Listen! There Are Other Road Users Close to You – Improve the Traffic Awareness of Truck Drivers

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Abstract. As the amount of good transportation on road is increasing the accidents involving heavy trucks and other road users are also increasing. To make the truck driver aware of other road users close to the truck is very important to avoid accidents. Present study tested different auditory icons that were representing different road users and presented in 3 dimensions in the truck cockpit to see if such design could improve the driver traffic awareness in trucks. A prototype system including four different type-of sound themes has been developed to present the road users such as pedestrian, cyclists, motorcycles and other vehicles. The setting was tested on subjects and integrated in a truck-simulation at Volvo Technology Corporation. An experiment was conducted to test whether these 3D sounds can improve the driver's traffic situation awareness. The results suggest that natural or realistic sounds (auditory icon) are most suitable to this application due to their intuitiveness, distinguish ability and relatively low degree of disturbance.

Keywords: 3D audio, auditory icon, traffic, driver safety, truck cabin.

1 Introduction

As the amount of good transportation on the road is increasing, accidents involving heavy trucks are often happened. Collisions between heavy trucks and invisible other road users, such as small cars, pedestrians, cyclists, motorcyclists, etc are often happened and can cause fatal accident, not to the truck driver, but other road users [1]. For most of the road users, there are misconceptions about trucks and truck drivers [2]. Vehicle industry is introducing different technologies to avoid different kind of possible fatal accident [3]. The examples of the technologies that can help driver to avoid accidents are collision avoidance/warning system, adaptive cruise control, lane tracking departure warning, side sensing (proximity) devices, etc. For all of these systems, a warning signal normally should provide to the driver. The warning signal can be provided in different kinds of modalities, such as audible or visual alarm. The timing and frequency of such warning signal presentation is a big problem and different to find the consistent opinion among drivers [2]. Besides, warnings were considered as negative feedback by the driver and should be in the minority using [2].

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There are different ways to present the road information to improving the drivers' traffic awareness. One is to improve the driver's visual capacity by introducing many camera displays inside the truck cabin so the driver can have a better view of the traffic situation outside his truck, especially to those dead visual angles. Already nowadays, the driver's visual demands are considerable high [4, 5]. The amount of visual information from various devices such as navigation systems, audio systems, headway warnings and even the in-vehicle information systems tends to clutter the visual perception as well. At the same time, the audio perception has been almost blocked. The truck cabin is silent enough not to hear the traffic sounds. The "lack of sound" along with the limited view from inside the cabin significantly reduces the driver's traffic situation awareness.

A prototype that using synthesized 3D sound to simulate the traffic situation for the truck driver was designed and tested in the lab. The purpose of the study is to see whether a 3D sound system can increase the driver's traffic situation awareness by hearing different road user's location, distance, moving speed and moving direction related to the vehicle, so it can reduce the visual loading. This study is the first phase of series studies to evaluate different possibilities of providing positive information to the truck driver to avoid the potential accidents.

2 Method

Six traffic situations that have high probability of accident occurrence between truck and fellow road-users are identified, based on the limitation of truck driver's view, as user scenarios in the test. The scenarios are by Volvo Technology Corporation's internal study results, as showed in Figure 1.

In scenario 1, the shadowed area in the picture depicts the non-visible area of driver due to the masking from the right A-pillar and side rear mirror. A potential and impending collision may occur with the car from the right side. In scenario 2, the driver puts all his attention to the roundabout and has little chance to spot the car

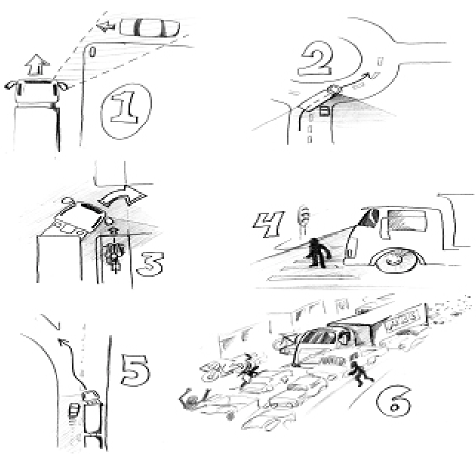

Fig. 1. The traffic scenarios that potential accident may happen

running tightly along the truck. In scenario 3, the bicycle to the right of the truck is simply too low, too close and too quiet to be recognized by the driver who intends to take right turn. In scenario 4, the driver is watching the traffic lights, and doesn't notice the old man, slowly crossing the street. He is below the driver's field of view. In scenario 5, the experienced driver properly checked his/her left rear mirror there was no sign of a car in the left lane, but as he starts to turn over, a car swiftly turns up from seemingly nowhere. In scenario 6, the traffic is moving very slowly, there is not really a risk for serious accidents, but some potential risks are exists.

Equipment

A sound engine was developed that could add 3D sound to the existing simulator. It can support sound playback for a predefined types of road users. Five types of road users were selected; car, truck, motorbike, pedestrian and bicyclist. All sounds used by the sound engine are 16 bit wav sound samples with sample rate 44100 kHz. The natural sounds that representing different objects were selected by subjective judgment. Seamlessly looping audio clips were created. The vehicle simulator at Volvo Technology Corporation is shown in Figure 2. The test driver is placed in the driver seat of a Volvo FH12 truck cab which has been detached from the chassis and placed on the floor. Three projectors, placed above the cab, together project a 140° field of view image on the curved wall in front of the cab. The wall radius from the driver's eye-point is 3.5 m to the screen.

The simulator executes traffic scenario, vehicle dynamics, data logging and graphics rendering on a Silicon Graphics Onyx2 with multiple CPUs and multiple graphic cards. The steering wheel torque is controlled from a separate PC and the I/O to and from the cab is communicated on a PC with CAN and analogue IO-interface. A single speaker, placed behind the passenger seat, is used to produce the engine sound. The quality of the engine sound is calculated from the vehicle dynamics models engine load and speed. This sound rendering is produced on a Silicon Graphics Impact2 workstation.

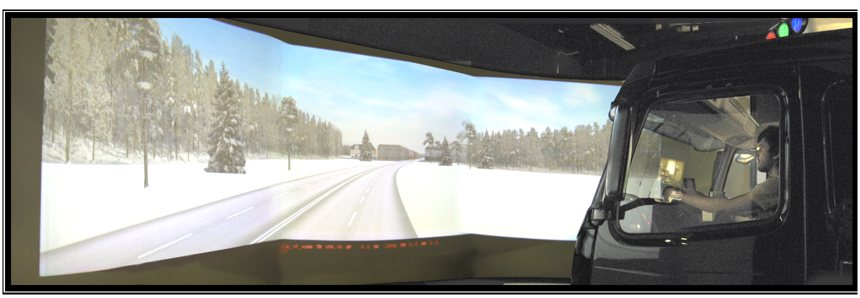

Fig. 2. The truck simulator at Volvo Technology Corporation

Speakers that generate the simulated 3D sound are located as to a 185 cm tall persons head as he/she is seated in the driver seat. The calibration was achieved by using white noise as speaker signal and the sound intensity was monitored and adjusted to 70dB(A) by a sound level meter set up for calibration of Loudness.

Procedure

Seven subjects participated in the experiment. Five of them were professional truck drivers and the other two were staffs from Volvo Trucks Company. All of them were males with the age between 26 to 55 years. The truck drive experience was from 2year to 30 years. None of them have problem with vision and hearing. The purpose and the design of the testing system was explained to the subjects orally and with written text, to make sure that the subjects understand it properly.

In the drive scenario, every test started with a “silent” run in the simulator i.e. the test person was obliged to make a ten minutes drive through the full scenario without aid from the 3D-sound system. After the silent drive, the 6 scenario sections were repeated in random order with the 3D-sound system on.

The experimenter took place in passenger seat to observe the drivers behavior. The subject was invited to freely comment on what he/she heard and how he/she experienced of the traffic situation and the influenced from the 3D sound system. The performance of each subject was recorded by a video camera for later observations and data analysis.

After the drive the subjects was asked to answer a questionnaire. The system acceptance in terms of usefulness and satisfaction were primarily desired to be estimated. This acceptance scale was developed by Van Der Laan’s [6]. Nine basic bipolar questions with a neutral or zero reference point, implying both direction and intensity, are used to pinpoint system acceptance (See table 1). Individual item scores run from -2 to +2 as +2 are most positive and -2 are most negative. This technique provides a reliable tool for the assessment of acceptance of new technologies [6]. Finally the test ended with a conversation/interview concerning the subjects driving reactions, etc.

Table 1. The modified Van Der Laan’s acceptance scale

Item 1.	useful	□	□	□	□	□	useless
Item 2	pleasant	□	□	□	□	□	unpleasant
Item 3	bad	□	□	□	□	□	good
Item 4	nice	□	□	□	□	□	annoying
Item 5	effective	□	□	□	□	□	superfluous
Item 6	irritating	□	□	□	□	□	likeable
Item 7	assisting	□	□	□	□	□	worthless
Item 8	undesirable	□	□	□	□	□	desirable
Item 9	raising alertness	□	□	□	□	□	sleep-inducing.

Among these 9 items, question1, 3, 5, 7 and 9 evaluate the usability aspects of the system, while question 2, 4, 6 and 8 evaluated the driver’s satisfaction. The usefulness scale is the sum of item 1, 3, 5, 7, 9 divided by 5, and satisfaction scale is the sum of items 2, 4, 6, and 8 divided by 4.

3 Results

The result of system acceptance in terms of usefulness and satisfaction was shown in Figure 3 by using Van Der Laan's acceptance scale [6]. A bi-dimensional diagram with subjects' assessed acceptances is plotted. High experienced usefulness corresponds to above midpoint values and a high level of satisfaction is to the right of the vertical center line. According to this scale all subjects except one find the system useful and only two out of total eight subjects find it not satisfactory. The black circle top right of the chart center is the average acceptance. The absolute value should be regarded as the level of acceptance. Using the SPSS computer statistic program to analysis the date, the results showed that it is consistent and reliable within subjects (Cronbach's $\alpha = 0.688$ for usefulness, 0.827 for satisfaction).

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- Very easy to interpret and understand the fellow road users type, position, move direction and distance by sound
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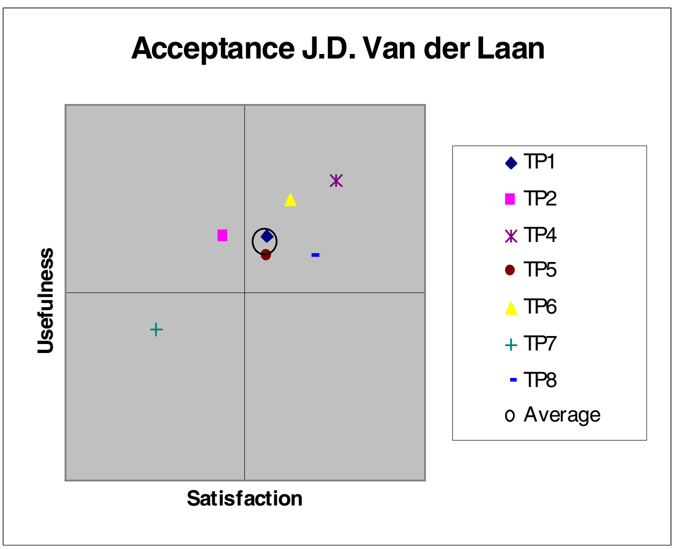

Fig. 3. Estimation of acceptance

The overall reaction to the design is very positive. It provides the users with "wow" effect. All subjects reported that they would probably use a system like this if it was available in their vehicle, but none of the subjects reported that they would use it all the time. All subjects reported that such a system is most usable in urban- or similar, dense traffic situations or in situations with reduced visibility, ex. fog, darkness or heavy snowfall. A majority of the subjects questioned the usability of the system in presence of music or radio, which was generally regarded as an almost sacred element in the daily round of a truck driver. Regarding specific sounds, the motorbike overtaking the test driver at the freeway section was auditory perceived as much faster than it was in reality. Everyone, though, recognized it as a motorbike even before it was seen.

4 Discussion

The prototype has been a valuable tool for the investigation of the 3D sound concept. It is encouraging and promising that most of the system criticism in fact has concerned in prototype implementation designs. Still, the study reported here is just a preliminary study to test the design concept. A lot more work is needed to be done.

There was an augment on what kinds of sounds should be used, earcons or auditory icons as we used in present study. To be able to answer the question, this pilot study which reported here was carried out. Most subjects select the auditory icons because it provided the intuitive information of approached objects from the sounds. A variety of factors may play an important role for the achievement of using 3D audio for enhancing traffic awareness. Usability and satisfaction estimations based on the ten minutes drive in the simulation seem too short. Audio system annoyance may be far more manifested for longer drive time.

A common reason for degrading the system was subject disbelief in the system realization feasibility. Several subjects followed the line of reasoning "It works very well in the simulator but it won't work this good in reality" and thereby assigned the concept less credibility.

It is observed that when the 3D was presented, the subjects listened up or started to turn their heads in an unmistakable direction telling way. Others tried to look in the rear mirrors or through the windows (though impossible). The lack of functional rear mirrors in the simulator setup should be noted as one of the major drawbacks of the simulator since it induces a great reduction in awareness compared to reality.

As it is well-known problem that due to the problem of many blind spot surround the huge truck, it is hard for the driver to detect all possible hazards on time visually. Using auditory cues to guide the visual searching can be a good help, especially when the hazard objects are in the blind spots, the auditory cue can be the only channel to present the existing potential hazards. The integration design in detail and the safety value of the system needs to be investigated in the future.

In conclusion, the 3D sound system concept proved to possess a good acceptance rate in terms of usefulness, satisfaction and desirability.

5 Future Work

Sound realism should primarily be improved by elaborating more advanced models for road user object dynamics and minimize the possible distraction from the sound. Some extensive user studies must be performed to statistically assure those results.

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