ADAS Presentation Modalities 2

Project within Electronics, Software and Communication

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FFI

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1. Executive summary

The project “ADAS Presentation Modalities” was an applied research project in the area of Vehicle HMI (Human Machine Interaction). The project resulted in new concepts for a multimodal (visual and auditory) interaction design of ADAS (Advanced Driver Assistance Systems). The research made in this project “ADAS Presentation Modalities 2” is a direct continuation of the work performed by PhD student MinJuan Wang at Chalmers University of Technology and has enabled her to complete her PhD degree.

The project has involved research in both visual and auditory information modalities in order to investigate what information is suitable to be presented in which modality. To optimize the design solutions, methods such as interviews, ecological interface design, human centred design, expert evaluations, and simulator studies have been be carried out to further develop and evaluate the design concepts. Differences between Swedish and Chinese drivers has also been addressed in the project. Design suggestions and guidelines have been generated for the industrial design at VCC.

Within this project, a number of studies have been carried out regarding the conceptual design and evaluation of visual and auditory Advisory Traffic Information System (ATIS). Following are the main outcomes and contributions from the studies.

- A conceptual user interface design of visual ATIS was developed and evaluated in both Sweden and China. Based on the user interviews, focus group study, contextual analysis and evaluation study, a number of design recommendation and limitations was established.
  - The results proved that the conceptual system supported the driver with good performance in general.
  - The driving performance results underlined that driving cultures may differ significantly between Sweden and China, and this difference in turn affects how drivers respond to advisory traffic information systems.
  - The results highlights a number of differences in driving culture, how driving behaviour is changed by a cross-cultural visual ATIS and, most importantly, what general conclusions can be drawn from this in respect to the design of future ATIS systems.

- A conceptual user interface of 3D Auditory Advisory Traffic Information System (3DAATIS) was designed and implemented in a driving simulator. The evaluation study is a proof of concept, showing that advisory, spatialized sound cues can be successfully used in a 3D Auditory Advisory Traffic Information Systems in order to improve drivers’ situation awareness and performance. A number of design implications were identified from the study:
  - Spatial sound cues work ideally in situations involving single road users in the

front and side sectors.

– In complex situations, spatial sound cues can be confusing; in these cases, supporting them with visual information ought to be beneficial.
– It is beneficial to support drivers with both advisory information sound cues and warning sounds.
– Non-obtrusive, harmonious sounds work well for advisory driver information. A lot of work remains before this can be implemented in real cars, but our results point in a positive direction and show that this will be a worthwhile addition for drivers, increasing driver safety and situation awareness.

2. Background

Advanced Driver Assistance Systems (ADAS) are important selling points on the automotive market today and they are expected to be even more important in the future. Examples of ADAS functionality today are: advanced navigation systems, Adaptive Cruise Control (ACC), lane departure warning system, lane change assistance, collision avoidance, intelligent speed adaptation, Pedestrian protection, automated parking, traffic sign recognition, blind spot detection and lane keeping aid. At Volvo Cars, ADAS systems are manufactured and sold already today. There is a general trend in electronics that hardware (computer hardware, radar, sensors, etc.) will continue to include more functionality and higher capacity in each generation. There is also a trend that Human-Machine Interaction (HMI) is becoming more and more important.

As more ADAS technologies are introduced into the vehicle, some important questions need to be answered: How can we design the interaction between the driver and the ADAS systems so that ADAS technologies can provide suitable assistance for the driver? Presently in the automotive industry ADAS design is often technology driven. However, this type of design has not taken the real needs of the driver into consideration. A great deal of the information from ADAS is presented visually to the driver.

Recent research has pointed out that the demands on drivers' visual workload are already too high [5,18] and about 90% of the information is received visually [13]. The results from the "100-car study" [8] showed that visual inattention was a main factor in 78% of crashes and 65% of near crashes. Moreover, glances away from the road for more than 2 second for any purpose double the risk of the near-crash/crash [17]. Thus, it is vital to design ADAS that actually support drivers' attention and guide drivers' visual search effectively and efficiently. Research has shown that road safety can be improved by increasing the driver's situational awareness through information presentation.
It was reported [11] that visual information support was appreciated more by the driver in high speed driving. At the same time, many of these studies have shown the great potential of using auditory information for presenting environmental and traffic stimuli. Aviation studies showed that using 3D audio signals could reduce the target searching

time and therefore increase the pilots' situational awareness [3,7]. Begault, Tan and Lerner [1,2] indicated that directional acoustic cues to hazardous direction have the potential to precipitate driver response.

In ADAS design, important issues need to be addressed: firstly, *time issue*, when should the information/warning be presented to the driver? If the information is presented too early, it may cause distraction and discomfort. If it is presented too late, the drivers may not have enough time to react to. Secondly, *information transparency*, warning signals are often used to present information from ADAS. Warning signals can alert the driver in urgent situations, but without providing information on what the danger is and how to react to it. Studies [15] have indicated that a warning signal was considered as negative feedback by drivers and should not be used often.

The FFI EFESOS DRIVI project investigated how to design intuitive and straightforward visual and audio information support to the driver during normal driving. Studies from EFESOS project have underlined that increase the driver's traffic and driving situational awareness through visual information presentation is an effective way to improve road safety. In addition, the results from drivers' requirements study showed a positive attitude towards 3D auditory information presentations. The FFI EFESOS DRIVI project was among the first projects to focus on presenting *intuitive* traffic *situational information* to the driver in *normal driving situations*, specifically, the outcomes have underlined promising results on presenting information to enhance the traffic situation awareness, rather than warning. Still, those results are not enough to settle the issue of whether current designs will assist drivers straightforwardly and intuitively under the real traffic situation. Therefore, significant work still needs to be done. In this respect, a set of new design suggestions and research questions should be further investigated, which is the starting point for this project where the development of a seamless interaction between two modalities has been investigated.

3. Objective

The objective of the project was to develop and improve the design concepts and methodologies on supporting driver with multimodal ADAS information presentation during normal drive to enhance traffic situation awareness and avoid potential traffic accidents. Visual and auditory presentation modalities has been the focus. The project has explored on different variables such as road types, traffic situations, different road users, and drive contexts. Culture differences between China and Sweden has also been considered.

4. Project realization

WP1 –ADAS Visual traffic information presentation

In WP1, a cross-cultural information requirements study and design and evaluation of Visual Advisory Traffic Information System (ATIS) were conducted. The ATIS was tested in a driving simulator in both Sweden and China. The aim of the WP was to understand if it is possible to design an interface for drivers from different regions, making them drive more safely and investigate if they respond in the same way to different traffic situations and to the information given by the ATIS. The details of the studies within this WP can be found in the following figure1.

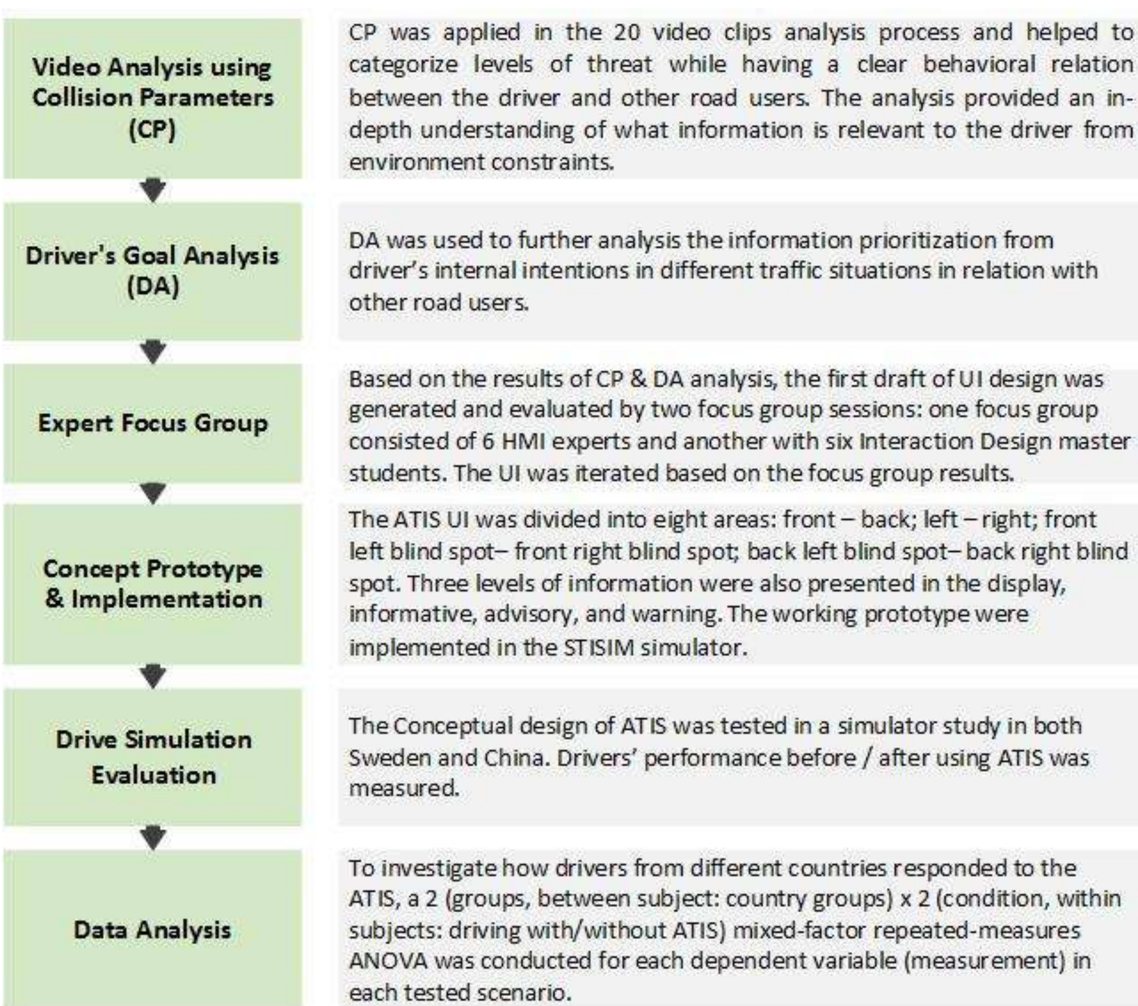
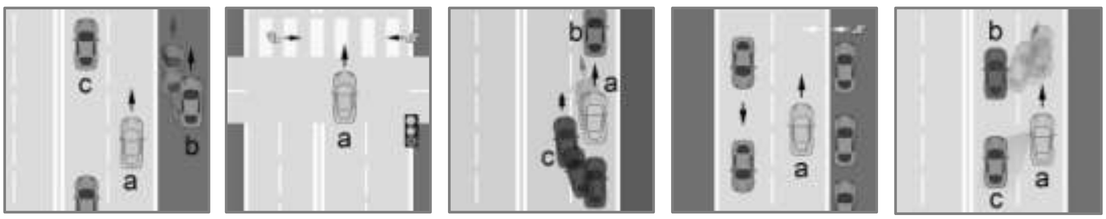


Figure 1: The design and evaluation process of visual advisory traffic information system

WP2 – ADAS auditory modality

In WP2, a prototype of a 3D Auditory Advisory Traffic Information System (3DAATIS) was developed, which aimed to provide relevant advisory information regarding road users in the vicinity of the own vehicle. This information includes in which direction the road users move and which risk level they are at (in terms of time/ distance to collision).

A simulation drive study was conducted to evaluate the conceptual prototype. The study was utilized a within-subject experimental design, treatment conditions (Baseline: without 3DAATIS / with 3DAATIS), and five traffic incidents scenarios (Cut In, Intersection, Overtake, Pedestrian and Red Cab) as independent variables (see figure 2).



Cut   Intersectio   Overtak   Pedestrian   Red Cab

Figure 2 The traffic incidents scenarios studied

The overview of the studies within WP2 is shown in figure 3.

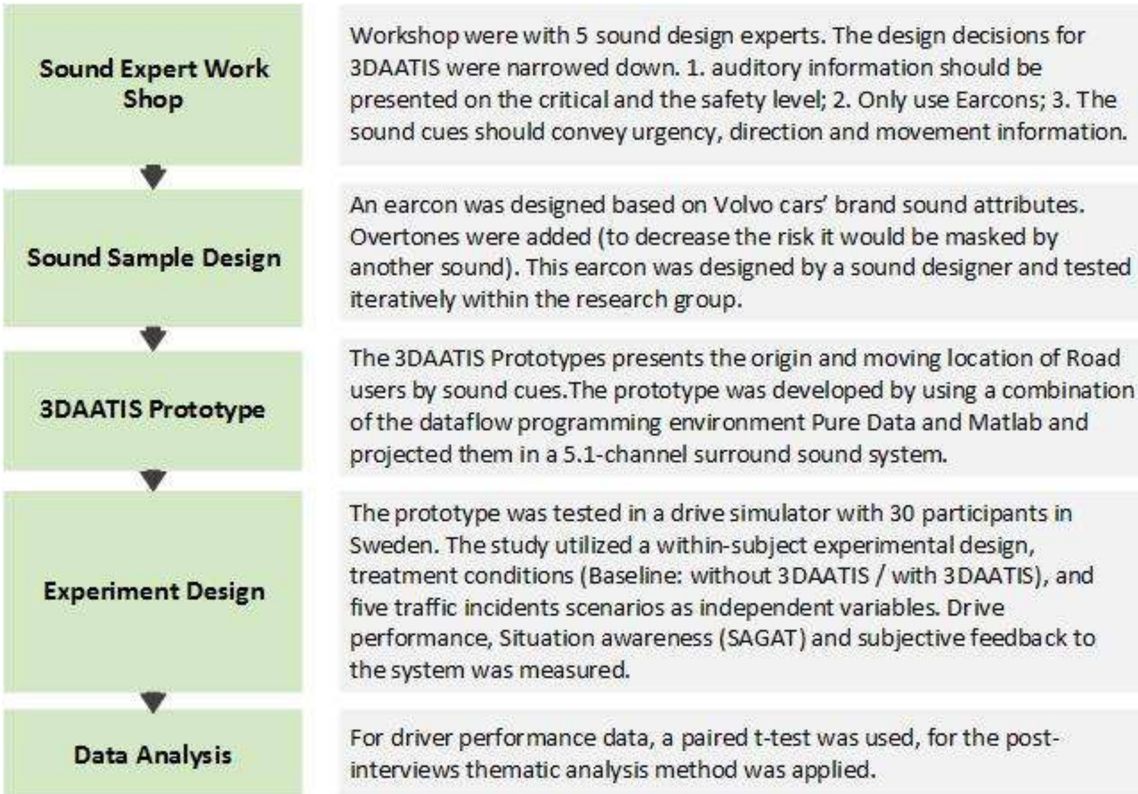


Figure 3 The design and evaluation process of 3D Auditory Advisory Traffic Information System

WP3 – Seamless multimodal interaction

This WP was postponed due to time constraints.

WP4 – Dissemination

The PhD dissemination is planned to May 2017.

WP5 – VCC In-Kind – HMI 2.0

The VCC in-kind project HMI 2.0 focused on simplifying the interaction with the displays in the car cockpit – driver information module, center stack display and head up display – to decrease the visual demand in the interaction. The project focused on making the displays into one entity, have more robust gestures and states, be simplified, have better reach, and to prepare for customisation and functional growth. Air gestures and proximity sensing were also explored in the project. The project resulted in an interactive prototype that was installed in a car.

5. Results and deliverables

5.1 Delivery to FFI-goals

The goal of the program Electronics, Software and Communication is to contribute to a global leadership in vehicle electronics and software as well as to increase the competence in verification and development methods.

- The research made in this project has created a foundation that in turn can be used to improve ADAS systems in future cars. It has contributed to enhanced innovation capacity as well as competitive capabilities.
- The project have had an international focus, with emphasis on China, which has created a greater understanding of this important market.
- The knowledge built-up in this project has substantially increased the expertise in verification and development methods specifically for ADAS.

6. Dissemination and publications

6.1 Knowledge and results dissemination

WP1 ADAS Visual traffic information presentation

Overall, from the results in WP 1, we see the same driving behaviours reflected in our results on driving patterns. For the majority of Swedish participants the first reaction was a longitudinal strategy (i.e. slowing down), whereas Chinese participants' first response was steering. The significant differences found between groups indicate that even if performance improved with the ATIS, it did not change or shaped their original behaviours. Swedish participants maintained their longitudinal strategy whereas the Chinese preferred lateral strategies.

The Cut In scenario is especially interesting in this regard. Chinese participants' data indicate that the ATIS helped the drivers by making them aware of cut in vehicle. But instead of braking or stopping for the vehicle to pass first, they utilized the information from the ATIS, in that they instead of stopping, switched to another lane (which they through the ATIS knew was empty) to avoid the vehicle but still be able to drive on, despite the fact that this behaviour is not encouraged from a safety perspective. So here, the interface actually encourages a lateral strategy for a driver preferring this. This particular result is in line with an earlier observation we did in China with the Blind spot warning information. When the blind spot information system (BLIS) is activated, the Chinese drivers do not do any visual check up on the other lane, they just change lane based on the information showed on the BLIS. This is a typical non-intended use of the system, since the drivers trust the system too much. Most of the automated systems are reliable and usually work as intended, but unfortunately, some may incidentally fail or behave unpredictably. It is problematic if drivers trust them too much, i.e. rely uncritically on their cars' ADAS without recognizing their limitations or irregular behaviours.

In contrast, Swedish drivers used ATIS information as a basis for slowing down more than anything else; and examples can be found in the Intersection scenario, where Swedish drivers utilized the ATIS to react earlier than the Chinese since, as shown from the information requirements, Swedish drivers are more interested in information regarding what is going on in front of them.

Both driving performance measurement analysis and drive pattern category analysis indicated that when drivers interacted with pedestrians, Chinese drivers and Swedish drivers showed totally different behaviours. Chinese participants tended to steer away to avoid the pedestrians but keep on driving. Swedish drivers, on the other hand, slowed down, being more concerned about their safety distance to other road users. This reflects two things; firstly how drivers perceive the risk of causing an accident involving vulnerable road user. Secondly, it shows how drivers have been socialized into certain behaviours as per based on the traffic situations they are used to. Swedish drivers break, based on that the car behind, likely has enough safety margin to break too. Chinese drivers change lanes if possible, assuming that the cars behind do not have time to break, which might cause a serial crash. In accordance, field studies on Chinese traffic situations and driver behaviours have pointed out that high traffic density, ignorance of traffic rules and chaotic combination of trucks, cars, scooters, bicycles and pedestrians are the main problems of driving in the city. Moreover, in China, it is not the driver's obligation to give way to the vulnerable road users, such as pedestrians – instead the other road users need to watch out for the cars. Therefore, when drivers encountered the situations with vulnerable road users, they tended to avoid them by changing to another lane and then continue driving. Consequently, the second most common crash pattern in China in 2009, contributing to road traffic deaths was side-to-side crash (25.5%): only 1% less than frontal crash making these the two most common crash patterns [19].

This shows how notions of "safe behaviour" may differ from case to case. If an emergency brake will lead to a serial collision, it might be better to change lanes in order to avoid a pedestrian, hopefully not hitting another, unnoticed pedestrian.
The unanticipated behaviour described in the previous section, as well as our insights in the very different traffic situations in Sweden vs China raised a design question for us: is it up to us to assume that there is some international standard for what "safe driving" entails? Can we always know which behavior is safe and which not, i.e. can we design our systems in such a way that we shape driver behaviour towards this assumed safe behaviour? We are no longer certain that this is neither possible nor wise. Our study shows that Traffic Safety Culture is more deeply ingrained in the drivers' behaviours than

we thought, and in conclusion we believe that one needs to think through this issue more than once before trying to design a more persuasive interface.

WP2 – ADAS auditory modality

In this WP, we *studied whether spatialized sound cues can be used to present situational information in such a way that it supports situation awareness and driving performance in a real driving context*. In general, the results were promising. Participants perceived the system as being useful, response times were better, and in a majority of situations SA and driving performance increased. Interesting findings were obtained in those situations the system supported SA and performance, and those it did not, resulting in a number of design implications, as being discussed below.

As for acceptance, the 3DAATIS received notable positive scores on perceived usefulness, which means that **participants are open for spatialized sound cues.** Moreover, we used only one sound displaying three dimensions (direction, movements and urgency), and participants did not have any problem understanding this underlying concept, meaning that it was **easy to learn**. To some extent these findings go against the common car-industry notion that auditory displays should be avoided in the vehicle compartment, due to distraction and annoyance when the number of sound increases. However, we did consider these negative effects in several ways. Firstly, our focus was on ***advisory*** sounds (being more pleasant and less urgent than warning sounds).Secondly we aimed to design the system as to only make sounds when really needed, as shown by our thresholds (table 1 and related text).The fact that the sound cues (65 dB) worked together with ambient traffic sounds (45 dB) is promising.

The most important finding is that **spatial sound cues work ideally in situations involving single road users in the front and side sectors**. In less complex situations, or when single road users occur in front or in the front side sectors, drivers can quickly perceive and associate the localized sound cues with what they see from the traffic situation outside of the car; feedback is instant. Therefore, even though sound localization resolution is quite low, drivers' performance and Situation Awareness in these situations was still increased, as exemplified in the scenarios *Cut In*, *Intersection* and *Pedestrian*. The second was that **if the situation is complex, spatial sound cues can be confusing**. If, for instance, there are several road users around the car, and/or sound cues come from the back, the limited auditory localization resolution and/or front-back confusion makes the information ambiguous, confusing drivers. This was clearly shown in the scenarios *Red Cab* and *Overtake* in terms of number of collision, response time and driving performance. In the *Red Cab*-scenario neither the system nor the human capability to discern the exact direction of the sound could help the drivers to tell the two vehicles' sounds apart; the angle between them was too small. Others have made similar findings. Tan et al [1] carried out an extensive test on sounds and sound localization accuracy by placing participants in a car equipped with 16 speakers (as opposed to the 4 we used), concluding that localization in general is accurate enough to orient the listener towards the direction of sound source, but with mean errors about 10 to 20 degree. In addition, several cases of perceptual reversals (i.e. more than 90 degrees off) were observed. From this, we take that **in these situations, supporting sound cues with visual information to avoid confusion ought to be beneficial**.

Like other car-related studies [6,16], our study also concluded that it **is beneficial to support drivers with both advisory/situational information sound cues and warning sounds.** The results from the SAGAT enquiry showed increased understanding and projection of the future situation in three (*Cut In*, *Pedestrian* and *Overtake*) of the four scenarios tested for this. Again, *Red Cab* was the outlier. In addition, drivers' response time improved in all scenarios as compared to baseline. These results suggest that drivers, whose attention has already been directed towards a potential hazardous situation, either avoid it all together, or react faster to the warning sound. It is worth noting especially, that in the *Overtake*-scenario, the overtaking car came up so fast, that the system went directly into warning-mode, skipping over the advisory level, which also indicates that the advisory level really adds to SA and performance. For *Overtake*, drivers did react faster, but not necessarily in the right way; the front-rear confusion came into play as mentioned above.

We believe that the last finding is particularly interesting in the light of semi-automated driving. As more and more ADAS are introduced, bringing even more displays into the car and overloading the visual channel, we believe that an auditory display could be good candidate to offload the visual channel and highlight the most important situational information. Moreover, as drivers might switch between driving and other secondary tasks during semi-autonomous driving, jumping directly to the warning level might be too abrupt. Instead, **advisory level sound cues should be used to bring drivers back to into the loop with good situation awareness**. For instance, Lee et al [10] investigated how users, working with another task, responded to collision warnings, showing that graded alerts led to a greater safety margin and a lower rate of inappropriate responses to nuisance warnings. In addition, they found that graded alerts were more trusted than single stage alerts. (One could argue that if the car is truly self-driving it should not be necessary for drivers to take over, but until the car industry has solved the ethical dilemmas that may arise in acritical situation, there still needs to be a way for humans to quickly take back control.)

Here, we believe that the car industry has a lot to learn from the game industry, since it has long experimented with the use of ambient sounds as a means to provide players with a general sense of what is going on in the environment – this is especially relevant for any location based games where players move around in the real world [4,9,14].

In this WP, it was not specifically designed to give conclusions on the sound design, but from the post-interview and test results, we can still draw some conclusions. We designed custom sounds devoid of the harsh and inharmonious qualities associated with warning sounds, which we assumed would work better for advisory purposes. Despite the fact that the sounds now were no longer typical, attention-grabbing, warning sounds, drivers still observed and responded to them. Thus, one conclusion is that **non-obtrusive, harmonious sounds work well for advisory driver information**.

Another implicit conclusion is that the setup of the speaker system is crucial, as is calibration of panning algorithms and acoustic preparation of the listening environment. Our rather basic setup was a simple proof of concept, and can naturally be much improved. In a real car, a larger number of speakers must probably be used for improved precision, but, resolution of directional localization will always be somewhat limited because of how human perception works. Similarly, it is worthwhile to investigate the use of different timbre as suggested by [12].

6.2 Publications

Publications

1. Fang Chen, Minjuan Wang, and Lian Duan. 2014. (Book Chapter) Letting Drivers Know What is Going on in Traffic. *Advances in Intelligent Vehicles*. Elsevier.
2. Fang Chen, Călin Giubega, Peter Chen, and Minjuan Wang. 2014. Designing an In-Vehicle Advisory System to Support Traffic Awareness. *10th ITS European Congress, Helsinki, Finland*, 10th ITS European Congress, 1–12.
3. MinJuan Wang, Lian Duan, Jia Xin Wang, Lin Li, Dong Sun, and Fang Chen. 2016. Drive Advisory System : Do Swedish and Chinese Drivers Appreciate It in the Same Way ? *International Journal of Engineering and Technology* 8, 4: 286–292.
4. Minjuan Wang, Sus Lundgren Lyckvi, and Fang Chen. 2016. Same, Same but Different: How Design Requirements for an Auditory Advisory Traffic Information System Differ Between Sweden and China. 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications.
5. Minjuan Wang, Sus Lundgren Lyckvi, and Fang Chen. 2016. Why and How Traffic Safety Cultures Matter when Designing Advisory Traffic Information Systems. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.
6. Minjuan Wang, Sus Lundgren Lyckvi, Chenhui Hong, Palle Dahlstedt, Fang Chen. 2017. Using Advisory 3D Sound Cues to Improve Drivers' Performance and Situation Awareness. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.

Master theses

Peter Chen,Calin Giubega,	Development and evaluation of an in vehicle advisory information system	2013.12

Maria Kougioumoutzi	Development of an in vehicle advisory information system	2013.06
Chenhui Hong	Development of a 3D auditory in-vehicle advisory interface for traffic information presentation	2016.09

7. Conclusions and future research

WP1- ADAS Visual traffic information presentation

In conclusion, the results from this WP indicate that drivers from two different driving cultures showed distinctly different driving strategies. Swedish drivers tend to stay in the lane and slowdown in response to an incident, whereas Chinese drivers are much more prone to change lanes and move on. This was especially significant if pedestrians were involved. These behaviors can be coupled to driving culture aspects such as national traffic situations etc. Further, we have shown that it is possible to design an Advisory Traffic Information System that improves the performance for both groups, but, at the same time we show how Chinese and Swedish drivers respectively, still are influenced by their own driving culture when responding to the ATIS; both groups performed better, but in different ways. In conclusion we believe that if one wants to maximize the driver performance outcome with an ATIS, the design has to consider the driving culture where the ATIS is to be used. We also conclude that one needs to be very cautious if one aims to persuade users to take the safest action: what is “safest” may differ significantly between culture and situation.

WP2 – ADAS auditory modality

In conclusion, the study in WP2 is a proof of concept, showing that advisory, spatialized sound cues can be successfully used in a 3D Auditory Advisory Traffic Information System in order to improve drivers’ situation awareness and performance. Unlike previous studies this one included a simulator drive under as natural conditions as possible, featuring other road users and complex situations.
The most important implications of this research are that:

- Spatial sound cues work ideally in situations involving single road users in the front and side sectors
- In complex situations, spatial sound cues can be confusing; in these cases, supporting them with visual information ought to be beneficial.
- It is beneficial to support drivers with both advisory information sound cues and warning sounds.
- Non-obtrusive, harmonious sounds work well for advisory driver information.

A lot of work remains before this can be implemented in real cars, but our results point in a positive direction and show that this will be a worthwhile addition for drivers, increasing driver safety and situation awareness.

8. Participating parties and contact persons

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9. References

1. Tan A.K. and Lerner Neil D. 1996. Acoustic localization of in-vehicle crash avoidance warnings as a cue to hazard direction. *U.S. Department of Transportation National Highway Traffic Safety Administration*. Retrieved from http://trid.trb.org/view.aspx?id=474030

2. Durand R Begault. 1993. Head-up auditory displays for traffic collision avoidance system advisories: A preliminary investigation. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 35, 4: 707--717. http://doi.org/10.1177/001872089303500409

3. W Dell. 2000. The use of 3D audio to improve auditory cues in aircraft. *Department of Computing Science, University of Glasgow*.

4. Inger Ekman, Laura Ermi, Jussi Lahti, Jani Nummela, Petri Lankoski, and Frans Mäyrä. 2005. Designing sound for a pervasive mobile game. *Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology*, 110–116.

5. J Engstrom, E Johansson, and J Ostlund. 2005. Effects of visual and cognitive load in real and simulated motorway driving. *Transportation Research Part F: Traffic Psychology and Behaviour* 8, 2: 97–120. http://doi.org/10.1016/j.trf.2005.04.012

6. Johan Fagerlonn and Alm Håkan. 2010. Auditory signs to support traffic awareness. *IET Intelligent Transport Systems* 4, 4: 262--269. http://doi.org/10.1049/iet-its.2009.0144

7. Ellen C Haas. 1998. Can 3-D Auditory Warnings Enhance Helicopter Cockpit Safety? *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 42, 15: 1117–1121. http://doi.org/10.1177/154193129804201513

8. S G Klauer, Thomas A Dingus, V L Neale, J D Sudweeks, and D J Ramsey. 2006. *The Impact of Driver Inattention On Near-Crash / Crash Risk : An Analysis Using the 100-Car Naturalistic Driving Study Data*. National Highway Traffic Safety Administration. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:The+Impact+of+Driver+Inattention+On+Near-Crash+/+Crash+Risk+:+An+Analysis+Using+the+100-Car+Naturalistic+Driving+Study+Data#0

9. Jason Kurczak, T. C. Nicholas Graham, Claire Joly, and Regan L. Mandryk. 2011. Hearing is believing: evaluating ambient audio for location-based games. *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, 32. http://doi.org/10.1145/2071423.2071463

10. John D Lee, Joshua D Hoffman, and Elizabeth Hayes. 2004. Collision warning design to mitigate driver distraction. *Proceedings of the SIGCHI Conference on Human factors in Computing Systems*, 65–72. Retrieved March 24, 2012 from http://dl.acm.org/citation.cfm?id=985701

11. Anders Lindgren, Alexander Angelelli, Paul Alvardo Mendoza, and Fang Chen. 2009. Driver behaviour when using an integrated advisory warning display for advanced driver assistance systems. *IET Intelligent Transport Systems* 3, 4: 390–399. http://doi.org/10.1049/iet-its.2009.0015

12. David K McGookin and Stephen A Brewster. 2004. Understanding concurrent earcons: applying auditory scene analysis principles to concurrent earcon recognition. *ACM Transactions on Applied Perception (TAP)* 1, 2: 130–155. http://doi.org/10.1145/1024083.1024087

13. P L Olson and R E Dewar. 2002. *Human factors in traffic safety*. Lawyers & Judges Publishing Company.

14. Natasa Paterson, Katsiaryna Naliuka, Soren Kristian Jensen, Tara Carrigy, Mads Haahr, and Fionnuala Conway. 2010. Design, implementation and evaluation of audio for a location aware augmented reality game. *Proceedings of the 3rd International Conference on Fun and Games - Fun and Games '10*, 149–156. http://doi.org/10.1145/1823818.1823835

15. M Roetting, Y Huang, J Mcdevitt, and D Melton. 2003. When technology tells you how you drive—truck drivers' attitudes towards feedback by technology. *Transportation Research Part F: Traffic Psychology and Behaviour* 6, 4: 275–287. http://doi.org/10.1016/j.trf.2003.09.001

16. Nash Stanton, Roger Lew, Nolan Boyle, et al. 2011. An Implementation of a Graded Deceleration Display in Brake Light Warning Systems. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 55, 1: 1573–1577. http://doi.org/10.1177/1071181311551328

17. D. L. Strayer and W. a. Johnston. 2001. Driven to Distraction: Dual-Task Studies of Simulated Driving and Conversing on a Cellular Telephone. *Psychological Science* 12, 6: 462–466. http://doi.org/10.1111/1467-9280.00386

18. T Victor, J Harbluk, and J Engstrom. 2005. Sensitivity of eye-movement measures to in-vehicle task difficulty. *Transportation Research Part F: Traffic Psychology and Behaviour* 8, 2: 167–190. http://doi.org/10.1016/j.trf.2005.04.014

19. Xujun Zhang, Hongyan Yao, Guoqing Hu, Mengjing Cui, Yue Gu, and Huiyun Xiang. 2013. Basic characteristics of road traffic deaths in china. *Iranian journal of public health* 42, 1: 7–15. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3595633&tool=pmcent

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