables of the driver's behavior while approaching the intersection were determined:

- Vi: driver's initial speed value, identified at the moment when the driver starts to decrease his speed, releasing the accelerator pedal or pressing the braking pedal, in response to the violator vehicle;
- Vf: minimum speed value reached by the driver to avoid the collision;
- dm: the average deceleration rate during the speed reduction phase from Vi to Vf;
- RT: driver's reaction time, which is the elapsed time between the activation of the warning signal (when the test vehicle was at 100 m from the intersection) and the moment in which the driver starts to decrease his speed.

In the intersections where no warning was provided to the driver, the reaction time was assumed equal to the elapsed time between the moment when the test vehicle was at 100 m from the intersection and the moment in which the driver starts to decrease his speed, in response to the violator vehicle. From the sample were excluded the data of the following cases:

- the driver adopted a too much low (2 data: 1 for the condition of No ICWS and 1 for the auditory speech message) or to much high speed

(9 data: 6 for the condition of no ICWS condition, 2 for the visual warning and 1 for the auditory speech message) and, thus, the violator vehicle did not affect the driver's behavior (the driver crossed the intersection much late and well in advance compared with the violator vehicle, respectively);

- the driver collided with the violator vehicle: 11 collisions were recorded in the condition of "no warning".

Thus, 224 observations were used for the analysis.

4 DATA ANALYSIS AND RESULTS

A statistical model (Weibull AFT model) of survival time for the reaction time was developed using the continuous variable driver's initial speed, final speed and average deceleration, the categorical or indicator variables ICWSs condition and the direction of the violator as explanatory variables. The mean values and standard deviations of the continuous and categorical variables are reported in table 1. For the reaction time only the initial speed value was used as explanatory variable, due to the fact that the driver's reaction in response to a violator vehicle is not affected by the variables minimum speed and average deceleration (such variables are recorded at the end of the decreasing speed maneuver).

Table 1: Descriptive statistics

Variables and factors		Mean Value	SD
Dynamic variable			
	V_i	83.11 Km/h	11.67 Km/h
	V_f	33.38 Km/h	15.17 Km/h
	d_m	4.78 m/s^2	1.33 m/s^2
	RT	0.99 s	0.61 s
ICWS Condition			
	Auditory speech message	0.34	0.47

	Visual warning	0.35	0.48
	No ICWS	0.31	0.46
Direction of the violator			
	Right	0.51	0.50
	Left	0.49	0.50

4.1 Hazard – based duration model

Weibull accelerated failure time (AFT) was used to modeling the divers' reaction times (RT). Two extensions of this model were tested: the Weibull AFT model with clustered heterogeneity and the Weibull AFT model with shared frailty. The frailty was gamma distributed. The two models were compared with their likelihood ratio statistics [23] and with the AIC test [36]. For the RT, the likelihood ratio statistic of the Weibull AFT model with clustered heterogeneity was -145.82 while that for the Weibull AFT model with shared frailty was -167.532, highlighting that the first was preferable. The AIC test also confirmed the previous result; for the clustered heterogeneity model and for the shared frailty model the AICs were 305.64 and 348.65 respectively (the model with the lower AIC is preferable). Thus, based on both likelihood ratio statistics and the AIC, the Weibull AFT model with clustered heterogeneity was the preferable for modeling the drivers' reaction time. The table 2 shows the significant parameter estimates for the Weibull AFT model with clustered heterogeneity for RT. The scale parameter P has an estimate value equal to 3.895, meaning that the survival probability of RT decreased with the elapsed time. On average, in fact, the probability of fail to detect the violator vehicle after 2 s was approximately 7 times higher than that after 1 s (i.e., (2/1)3.895-1).

Table 2: Weibull AFT model with clustered heterogeneity estimates for the reaction times

Variable	*Estimate (β)*	*SE*	*z-Statistic*	*p-value*	*Exp (β)*	*95%Conf. Interval*	
V_i [Km/h]	-0.012	0.002	-4.77	0.000	0.99	-0.016	-0.006
<u>*ICWS*</u>							

condition							
No ICWS	-	-	-	-	-	-	-
Visual warning	-0.379	0.045	-8.34	0.000	0.68	-0.468	-0.289
Auditory speech message	-0.546	0.069	-7.82	0.000	0.58	-0.682	-0.409
Direction of the violator							
Left	-	-	-	-	-	-	-
Right	-0.057	0.058	-0.98	0.326	1.06	-0.171	0.056
Constant	1.217	0.212	5.73	0.000		0.800	1.633
P	3.895	0.613				2.861	5.304
Log-likelihood at convergence (Pseudo)	-145.82						
Log–likelihood at zero	-178.24						
AIC	305.64						
N° of observations	224						
N° of groups	41						

The model identified that the driver initial speed was statistically significant for the drivers' RT. The coefficient of the initial speed was negative, which means that when the value of this variable increased, the RT value decreased. This is consistent with the drivers' behavior; when the driver arrives at the intersection with higher speed he tends to compensate the higher risk by increasing his attention, and thus, decreasing the reaction time in response to a unexpected event such as a violator vehicle [37, 38]. More specifically, for 1 Km/h increase in the driver's initial speed, the time required to react was 1% lower (Exp (β)=0.99).

Among the ICWS conditions, both the visual warning and the auditory speech message were statistically significant (P=0.00) and negatively associated with the reaction time. The visual warning and the auditory speech message had values of RT (equal to 1.49s and 1.26s for null survival probability, respectively) shorter than for the no ICWS condition (2.18 s; mean difference = 0.69s, P=0.000; mean difference = 0.92s, P=0.000, respectively) (figure 1). More specifically, for the visual warning the time to react was 32% shorter (Exp (β)=0.68), while for the auditory speech message was 42% shorter (Exp (β)=0.58). In addition, a pairwise comparison with Bonferroni's correction was also performed; results showed that RT for the auditory speech message was statistically significantly shorter than that for the visual warning (mean difference = 0.23s; P = 0.018). Comparing the directions of the violator, the reaction time with violator vehicle from right was 6% longer (Exp (β)=1.06) than that for violator vehicle from left but the difference was not statistically significant (P=0.362). The representation of the drivers' reaction patterns was possible by the plotting of the survival curves with the use of the estimated coefficient (statistically significant) of the initial speed and the warning signals; the coefficient of the direction of the violator vehicle were not used because these variables were not statistically significant on the RT. The survival curves (for the ICWS conditions) were plotted by using the mean value of the continuous variable initial speed (tab. 1) and the estimated coefficients of the ICWS condition in table 2, in the equation 9. Using this method, the survival curve for each ICWS condition was plotted (fig. 1).

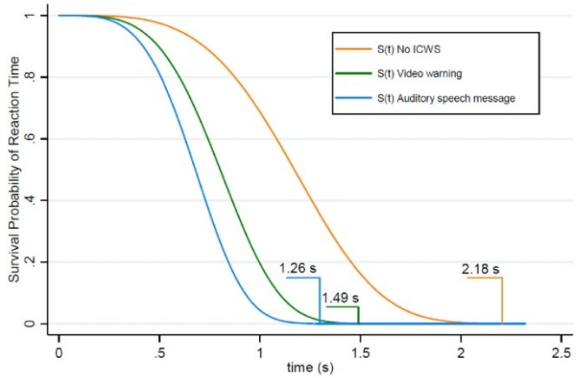

Fig. 1 Survival curves of RT for ICWS conditions (the values of RT for null survival probability are also shown)

4.2 Outcome of the questionnaire

The results of the questionnaire about the perceived effectiveness of the warning signals showed that the entire sample indicated that both the visual warning and the auditory speech message were effective. Auditory speech message obtained the highest score for both the speed reduction effect (mean = 8.3, SD = 1.3) and the increase of the level of attention during the drive (mean = 7.3, SD = 2.3). These results indicate that the participants believed to have been more influenced when the warning signals were present; moreover, the auditory speech message was believed more effective than the visual warning.

5 DISCUSSION

The survival curves for different ICWS conditions show that, for a fixed value of the elapsed time, the lower survival probability of RT was obtained for the auditory speech message while the higher survival probability of the RT was obtained for the condition of No ICWS. For example, after 0.75 s, the probability that the driver fails to react in response to the violator vehicle is approximately 38% for the auditory speech message, 60% for the visual warning and 89% for the No ICWS condition.

The results on RT showed that, despite the two warning signals provided the same information to the driver (i.e. the direction of the vehicle), the auditory speech message was better than the visual warning. Differently from the case of car – following in which the additional information in the warning signals is not necessary because the driver have not to discern the direction of the vehicle [39], the benefits of the additional information in the speech message for the ICWS remarks the results of the previously studies [39, 40]. The higher reaction time for the visual warning (1.49 s) compared with that for the auditory speech message (1.26 s) can be due to the fact that for the first, the driver had to focus his attention, and thus his glance, before on the visual signal to identify the direction by the red car icon, and then on the intersection to detect the violator vehicle. For the auditory speech message the driver, instead, could directly detect the position of the violator after he heard the audio signals with the directional information and, thus, advance the beginning of the braking. This result is consistent with previously studies [9, 11]. Most of the driving activity, in fact, requires the visual task; this implies that the comprehension of the video signal (i.e. an additional visual task) could disturb the driving activity and, thus, delay the reaction of the driver. The dynamic variable initial speed (Vi) was negatively associated with the drivers' reaction times; this finding suggests that with the increasing of the speed, the driver is more focused on the road environment, and thus, on the possible critical situations. This result is consistent with previously studies [38, 41, 42] where the speed of vehicle was negatively associated with the driver reaction time.

For the direction of the violator no statistical difference was recorded and this result highlight that the effectiveness of the different ICWSs was the same with respect of the direction of arrival of the violator vehicle.

6 CONCLUSION

The hazard-based duration model identified that the drivers' initial speed (Vi) and the warning signals affected, in a statistically significant way, the driver's reaction time in response to a violator vehicle. The shape of the survival curves of RT for the different ICWS conditions showed that for the auditory speech message the drivers were more able to react and start to decrease the speed earlier than that for the visual warning and the No ICWS condition. The reaction time for both the warning signals were lower (statistically significant) than that for the No ICWS condition. Moreover, the RT of the auditory speech message was lower (statistically significant) than that for the visual warning, highlighting that for the first the driver could advance his braking maneuver because his glance was always focused on the road environment; for the visual warning, in fact, the driver had to focus his attention first on the visual warning to understand the direction of the violator vehicle, and then on the road environment to detect the violator vehicle. The benefits of advance the braking maneuver resulted in no collision event for the warning signals, while for the No ICWS condition, on average, the 14.3% of the drivers collided with the violator vehicle. These findings were also confirmed by the outcomes of the questionnaire on the perceived effectiveness of the warning signals; the entire sample reported that the warning signals were effective. Moreover, the drivers reported that the auditory speech message was more effective of the visual warning in terms of speed reduction and improvement in the level of attention.

7 ACKNOWLEDGMENTS

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ANGER AND DRIVING: TOWARDS THE ADAPTATION OF ADAS

F. Techer, C. Jallais, Y. Corson, and A. Fort

IFSTTAR, France

ABSTRACT: Anger is a commonly reported emotion in driving. It can lead to many behavioural modifications. Like other negative emotions, anger may promote attentional failures in driving which are attributable to mind-wandering. Besides positive expected impacts, advanced driving assistance systems (ADAS), can also increase cognitive underload and reduce available attentional resources. Consequently, the detrimental effects of negative emotions may get even more threatening to road safety when driving with ADAS. A better comprehension of emotions in driving would allow an adaptation of ADAS to reach an optimal level of performance.

6 INTRODUCTION

This paper briefly summarises current concerns about anger and advanced driving assistance systems (ADAS) and the main solutions considered by researchers.

7 ANGER AND DRIVING

Anger is a frequently reported emotion while driving (1,2). Its impact on driving is not necessarily detrimental. Conjointly with a negative effect on the reactivity to traffic speed changes, it may improve the detection of pedestrians (11). However, anger increases the propensity of risk taking and number of infractions (3–7). It also adversely impacts the longitudinal and lateral control of the vehicle (8–10). Concerning the attentional dimension of driving, anger promotes a more superficial processing of the environment and a reduction of the attentional breadth (12), leading to stereotypical judgements, slower reaction to unexpected hazards, and a reduction in the situation awareness (5,13,14). According to Jeon and colleagues (8), the reduction of situational awareness may be the main factor explaining the effect of anger on excessive speeds. Additionally, anger promotes the emergence of ruminations (15) which means that the attentional resources of the drivers will often be directed towards internal thoughts unrelated to driving. Consequently, anger appears as a complex issue for road safety because of its various effects on behaviour and cognition during the driving task.

8 NEGATIVE EMOTIONS AND ATTENTIONAL RESSOURCES WHILE DRIVING WITH ADAS

8.1 Negative emotions and attentional dynamic

The allocation of attentional resources on self-generated thoughts is commonly designated as “Mind-wandering”. Epidemiological studies about mind-wandering seem to be consistent about the hazardousness of this attentional state. For example, amongst a population of patients admitted in an emergency department due to a car crash, reported mind-wandering was the best predictor of the accident responsibility (16). Detrimental effects of mind-wandering on road safety may be explained because it is accompanied by perceptual decoupling, which means that attentional processes are not the reflect of sensory input (13).

Mind-wandering seems to be particularly associated with negative moods (13,17). This is probably one of the reasons explaining the correlation between the occurrence of negative life events such as divorces or separations, and the prevalence of accidents (18). Altogether, studies suggest that negative emotions may be a threat to road safety because of the engendered attentional perturbations. Based on this statement, it seems clear that interaction between emotions and other sources of attentional perturbation should be taken seriously while designing future driving assistance systems.

8.2 Impact of ADAS on attentional resources

So far, most driving assistances focused on the task complexity reduction so as to increase available attentional resources in case of emergency situations, thus facilitating crash avoidance (19). Often, they opted for an automation of driving sub-tasks, which means that the vehicle was able to perform several tasks previously performed by the driver (20). This can lead to cognitive underload. Unfortunately, cognitive underload is as detrimental to the driving performance as cognitive overload. This counter-intuitive issue could be explained by considering that the quantity of available attentional resources is partly function of the task demands (21). However, for a benefit from informative ADAS such as forward collision warnings, attentional resources have to be available to process information given by the system (22).

Considering the impact of negative emotions on attentional resources in driving, the use of ADAS may not be as profitable as expected. Future studies should investigate about the way emotions interact with ADAS while driving.

8.3 Impact of Emotions while driving with ADAS

On this topic, Techer and colleagues (in preparation) assessed the impact of an angry state on driving performance and attention when driving on car simulator with a forward collision warning system during a monotonous driving task. Reaction times, several behavioural metrics and electrophysiological data were recorded. Results revealed that an anger state impaired lateral control and impacted the nature of self-generated thoughts. Event-related potentials revealed that the nature of self-generated thoughts modified the attentional processing of target stimuli. This study contributes to a better comprehension of the influence of an anger state on attentional processing while driving with ADAS. It is important to keep studying how emotional states impact the attention and driving performance in order to prepare the introduction of future driving automation systems.

9 REDUCING THE DETRIMENTAL EFFECTS OF EMOTIONS ON DRIVING PERFORMANCE

Intuitively, two types of actions have been considered to reduce the effects of emotions on driving performance.

9.1 Emotion regulation

On one hand, if a particular emotional state is a threat to road safety, a possible action might be to encourage drivers and help them to recover a more neutral mood. Most of the propositions about emotion regulation are based on the “process model” of emotion regulation (23). Since it is not always possible to change the driving environment, cognitive “reappraisal-down” is believed to be more appropriate strategy in order to prevent the apparition of irritability (24). This strategy consists of convincing the driver that the frustrating event which occurred was unintentional and less hazardous than perceived. However, for an increased efficiency, this method requires that the reappraisal message is displayed during a short time before or after the critical event. Emotion regulation have been found to be efficient to improve driving performance, avoid or reduce negative moods, and even reduce perceived workload (8,24). Another possible strategy of emotion regulation is to improve driver's comfort, like creating an enjoyable atmosphere through coloured lights or playing music appreciated by the driver when he is in a bad mood. However, this implies that in-vehicle systems are able to discriminate different emotions.

9.2 Situational awareness improvement

On the other hand, an important proportion of driving errors such as speeding may be accountable to an impaired situational awareness (8). Thus, systems might provide useful information about critical events in order to raise drivers' situational awareness, and thereby allow them to cope more efficiently with hazardous situations. Variables such as alerting systems reliability or timing of alert may impact the ADAS efficiency (25). Thus, it is conceivable that when attention is disrupted by emotional state, the optimal timing of alert may change. Therefore, future ADAS may need to be adapted to cope with a particular emotional state's weaknesses or strengths. For example, a shorter delay between critical events and alerts would allow an earlier reaction to hazards through an improved situational awareness. This type of intervention can be applied for negative as much as positive states. However, each emotional state may impair a specific dimension of the driving performance. Ideally, future systems may only provide information corresponding to the weaknesses of driver's current state. Again, this kind of intervention requires that the system is aware of driver's emotional state.

Emotional regulation and situational awareness improvement strategies may also be complementary for ADAS efficiency improvement.

9.3 Complementary interventions

Jeon et al. (8) decided to evaluate the usefulness of an in-vehicle agent to improve driving performance of drivers accumulating integral and incidental anger induction. The in-vehicle agent using a speech-based interface provided either situational awareness or emotion regulation prompts. Both types of intervention efficiently improved driving performance and situational awareness, but the situational awareness agent was evaluated as more useful and friendly. Moreover, the in-vehicle agent reduced perceived workload for both groups. Further analyses revealed that this perceived workload reduction was due to scores decreases in different sub-dimensions of the perceived workload scale, which could be useful to adapt the agent to driver's specificities. Those two kinds of interventions seem to be complementary in order to adapt to drivers' specificities and current states.

However, despite promising experimental results, several improvements might be important for the conception of future driving assistance systems.

10 MAJOR IMPROVEMENT FOR FUTURE ADAS

10.1 Specificities of various emotional states

In driving, anger, happiness, and fear do not impact the driving performance and the attention in a same manner (9,26). Different moods may also positively affect a number of attentional variables. For example, previous research revealed that anger improves the pedestrian detection (11). Apart from a driving context, anger also increases the alerting network efficiency (27). Consequently, future systems should provide appropriate information in order to cope with the particular attentional needs of the driver, while taking advantage of the positive side of emotional states.

Moreover, according to the driver's current mood, the system should adjust the conditions of information transmission. For example, in the case of a speech-based interface, the characteristics of the system's voice may play an important role in the driver-car cooperation. Happy drivers seem to take a better advantage of an energetic speech system, while angry drivers will better cooperate with a more subdued system (28). Critical information presented in a style adapted to drivers' mood would promote human-car cooperation which may help reaching an optimal level of performance.

However, emotional states, unlike personality traits, are able to change during the driving task. Therefore, another major issue is to be able to monitor in real time the emotional state of the driver. This issue may be reached by taking into account physiological and behavioural measures.

10.2 Online detection of internal states

According to Lazarus (26), each emotional state contains an action tendency which goes along with a specific pattern of physiological activation. Consistently with this idea, merging a set of physiological variables seems to be an appropriate method towards the inference of driver's internal state. Several studies investigated about the physiological response associated with emotional states using variables such as heart rate, respiration, skin conductance or body temperature (1,5,27). For example, fear and anger, which are two negative and highly arousing emotions, seems to be distinguishable on the basis of the physiological patterns provoked (27). Physiological patterns have also been identified for mind-wandering using electroencephalography methods (28), revealing that perceptual decoupling occurring in mind-wandering is observable at a cortical level.

Taken together, the identification of emotional states and possible mind-wandering associated may be the first step towards an adaptation of ADAS.

11 FUTURE ISSUES

With the development of autonomous vehicles, technology will completely redefine the driver's role from an operator to a supervisor required to take over the car for emergency purposes. In the occurring of an urgent takeover, drivers should have an optimal situation awareness and enough cognitive resources to deal with the emergency manoeuvre. Thus, the effects of emotions on attention in driving will remain an important concern for road safety.

According to existing literature, four major axis have to be investigated in order to prevent potential threats for future road safety.

- Understand how various discrete emotional states affect driving performance and attentional processing of a driving situation.
- Further investigate about the impact of mind-wandering considering the nature of self-generated thoughts.
- Develop accurate real time monitoring of internal states including mind-wandering.
- Prepare future adaptive assistance systems able to identify critical information in the driving environment and deliver it in the more

appropriate conditions corresponding to the driver current state.

- Investigate about optimal thresholds of alerting systems according to each emotional state in order to promote situational awareness.

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HMI DESIGN METHODOLOGY: EVALUATION OF HMI PROPOSAL FOR COMPASS4D SERVICES THROUGH FOCUS GROUPS WITH FINAL USERS.

Eva García, Pablo López, Francisco Sánchez, Rosa Blanco, Adelaida Hernández, Marta Miranda & José Manuel Martínez (Centro Tecnológico de Automoción de Galicia, CTAG)

ABSTRACT: Compass4D is an European Project focused on several services: Red Light Violation Warning, Road Hazard Warning and Energy Efficient Inteserction. These three services increase drivers' safety and comfort and improve efficient driver behaviours. Information for these services was provided by a mobile application. The objective of this paper is to present the methodology used for designing and evaluating an HMI proposal for the services mentioned before. With this aim three different focus groups were performed with three different final users: standard drivers, bus drivers and taxi drivers. Results about this focus groups activity will be presented in this paper hightlighting the implications for the final HMI definition.

1. INTRODUCTION

Compass4D is an European Project oriented to the application of Cooperative Intelligent Transport Systems (C-ITS) for giving to the driver information during driving activities, for example, when there is a hazard on the road ahead or if a vehicle is going to violate the red traffic light [1]. It is focused in three different services:

1.1. Red Light Violation Warning

The Red Light Violation Warning (RLVW) service is focused in giving information about iminent violations of Red Light in a crossroad. Its aim is to give information to the driver for alerting about a risky situation.

1.2. Road Hazard Warning

The Road Hazard Warning (RHW) service aimed to reduce road dangerous situations by sending drivers warning messages which contain information about hazard situations on the route.Two types of road hazards can be distinguished: static and dynamic. Static road hazards alerted about potential static dangerous situations (road works, traffic jam…) and dynamic hazards concerned to emergency vehicles approaching situations.

1.3. Energy Efficiency Intersection

The Energy Efficient Intersection Service (EEIS) aimed to reduce energy to be used in the manouvers of approximation to a crossroad regulated by traffic lights. Driver is informed about traffic light state and time to change.

The aim of this paper is to summarize and describe the initial phases carried out for defining final HMI in Compass 4D. As it can be observed in the next figure the used procedure is the following:

Fig. 1 Procedure for evaluating compass4D HMI

First phase was focused in the analysis of the different inputs to the HMI definition. Compass 4D initial requirements, Standards, Normatives, Trends and Benchmarking information were taken into account for stabilishing the bases for further phases. In the second phase of “Initial Ideas”, taking into account the results of the analysis, several proposals were prepared as possible solution for final HMI. Later on, these proposals were presented and discussed with final users in several focus groups. The main objective was to evaluate the design in a first stage and get inputs for final development. Next phases were focused in the development of final HMI concept according focus groups results, implementation and evaluation of it in real environment.

2. HMI INITIAL PROPOSALS

After the analysis phase, several proposals were developed taking into account different inputs. One of them was selected as initial idea to be tested in the different focus groups in order to get inputs for a deeper development.

First phase of the design was to identify the different services and prioritize them. Different layouts were presented and discussed as well as graphical proposals.

Figure 2 Initial Layout proposals for Compass 4D App

Figure 3 Initial Graphical proposals for Compass 4D App

Initial proposed solution to be evaluated in Focus Groups was thought in portrait layout. An initial screen with a map was proposed to show information for RHW on it. Also, when EEIs warnings were needed, layout were divided into two differenciated areas. Top one focused in EEIs and RLVW information and bottom one in keeping map with RHW information.

EEIs information included arrows that indicated directions and color state of traffic light for each direction. Also, a traffic light representation would show the state of the main direction traffic light state. A numeric count down was included to give to the driver information about timing remaining to change the traffic light phase.

In case of RLVW a full screen warning would cover full all alerting about possible collision and direction.

3. FOCUS GROUP SESSIONS

Focus groups are frequently used to evaluate HMI proposal with final users. These group interviews are guided by a moderator to obtain revelant information for improve proposal and to have in mind which information is important to take care for final users. As Morgan et al. expressed focus group is a special task to gathering data on specific topics [2].

In Compass 4D, three different focus groups took place. Each one of them were focused in specific final users (standard, bus and taxi drivers). Selected proposal of HMI was presented on them and participants were asked about in order to get their impressions.

3.1. Participants

Figure 4 Drivers Group Participants Composition

Bus sample was composed by 3 participants, two bus drivers and one manager of a bus company. One of the drivers had 9 years of experience as bus driver meanwhile other had only 2 years. It was very interesting this profile in sample because the appreciations where sometimes different for the novel and the expertise driver. The third participant had experience in the bus driver organization as responsible of IT Department.

Taxi sample was composed by 4 participants, two of them in their sixties and the other two in their forties. Moreover, it was possible to have different opinions with taxi drivers with a lot of experience and other with less.

Six standar participants participated also in this task. Four persons had experience as participants in projects with cooperative systems, like SISCOGA (Spanish National FOT) and DRIVE C2X, and other two had none experience with cooperative systems. Half of the sample was women and the other half men.

In any case, they had not previous knowledge about COMPASS4D project.

3.2. Procedure

The participants took part in the Focus Group following the agenda prepared for this purpose. After welcoming all the subjects involved in the discussion group were presented to create a climate of confidence and a better interaction between all participants. Then, the moderator and the assistant explained the procedure of the focus group to provide a general explanation of the different tasks during the session. A series of guidelines were provided to be followed during this activity.

During the session different HMI proposals were showed to the drivers and they could see screen shots of the application in a tablet or smartphone to be more aware of the suggested solution. With a structured interview participants expressed advantages, disadvantages or other issues to take into account to improve the HMI.

4. RESULTS

For each HMI proposal each final user group were analysed in order to identify main conclusions.

For **standard drivers** it can be concluded that they expressed the need of having some acoustic signal or blinking to catch the attention. They also choosed to have the time counter placed right in the traffic light icon. Participants had not clear if speed recommendation should be presented in the HMI.

Participants in this focus group also commented that they prefered to have a map in order to include a location adding the possibility to show RHW on that.

Considering **bus drivers**, it was highlithted that they were really worried about screen brigtness, they believed that it was better to have an horizontal orientation for HMI and drivers were not sure about the possibility of having a counter. If they had had to choose, they had preferred to have a counter with numbers instead of recommendations about speed because this information is not useful in a real situation.

Bus drivers were not favour of having arrows in the final HMI for having more space to show other information. For them it was clear that information must be as simple and clear as possible.

Once again, also this group indicated that they wanted to have a map for showing events on it. Furthermore, it was pointed out that it is forbidden to use acoustic warnings in a bus.

Other recommendation for this group was having the possibility to introduce a ID number at the beginning of the running to have the possibility to associate bus driver with route.

Finally, **taxi drivers** hesitated if they could manage another device in their cars because they use navigation system and other device to deal with their services.

This taxi group preferred to have the counter with seconds but they were not sure if having information about last seconds. An idea expressed by one driver was to positionate the counter number inside the circle of the traffic light colour in order to have more space and to be simpler the information.

Taxi drivers did not like to have a map because as it was indicated before they use their own navigation system except if alternative routes could be recommend on it.

Moreover they considered that the entire screen should be in red in case of inmiment danger (as violating a red traffic light).

5. CONCLUSIONS

There are several recommendatios and principles to have in mind when designing HMI [3,4,5,6], this guidelines should be always considered and furthermore it is adequate to “use focus group research at the early stages of the project to preliminary concepts with representative users” (pag. 17) [7]. In fact, focus group is a technique deeply used in automotive field [8, 9, 10, 11, 12]. After the three focus group sessions, there are some important issues that should be taking into account:

- It seems drivers really appreciate to have the information on a map. Moreover, it should help them to have a reference where they are and where events o incidents are located.
- Other relevant topic is to provide a spatial or temporal reference about the information for traffic lights colour change, it would help to have a more reliable system.
- An interesting proposal that participants pointed out was to integrate arrows in the traffic light icon, it would simplify the information showed.
- In case of warning they think that an acoustic feedback would help to understand the nature of this warning but taking into account that drivers should not be stressed or scared with it.
- Moreover, it will be necessary to take into account light reflections on the device where information is presented with the aim of improving the perception.

To summarize, having simple information, as simple as possible, a better understanding about what system information means is brought.

Further phases of the project were focused in applying the conclusions of these initial phases in final HMI definition.

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