Synesthetic Metering for Speed - Evaluation applied to young drivers’ speeding

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Abstract

In previous work, we have been talking about the reduction of accident levels by improving the driver’s perception of the environment through multisensory interaction [27]. Being the vision the primary sense used during driving, it suffers a large overhead and, therefore, leaves space for the increased human error. For this reason it has been proposed the use of alternative means of communication by associating the sense of audition applied to the vehicular interface. The sense of audition used as a complementary interface involves several issues which have been identified such as the rhythm and intensity. The research described in this paper, instead, aims, first, at contributing to the reduction of accidents caused by speeding; and second, through the use the multisensory information, to aid the driver to maintain a more regular driving and controlled speed. It is a system for conscious users to whom is given the choice of establishing his limits, using his goals and needs as reference. Based on sound attributes, auditory communication and the aim of helping the driver to maintain a more regular speed for greater safety, a prototype system has been developed. As research methodology, tests were conducted, using a driving simulator, to evaluate the efficiency of the system, including user’s preferences and comfort. Through the data obtained by the simulator, we sought to observe the variation of the average speed under the influence of time pressure. The questionnaire indicated no discomfort in using the auditory icons, also helping to keep a greater concentration on the road compared to the use of the speedometer only. Tests indicated that the duration of the trip as well as the dynamics of the landscape are important variables.

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1. Introduction

Italy suffers from the problem of crashes involving speeding – in 2012 the number of accidents in Italy caused by speeding was about approximately 31,000, equivalent to 16.6 percent of national crashes, causing 3,653 deaths and more than 264,000 injuries [1]. These accidents are specially provoked by young drivers [2]. In United States the situation is not different – in the same period, there were registered 10,219 fatalities provoked by speeding involving young drivers (between 15 and 20 years old), representing 37 percent of males and 24 percent of females [3].

A variety of factors influence the speeding problem, such as alcohol consumption, estimation of the driving speed, lack of experience, the influence of other drivers through speed comparison – psychological and social factors are the main ones.

Concerns about speeding consequences are motivation to develop devices to inform the driver about his speed. This can be evidenced through the history itself, since the use of vehicular interfaces to inform the vehicle speed has been one of the earliest interfaces used, from the very first years of the creation of the automobile [4].

Nowadays, to reduce accident statistics, Intelligent Speed Adaptation devices (ISA) are used. These systems use interfaces to inform the speed through sound alerts, verbal sound alerts, tone signals, beep and multisensory, such as auditory and visual alerts or auditory and tactile. Multisensory information through auditory warnings applied on other devices demonstrates to be more effective in improving performance and reducing reaction times, helping the driver to perform the primary tasks [5]. However, concerns on applying the ISA system are that auditory warnings in some situations showed a lower comfort, when used like vocal message or beep, combined with visual and haptic systems, annoying drivers and therefore not being appreciated and lightly increasing the mental workload [6,7,8,9].

Vehicular interfaces making use of multisensory information are applied to different situations, demonstrating to be an efficient way to bring information to the driver. This information is responsible to orientate the driver to have control over devices and especially over his actions and decisions regarding the vehicle in the traffic.

The driver’s activity could be divided into three different categories of tasks. The first one, called the primary, is responsible for activities such as maneuvering the steering wheel and pedals, the secondary tasks are those which maintain the security (for instance, turning on devices like wipers), and the tertiary are responsible for the activation all the other comfort, information and entertainment devices [10].

Such quantity of tasks generates competing demands, resulting in mental overload due to the driver’s limited cognitive resources, mainly regarding vision, that is the most used sense, compared with the others [11,12].

The in-vehicle system complexity, together with the presence of the different devices inside the vehicle, create an increase in research to find new ways of reducing information overload to the driver, applied in different situations. Some of these researches are looking to integrate multisensory information using senses like auditory and haptic, resulting in an important action for the driver performance.

Using multisensory interfaces in the in-vehicle devices create a more immediate and richer means of communication. They are able to convey a more complete information to describe compound situations, showing, for instance, the direction of the event and urgency levels, that may improve Reaction Times (RTs), and reduce workload [13,14,15,16]. The perception and distinction of the urgency level is also influenced by the complexity of the task to be performed, resulting in the different RTs [17].

Many studies in the automotive field use guidelines where the urgency of an alarm is represented by fundamental frequency, intensity, duration of the pulses and inter-pulses [18].

Natural sounds can offer a more viable solution to inform a state of a product. Natural sounds can contain semantic information of the event, informing intuitively and naturally [19] and therefore creating a positive emotional experience between the product and the user. This was demonstrated in other in-vehicle interfaces, through the auditory icons concept [20,21] showing a direct relationship between the warning with the type of event and demonstrating good results.

Some variations of ISA systems are used as "mandatory", which inhibit speeding through stringent actions such as reducing fuel injection; others may be less stringent consisting of "advisory" reminders to the driver through visual or audio signal; and yet there are the "voluntary" ones that make difficult to speed up by upward pressure on the accelerator pedal, but even so being usually possible to override this limitation. Drivers, in general, prefer to be allowed to override the ISA when necessary, and are not very receptive to stringent speed control systems [22].
The acceptance in the use of "voluntary" ISA during tests determined that drivers who drove more times above the speed limit, had a lower acceptance of the system. In other words, drivers making use of "voluntary" systems are less likely to respect the warnings, violating the speed limit [23].

Low acceptance in "mandatory" devices can be explained by the fact that they often use strong actions that inhibit speeding, as reducing fuel injection or closing the throttle and applying the small brake pressure to the hydraulic system, resulting in frustration of drivers, but above all taking of the driver the freedom to choose when to activate it. Stopping this action causes a feeling of frustration in the vehicle control. The personal frustration for incapacity in the use of a device when it does not correspond to your expectations is one of the most hated feelings for user interfaces and it is necessary the use of conceptual models, mapping and affordance applied to them [24].

The low acceptance in the use of audio warning, like verbal or beeps applied to ISA devices can be accredited to the fact that the types of warnings sometimes do not have a direct connection with the event. Users of devices that use beep or verbal sounds tend to annoy and make uncomfortable because of this artificiality, especially if they are played for long periods. In addition, the effect of novelty should be considered – hearing a sound for the first time usually calls attention and activates reactions; as it becomes known and repetitive the driver becomes confident with the alert which then becomes annoying and induces sleepiness instead of provoking an action.

Frequency and rhythm can convey the quality of information in the case of vehicle’s speed. Studies analyzed the use of information through the intermittence of the auditory warning using the perception of non-musical rhythms while in front of a computer – semantic differential scales and rhythms with the meanings of “Accelerating” and “Decelerating” [25]. Despite having shown the participants’ low familiarity with this test conditions, it is hypothesized that these sounds could be better perceived when being used in a specific context/ activity such as driving. Associating a sound with a visual experience can offer a different perception of an event. Besides, using auditory warnings that contain connections with the event can become one way to inform the quality of the event, informing how much the driver is over speed.

Examples supplied by researches where applied as test drivers’ interfaces using simple tones to give advices to the driver. Auditory signals were repeated (looping) expressing the level of urgency and informing about how much to slow down/speed up [26].

To offer the possibility of customization, such as alternative means of user-interface (communication and interaction) giving to the driver more control over the device, can increase the usability and acceptance of the system. Another important point is to make the correspondence between the audio warning intermittence with the acceleration and deceleration of the vehicle. Another relevant aspect is the use of natural sounds supplying information to the driver more intuitively without annoying him. It is believed these two points can offer new experiences to the driver, helping him to better accept the alarm, compared to ISA interfaces which are used nowadays.

It is necessary to design more articulated, informative and intuitive auditory alerts, taking into account semantic factors associated with the action of driving. These types of alerts can offer a more natural and better interaction, creating a more positive experience with the system’s interfaces.

In this paper it is proposed a continuation of the previous work [27]. Initial tests were applied using the auditory icons concept aiming at observing the first impression of drivers as regards driving between two speed limits (a minimal limit and a maximum one), using the natural audio warning. Driving under time pressure has been also evaluated.

As demonstrated by initial applied studies about audio interfaces through auditory warnings, they can inform to the driver not only the effective speed of the vehicle, but also the quality of the driving. Practical tests were conducted, with the aim of identifying the initial students’ perception regarding rhythm, intensity and acceptation. During a driving simulator’s test it was also analyzed possible future improvements on the application as an effective aid system to speed control. The acceptability of the audio warning utilized during the test has been evaluated also through a questionnaire in the end of the test.
2. Methods

2.1 Participants

Twenty young students of the Polytechnic University of Turin with good knowledge of Italian (19 male, 1 female) were selected to participate in the test. The age range was between 20 and 24 years old, with the average age of 21.4 years (SD = 1.5). The participants had a valid driver's license from an average driver experience of 3.1 years (SD = 1.8). The participants have never received any type of penalty. Problems regarding vision and hearing have not been detected. They have voluntarily participated in the test (with no specific rewarding), after having received a questionnaire via email and having being informed about the event through posters displayed in the university.

2.2. Design

For the realization of the test it was used a drive simulator emulation video game called RFactor® v1255 and also a software created for the purpose of assigning sound alerts when necessary and acquiring data – the information of speed, distance, time and time to activate the audio warning – creating at the end of each test a report for statistical purposes.

To run the Rfactor game it was used a laptop with 4 gigabytes of RAM and for the software that collected the data a desktop computer with 1 gigabyte of memory.

For the output of audio warnings from the desktop and engine sound from the laptop they were used two pairs of speakers. The first one was responsible for the sound notification positioned on the table, in front of the participant (100 cm distance), and the distance between a speaker and the other was of 100 cm. The second pair of speakers, responsible for the engine sound, was positioned under the table, with the same distances between the other pair. The projection of the simulation was done using a projector with the projection size of 51 inches, and the image was projected at 120 cm away from the participant. A 17” LCD monitor was used to inform the instantaneous speed and maximum speed on the route, positioned at the center of the projection. The joystick utilized was the Thrustmaster®, model Universal Challenge 5-in-1 V.4, with steering wheel (gear paddles type "butterfly") and pedals (brake and accelerator). The researcher remained on the right side of the participant, at 100 cm distance (see Fig. 1).

![Fig. 1. Experimental demonstration environment.](image)

2.3. Sound design

The kind of auditory warning used was based on the auditory icon concept, mimicking the wind sound perceived when driving with the windows open, like proposed in previous work [27]. The sound is based in a mp3 file, with duration of about 1 second and intermittence of the warning was determined for every 100 meters covered by the vehicle, so that the time between intermittent sound alerts is directly related to the speed.
For this step of research the sound utilized was downloaded from the sound effects website [28], and modified through Audacity® software, with the aim of generating 2 different types of auditory icon – one to alert when under speed limit and other to alert being over speed limit. The sound intensity utilized in the auditory icon during the tests was defined as 85dB (A) and to the engine sound was defined as 65dB (A) to 120 km/h.

2.4. The driving scenario

The total route corresponds to the distance of 25 km, totally straight and without traffic, and being divided among 5 maximum speeds (40, 60, 80, 100 and 120 km/h). The route has been divided in five parts according with the five correspond speeds making five subdivisions of 5 km of route for each speed. To obtain a more realistic test scenario, the 5 km corresponding to each speed were distributed randomly during the route, ensuring that participants are not to drive continuously 5 km for each speed at a time. For each part of the route it was established the maximum and the minimum speed allowed. The minimum speed was always 5km/h lower than the respective maximum speed. (35, 55, 75, 95 and 115 km/h). These two limits allow a security margin between the minimum and maximum speeds. No warning sound is heard, when the participant driving the car keeps it within those limits of speed (including the two extremes). For example, Fig. 2 shows two limits between 55 and 60 km/h, while the participant is outside the safety margin, below 55 km/h or above 60 km/h, the warning is heard every 100 meters covered. Then, the time between intermittent sound alerts is directly related to the speed at which the car is driven, while when the driver is inside of these two speeds, no warning sound is emitted.

![Fig. 2. Example of sound alerts when driving outside the safety margin between 55 and 60 km/h.](image)

During the application of the test, visual information was provided through road signs, only as regards the maximum speed. In the same screen it was also shown that the driver had to take as a reference both, the instantaneous speed and the duration of the test. For the minimum speed, the participants already had knowledge of the safety margin, which was explained during the presentation of the test, and then this information wasn´t visually provided.

3. Procedure

The participants had to do two tests – in the first one, called “Total travel time”, the participants had to complete a route of the 25 km without exceeding either the maximum or the minimum speeds, in a time frame of 24 minutes. This information was explained to the drivers at the beginning of the test. Time and speed were two characteristics to be measured in this test. The former, time, aims at establishing which group can realize the route closer to the time determined. The latter, speed, is to see which group can stay longer inside the speed limit, despite the time pressure to complete the route in the pre-defined period.

The second test was called “Maintenance of the speed between the minimum and the maximum (average)”. In this test participants were instructed to complete the same route, without breaking the limits of minimum and
maximum speed which means that the task was to complete the route in the average time. Just like the first test, but this time without information about the time to finish the test. As the first test, it measured the average speed, which group could stay longer inside the speed limit, but this time without the time pressure.

Participants were divided into two groups, each one of 10 students. The first one (control group) used the speedometer to control the speed. The second, made the test using both the speedometer and the audio warning (auditory icon) each time they were above or below a specific speed showed for them. To arrive at the pre-determined time means traveling between two speed limits. The goal of this division was to compare the results between the control group and the group that listened the audio warning.

Although both groups have made the two tests, it has been set that the control group first made the test "Total time travel" and afterwards the "Maintenance of speed between the minimum and the maximum" test. The opposite was done with the group which used audio warnings – they have started the test with the "Maintenance of speed between the minimum and the maximum". This has been made to minimize the effects of a possible conditioning of the participants in relation to the time provided in one of the tests, which could affect the subsequent test.

In the application of the test, first of all, the participant received an instruction sheet explaining how the first test would be done. At this point, if the participant had no doubt, he was free to drive for 5 minutes in the same route, at any speed. The goal of this part was to make sure the test environment was properly adjusted (devices - steering wheel and pedals – and the information present on the screen, including audio warnings). This would avoid the “novelty effect” when the official test started. The second test was performed with the same procedure as the first one.

After these tests, participants of the group that used the auditory warning answered a questionnaire with the purpose of giving their impression about the test. This questionnaire was created aiming to know whether the auditory warnings were considered annoying, if the warning was considered to help maintaining the concentration on the road compared to the speedometer, and if the warning sound was able to inform about minimum speed and the exceeding of maximum speed.

4. Results

4.1. Qualitative results

At the end of the tests, a questionnaire was applied to the participants that did the test with the speedometer together the auditory icons. It had four questions. According to the results of the questionnaire, the auditory icon was not annoying during the test to nine out of ten participants. The participants declared also, that the warning sound in its totality has helped them to maintain the focus on the road, compared to the speedometer only (ten out of ten). It was asked if the auditory icons were able to inform about the missing of minimum speed missing or the maximum speed excess. In the first case, the use of auditory icons was more homogenous according to participants. The information about exceeding maximum speed has proved even more efficient.

4.2. Quantitative results

According to the Analysis of Variance (ANOVA), the statistical results showed no significant difference between the speeds in respective situation of the use of the speedometer and speedometer with auditory icons, presenting a significance value ($p > 0.05$). In was observed no variations in speed between driving with auditory icons and driving control. This occurred in all the speed applied to the test, where ($p > 0.05$) ($p = 0.922$ at 40 km/h; $p = 0.543$ at 60 km/h; $p = 0.959$ at 80 km/h; $p = 0.506$ at 100 km/h and $p = 0.731$ at 120 km/h).

The pressure of the time in the execution of one of the tests also showed no variation of the average speed, in comparison with the test without the pressure of the time (see Fig. 3 a, b, c, d), with or without the auditory icon. With ($p > 0.05$) ($p = 0.733$ at 40 km/h; $p = 0.112$ at 60 km/h; $p = 0.223$ at 80 km/h; $p = 0.120$ at 100 km/h and $p = 0.902$ at 120 km/h).
5. Conclusion and discussion

In a former work, it was proposed a speed control system to help the driver to have a safer travel, using the auditory icons that mimic wind sounds when traveling with the vehicle windows open, informing when driver is under and over speed limits.

Based on the previous work, this research proposed a study about the initial impressions of the drivers about the use of auditory icons to inform the speed. A virtual test using a simulator was then applied aiming at understanding their behaviors and also a questionnaire was applied to collect their opinion at the end of the test.

The participants of the test have evaluated the experience as very positive. They have declared that the auditory icon utilized during the test was not annoying, was efficient and more useful to inform eventual speed excess, helping to maintain focus on the road.

The yet small number of tests performed though, was not sufficient to reveal a conclusive correlation between driving using the audio warning proposed and driving with the speedometer only. In this sample, in the two groups analyzed, the drivers were able to maintain a similar average speed. The time pressure also revealed no significant change of the participants’ behavior.

Adding a hazard evaluation in looking at the speedometer, through external signals, requiring the participant to perform an action due to the signals and thus evaluate its reactivity could be a possibility to apply in future tests. Another possibility for future works is to leave the intermittency warning customization level as a driver’s choice, which then could be more effective in the perception of speed and in its control, compared to intermittency level previously defined. An auditory warning that adjust its reproduction mode according to the duration of the trip may also affect the drivers perception.

The application of this device in a real context will then be important to demonstrate more details than it is possible in the virtual simulator.
References


