

## **A PRELIMINARY ANALYSIS OF THE IMPACT OF SASPENCE SYSTEM ON DRIVING STYLE**

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**KEYWORDS** – SASPENCE PReVENT EU project, driving style, Optimal Manoeuvre, ADAS, active safety.

**ABSTRACT** - In this paper the impact of the SASPENCE system on the driving style according to driving simulator test results is described. SASPENCE (SAfe SPEed and safe disaNCE) is a vertical subproject of the integrated project PReVENT funded within EU's 6FP. It deals with the development of ADAS (Advanced Driving Assistance Systems). The subproject's main goal is to support the driver in longitudinal dynamic of the vehicle in the range 0-200 m, with special emphasis on too high speed or too small headway scenarios. In order to assess the system performance and a potential customer's acceptance a campaign of driving simulator tests has been carried out. A selection of real drivers of different age and experience underwent standard scenarios and their reactions were monitored. In this paper the results are shown and discussed in terms of human reaction to different ways to communicate alarms, system effectiveness and overall impact of the system on the driving style.

### **TECHICAL PAPER – SASPENCE DESCRIPTION**

In the aim of reducing deaths and injuries caused by road accidents, European Union (EU) co-funded the PReVENT integrated project within the 6th Framework Programme.

SASPENCE is the PReVENT IP subproject which focuses on longitudinal behavior of the car, and aims at developing and evaluating an innovative system able to perform the Safe Speed and Safe Distance Concept, i.e. to aid the driver in avoiding potentially dangerous situations related to excessive speed or too small headway. SASPENCE is active in the range from 40 to 140 km/h and looks up to 200 m in front of the car. SASPENCE consortium comprises a number of public research institutes as well as private companies, many of them involved in car manufacturing. The project is planned to finish on April 2007.

A great importance in the design of the system has been given to driver in the loop, and a great amount of the research has been conducted in order to identify the best Human-Machine Interface (HMI) to cooperate with the driver. The system will never take the control of the vehicle: it is just informative. Final choice is always left to driver.

The system is based on three main layers: Sensors, Processing and HMI. The first one collects all the data from instruments and transfers them to Scenario interpretation, which is the first step of Processing layer. Once the scenario is reconstructed, a reference manoeuvre is calculated, basing on Optimal Manoeuvre (OM) concept (1,2). This manoeuvre is found minimizing a target function that ensures minimum risk, maximum comfort and mobility, prioritized in this order. Mobility is considered once minimum risk and maximum comfort are

satisfied. Minimizing in real time such a function requires high processor load, but tests assure that the calculus is compatible with refresh frequency of about 5 Hertz. Reference Manoeuvre (RM) is compared with trajectory estimation by Warning and Intervention Strategies module (WIS), which takes care to control HMI and finally to suggest the correct behavior to the driver.

#### TEST IMPLEMENTATION(PSA)

After a first phase of potential customer analysis the need for further investigation of drivers' reaction arised, and a first version of the system was installed on PSA SHERPA simulator. PSA is member of SASPENCE consortium.

SHERPA is a driving simulator placed in PSA technic center in Velizy (France). It is composed of a partial car chassis mounted on a Gough-Stewart platform that provides 6 DOF. Outside the car, three projectors ensure frontal view of the road, while LCD displays are used as external retroviewer and back window to show what is happening behind the car. The whole system is controlled by a server coordinates the work of a cluster of computers, each one with its own task: graphics, retroviewer, car dynamic, sound, platform control. Tasks are most of the time parallel one to each other, and computers communicate via ethernet.

The Optimal Manoeuvre Module for SASPENCE was developed by University of Trento and runs on a XEON computer in SHERPA cluster. That software simulates part of data fusion module (data are coming directly from car simulation parameters) and calculates reference manoeuvre. The software takes care also to implement a preliminary version of WIS and controls auditory, visual and haptic HMI. The cockpit is replaced by an LCD driven by a flash application that shows, together with traditional cockpit information, SASPENCE status, reason of alarm (when needed) and recommended speed. There were two different configuration of the visual HMI that had to be tested. SASPENCE relies also on an haptic HMI, which main devices are an active pedal (provided by IMITA – Sweden) and a vibrating seatbelt (provided by TRW). Both the devices were installed on the simulator for testing purpose.

Tests were designed in order to understand how the presence of SASPENCE can influence driving activity. There were 4 different haptic HMI configuration (h1...h4) and 2 visual (v1,v2). Tests were performed on 3 different tracks (number 2,3 and 4: track number 1 was used during system set-up). Each track contains urban road, rural road and also highway. Thirty-four drivers (most of them PSA employees) were asked to drive the simulator on each track and to fill questionnaires before and after the test. Questionnaires were prepared by Lund University. Each driver had a first experience on the simulator about a month earlier than the test in order to avoid simulator sickness, and then drove about 25 minutes on each track. One of the driving session was performed without Human Machine Interface, and the other two session were performed using two of the four HMI configurations, rotating in a random order.

In Table 1 is possible to find the meaning of different Haptic HMI:

	Safe Speed		Safe Distance	
	Alarm	Imminent danger	Alarm	Imminent danger
h1	Force Feedback	High Vibration + Force Feedback	Force Feedback	High Vibration + Force Feedback
h2	Vibration	High Vibration	Vibration	High Vibration

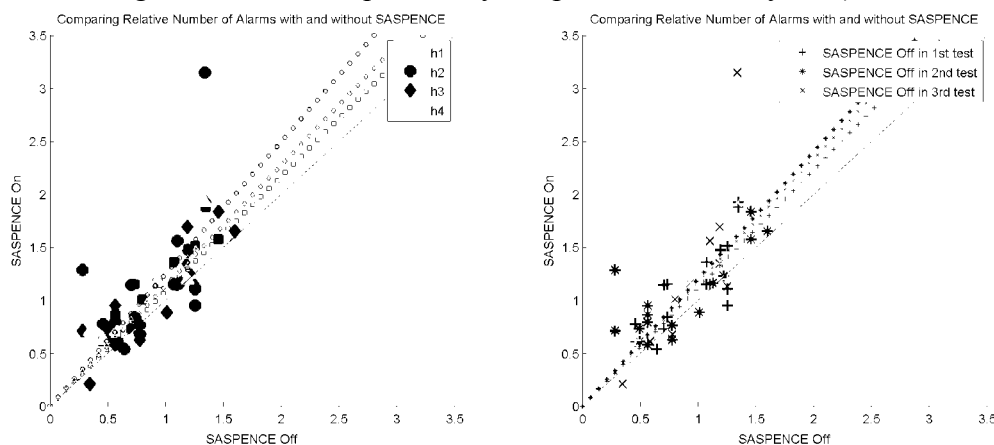
h3	Force feedback + seatbelt level 1	Force feedback + seatbelt level 2	Vibration	High Vibration
h4	Vibration	High vibration	Seatbelt level 1	Seatbelt level 2

**Table 1: haptic HMI scheme**

## INFLUENCE ON DRIVERS' MEAN BEHAVIOUR

Data from log-files have been analyzed in order to highlight the influence of the presence of the system on driving style. During tests when HMI was off, SASPENCE continued to work in a silent mode, so it is possible to know what the system would have produced in every situation and compare the reactions in silent mode with the reactions when Human-Machine interface was on.

The first analyses have been made on the number of times the driver got an alarm with or without feedback from SASPENCE (Figure 1). On the x-axis there is the measurement of the experiments without feedback to the driver, on the y-axis the measurements of the experiments when HMI was on, both normalized with respect to average number of alarms on that track. It can be noticed how these data are more or less scattered around the center line (bisector, i.e. no big and clear consequences by the presence of the system).

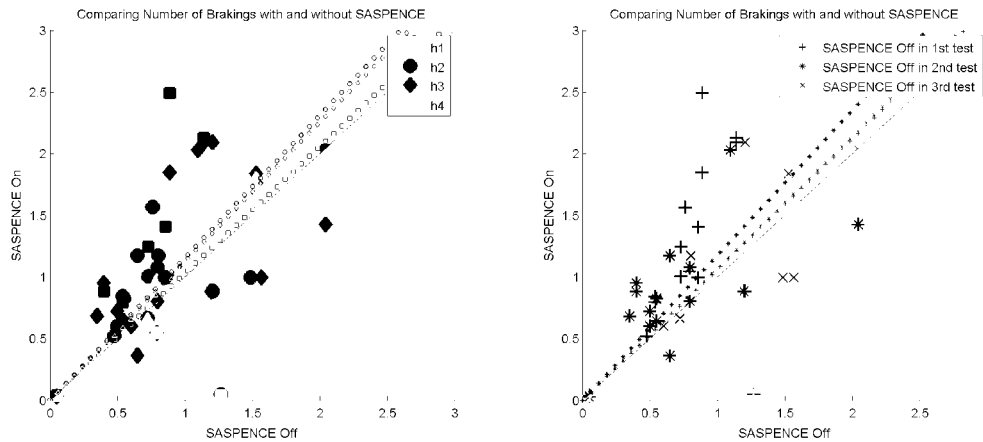


**Figure 1: Number of alarms - Comparison between SASPENCE on and SASPENCE off**

In order to highlight different behaviour depending on different Haptic HMIs and on different order in switching off feedback, the graphs are plotted twice adding the lines of mean angle. The performances are evaluated on the basis of the angle formed by the line through the point and the origin and the x-axis. The mean angle has been computed and then plotted on the graph to better highlight the medium tendency of the groups. The mean angle shows that SASPENCE presence increases (on the average) the number of alarms (by a 1.1583 factor). That can suggest two different considerations: the driver trusts the system letting him discover dangerous situations, but at the same time he wants to test the system going into potentially dangerous situations.

On the left the scattered plot involving different HMIs is shown: it is very easy to see how h2 leads to higher number of alarms, but it is probably due to the 2 points very far from the other ones. They are probably caused by the desire of the driver to test the system. Analyzing the plot on the right, it is quite easy to see that when the system is switched off in the first experiment, the number of alarms encountered in the next two experiments is slightly greater

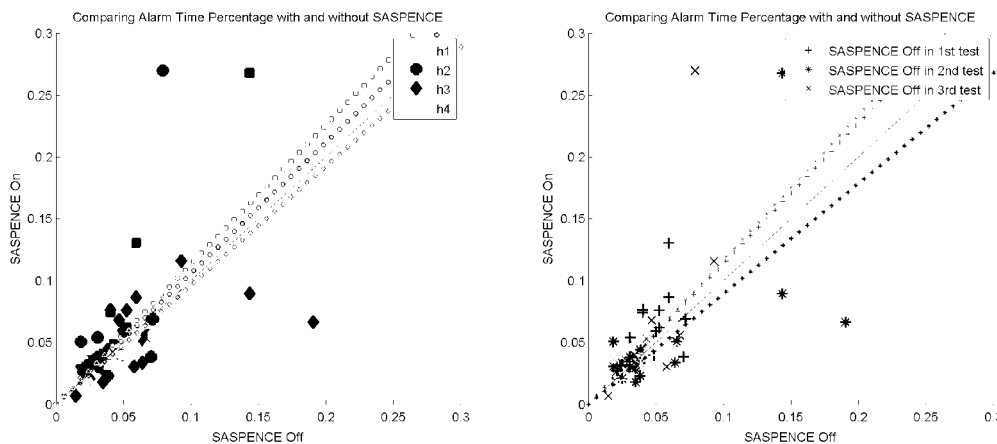
(ratio 1.116), where switching off in second (1.202) or third (1.167) experient leads to greater differences. That can be explained with the fact that the driver learns how to drive the simulator (his/her skill increases) and, at the same time, once the driver understands how the system works he is able to avoid the situations that can arise an alarm.



**Figure 2: Number of Braking. Comparison between SASPENCE on and SASPENCE off**

Almost the same analysis was performed using as parameter the number of times brake pedal was pressed. Usually, a great number means a rough driving style, and if the number increases when SASPENCE is on, the smoothness of driving is not preserved. Here again we find an increasing in the number of times the pedal is pressed during the experiments: the ratio between data having SASPENCE on and having SASPENCE off is 1.11. Again, we find that switching off SASPENCE during the second driving session causes higher ratios between the aforementioned situations: 1.175 while switching off in 1st and 3rd experiment leads to ratios of 1.060 and 1.071 respectively. It is worth noting here how h1 has the lowest increasing in number of braking: it is the only configuration where there is no pedal/seatbelt vibration for simple alarms (only force feedback): in this way the driver tends to slow down just by using throttle, without braking.

There is still another parameter that could be taken into account: the total amount of time spent in alarm situation. Quite surprisingly, switching off the system in second experiment brings to smaller ratios (0.893 vs. 1.137 and 1.168 in 1st and 3rd). This means that in the second run, having SASPENCE switched off, the driver stays quite long in hazardous situations. Switching off during the third experiment lets the driver understand where the system would work and how to avoid these situations.



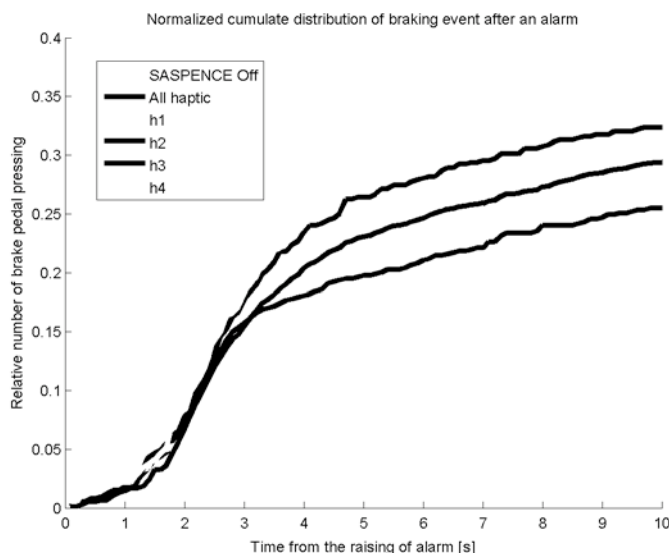
**Figure 3: Percentage of time when alarm is active**

In addition, it should be noted how h3 leads to an average decreasing in time spent in hazardous situations. That is partially linked with the two experiments in the low right part of the graph, but this fact should be taken into account and maybe re-analyzed after the analysis of system behaviour in risky situations.

## INFLUENCE ON THE BEHAVIOUR IN RISKY SITUATIONS

Such a system is designed to work at its best in hazardous situations, i.e. it works well if it is able to cause the right reactions by the driver when the safety margins are low. So, in order to evaluate its performance it is better to focus on the moments when the alert is communicated to the driver.

For example, a parameter that should be affected by the presence of the system is the time before the driver presses brake pedal after an alert. The first reaction in order to avoid a danger is often obviously to press the brake pedal or, at least, to slow down just by releasing throttle. In Figure 4, we can see how SASPENCE presence increases the number of times in which brake pedal is pressed after an alarm raised. It can be noticed that the big differences raise in the range 2-4 seconds after the alarm. Another interesting point is that less than 35% of total cases requires a braking: the system works most of the time in the range where it is possible to avoid dangers just by releasing the throttle.

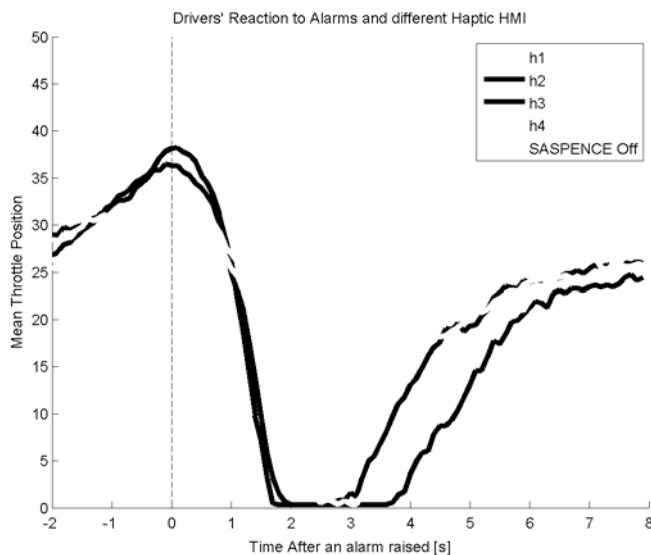


**Figure 4: Normalized cumulated distribution of braking**

Analyzing how different HMIs influence this parameter, it is worth noting how h2 and h4 induce the sharpest reaction. H3 leads to a response very close to h2 and h4 in the first 2.5 seconds, while later it raises smoother. H1 causes a later first brake pressing (gradual slope in the first 5 seconds) but then the slope is more or less the same as h2, h4 and SASPENCE off (the driver itself can recognize when there is a danger!)

As already said, if the alarm is recognized quite early it is possible to cope with this situation just by releasing throttle, even not completely. Different Human Machine Interfaces cause different reactions by the driver. We can highlight this concept just looking at Figure 5, that shows the median throttle position just before an alarm is recognized and after that event. We can see that the presence of the system causes a really different median behaviour by the driver. It is worth noting how after 2.5 seconds from the alarm the median throttle position is very close to 0 if SASPENCE is on, while is over 15% when SASPENCE is off. This fact

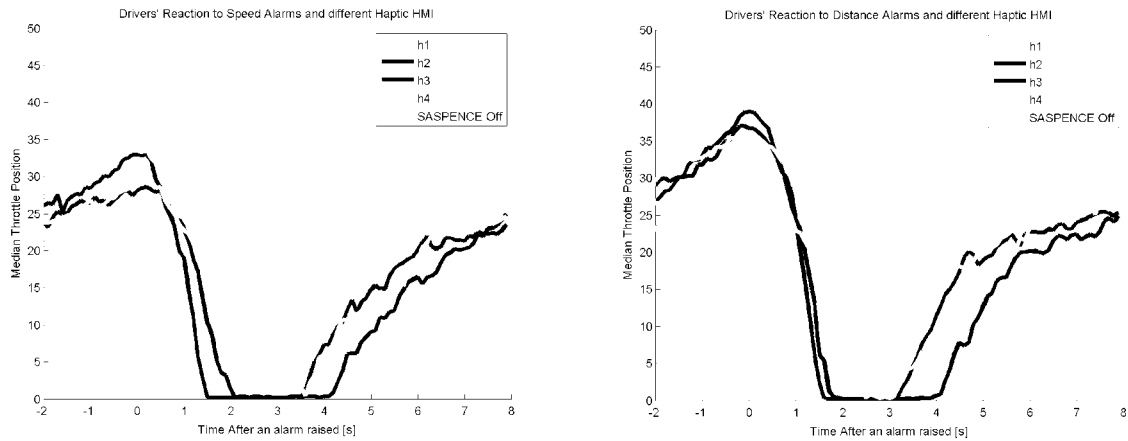
implies that the presence of the system makes the driver release throttle almost completely. Going into detail, different haptic HMIs cause slightly different behaviour. Combination h1, h2 and h4 cause more or less the same degree of deceleration in the first 2 seconds, just h1 bends a little to the right after 1.3s and doesn't go to 0 (as median). On the other hand, h4 causes a smoother slope in the first two seconds, so it can be considered slower than the other ones. Another interesting detail is the fact that h2 leads to a slower increase of the median position of the pedal after the alarm: it seems that the driver is scared about the system and waits a long time before pressing throttle again.



**Figure 5: Median throttle position around an alarm**

It is interesting to compare the results from Figure 5 with the results of Figure 4. As a matter of fact, h4 is the slowest when analyzing throttle position and at the same time the one that causes more reaction when analyzing brake. So, h4 causes late reactions but very sharp reactions, not the best way to cope with alarms: smooth reactions let in general the driver maintain bigger manoeuvrability margins.

It is also interesting to look at the differences between the reactions to Safe Speed (SS) and Safe Distance (SD) alarms, as we can see in Figure 6. It is easy to notice how h4 is slower than the other ones most of all in SD alarms, where it only uses seatbelt vibration, while in SS alarms is very close to h2 (that uses the same haptic interface). As for SS, h3 brings to the sharpest reactions, taking advantage of both force feedback on throttle and safety belt vibration.

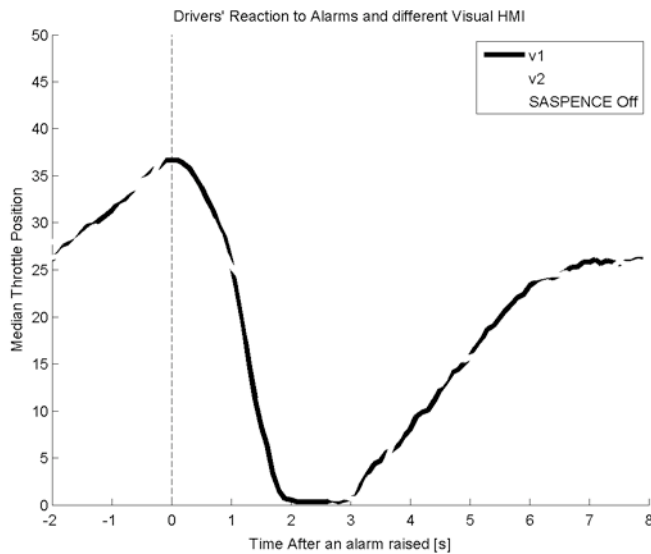


**Figure 6: comparison between safes speed and safe distance**

About Safe Distance, on the other hand, there are not big differences between h1, h2 and h3 except for the fact that h3 leads to faster re-acceleration after the alarm.

Visual HMI

On the simulator was active visual HMI, too. There were two different visual HMIs used by each driver, always together with haptic, but no big differences were found between them (see Figure 7)



**Figure 7: Comparison between different Visual HMI**

**CONCLUSIONS**

SASPENCE has proven to be effective in reducing speed when a hazardous situation occurs. It pushes drivers to slow down their car, both by releasing throttle and by pressing brake. It should be noted that such a system is just informative, it never takes control of the vehicle even if force feedback slightly changes throttle position. It was also proven that the algorithm used to discriminate alarms is good at least for what concerns the simulator where road and scenarios can be known in all details. Using the simulator also brings some uncertainty on the results compared with real driving style because of different traffic conditions, different perception of the acceleration and different mental condition. Further investigation on the

impact of such a system on everyday's driving is planned as soon as data from real car will be available.

The experiments helped also to decide which is the best HMI to use in the car. Using the results of the analysis of log files and of the questionnaires it was decided which HMI (visual and haptic) to use on the test cars. The final choice will be done after test on real road. It should be noted that such an experiment allowed to draw different conclusions than static tests, because during driving tasks the attention paid to haptic and visual warning is not the same seen in static tests.

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