Title: Effectiveness evaluation of in-vehicle warning system under reduced visibility conditions: a driving simulation study

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Background: There is wide state of art that addresses the issue of reduced visibility due to fog. Many researches use the correlation between traffic and the weather data to study this phenomenon, other employ the real-time data to investigate how foggy conditions affect the driver’s behavior up to lead to accidents. In recent times, the progress of technologies in this field allowed to develop more and more tools to support the driver in the driving task under reduced visibility conditions.

Aim: In this regard, the main objective of this research aims to evaluate the effectiveness of in-vehicle warning systems in low visibility conditions due to fog by means of a driving simulator study. Thus, this study will test ADAS assistance influence on driving behavior in foggy weather, in particular by using the Head-Up Display (HUD) technology (a type of in-vehicle HMI).

The driving simulator experiment is conducted employing an intersection and pedestrian detection assistance to send warnings to the driver when approaching respectively an intersection and pedestrian crossing. A combination of both audio and visual warning will be employed to alert the drivers during the experiments (based on literature findings that shows greater efficiency in double signal instead of single signal). The objective will address the assessment of effectiveness of HUD under reduced visibility condition, compared to no warning system.

Method: Thanks to the driving simulator, an advanced tool able to record all the driving parameters of a sample of drivers in a virtual reality environment, it is possible for this research to explore crash risks of specific drivers’ behaviors, such as car following, lane departure, approaching to intersections and pedestrian crossings, keeping same weather foggy conditions for all the drivers.

In fact, the scenarios, designed according to the Italian rules and regulations, have the following weather characteristics:

§ Scenario 1: clear visibility condition;

§ Scenario 2 and 3: the same reduced visibility condition characterized by an initial clear zone (approximately of 300 m length), followed by a constant 85 fog zone, in which the level of fog was alternately moderate (such as 100 m) and heavy (such as 50 m).

The data analysis is composed by two phases in order to enable a comparison firstly between drivers’ behavior under reduced visibility conditions and clear visibility conditions, and further between drivers’ responses under reduced visibility conditions with and without in-vehicle warning system. Each comparison was assessed related to different road sections: one consists in approaching an intersection and pedestrian crossing element, and the second one is simple section where the participants have to drive under normal and free flow conditions, that means no external conditioning (due to the presence of critical road elements) and low vehicle interference. All the
analyses are conducted for two different bibliographical indicators, i.e. kinematic and dynamic, which are able to measure the potential alterations in driving performance.

Summarizing, the data analysis is develop in three steps listed below:

- Analysis 1: NO FOG and FOG “no interference” on road segments;
- Analysis 2: NO FOG and FOG in approaching to pedestrian crossing and intersections;
- Analysis 3: FOG and FOG+HUD in approaching to pedestrian crossing and intersections.

Results: Due to progress in the areas of information and communication technologies, it is expected that in-vehicle warning information can play such a helpful role. Once established that fog conditions affect drivers’ behaviors in terms of speed reduction (around -15%), headway distance reduction (-42%) and with a significant decrease in time to arrival to critical elements, the results shows also the effects of in-vehicle warning system, considering in particular HUD technology, in case of approaching to intersections and pedestrian crossings.

Conclusions: The in-vehicle warning information provides by HUD (image and audio) before approaching to intersections and pedestrian crossings may help drivers get better prepared by harmonizing their speed. In particular regarding drivers’ braking process, it was found that HUD assistance in approaching to intersections produces the effect of controlling the use of the brake pedal better than in approaching to pedestrian. Thus, it suggests that drivers are more sensitive to visibility reduction when they are driving in approaching to pedestrian crossings, then to intersections.