Same, same but different: How design requirements for an auditory advisory traffic information system differ between Sweden and China

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Same, Same but Different: How Design Requirements for an Auditory Advisory Traffic Information System Differ Between Sweden and China

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ABSTRACT
Many advanced driving assistance systems have been developed based on the western automobile markets. However, it is widely known that the differences between Western and Asian markets are large in terms of traffic safety culture, traffic situation, and driver behavior. This study aimed to explore the differences between Swedish and Chinese drivers' information requirements in regards to a 3D Auditory Advisory Traffic Information System design (3DAATIS). A total of 46 participants took part in the study. The results showed that both Swedish and Chinese drivers appreciated the concept of a 3DAATIS. Moreover the two groups expressed similar information needs when interacting with a single road user, e.g. giving higher priority to vulnerable road users. In contrast, they expressed different information requirements in complex traffic scenarios. The results further imply that identifying drivers' requirements under different traffic scenarios can be a feasible approach to successful cross-regional adaption design.

Author Keywords
Auditory information; Advisory Traffic Information System; traffic safety culture; drivers' requirement study.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces.

INTRODUCTION
Within the design and development of automotive Human Machine Interface (HMI), there has traditionally been a focus on the needs and preferences of the drivers from mature markets [16]. However, many Advanced Driver Assistance Systems (ADAS), that have gained notable success in mature markets, have failed in emerging markets [2]. As a consequence, the importance of cross-regional issues within the design of an automotive HMI system has been acknowledged by different studies [13,15,17,31]. Not taking regional differences into consideration during HMI design development can result not only in lower user acceptance, but also – and far more problematic – in systems that are potentially harmful. As for the time being, neither industry nor academia have a detailed answer on how to design a HMI that will satisfy drivers from different regions.

This particular challenge has multiple facets. Firstly, the information presented to the drivers must be relevant to their needs in their everyday driving context in order to drive safely. Secondly, the definition of what is considered being safe in a driving context varies between regions due to different traffic situations and behaviours. Thirdly, there is no established cross-regional adaption design method in the field of in vehicle HMI. To optimize the automotive HMI design, especially for ADAS, it is necessary to identify and understand the needs of drivers in different driving contexts. Systems designed to warn drivers are targeted towards immediate responses on an operational level, i.e. fast and automatic reactions, and are thus not very culture-dependent. Advisory systems, on the other hand, aim to support drivers' planning and reasoning on a tactical and strategical level, e.g. using advisory information to decide whether, when and where to perform non-critical driving manoeuvres like overtaking. These tactical and strategical behaviours are largely influenced by driving context and traffic safety cultures.

The aim of this study is ***to understand design requirements for 3D Auditory Advisory Traffic Information Systems (3DAATIS)*** when considering different traffic safety cultures. The study was a focus group study based on a 3DAATIS, in combination with selected traffic scenarios displayed as movies. Hereby we could explore how regional factors like driving habits, behavior and traffic context may result in different design and information requirements.

Sweden and China were selected as example countries, this since most of their cultural dimensions provide opposite profiles according to the Hofstede cultural index [10]. Furthermore, they differ greatly in terms of traffic situation and driving behaviours. As for China, with the rapid increase of vehicles on the road, and traffic infrastructure not being on par, roads a crowded or congested, and traffic is often

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mixed. In line with this, a large number of traffic accidents in China involves vulnerable road users such as pedestrians and cyclist, especially in urban areas. Moreover, violations of traffic regulations are major factors contribute to accident rates [29]. The Chinese traffic situation resembles that of many other developing countries, e.g. India and Thailand. In comparison, Sweden is a mature market. Most drivers are second or third generation drivers, and the traffic infrastructure is well developed, e.g. traffic is often divided (e.g. specific lanes for cars vs cyclists). Safety awareness is very high, and Sweden has the lowest rate of fatalities per inhabitants in the world. The Swedish traffic situation is representative for the majority counties in Scandinavian and some European countries. In conclusion, our Swedish vs Chinese participants can be said to represent two quite different Traffic Safety Cultures, meaning that they in combination are well suited for exploring cross-regional design requirements.

RELATED WORK

In this section we will give a brief introduction to the topics of the paper.

Cross-Cultural Design and Automotive HMI Design

Different cultures create different patterns of social behaviour and interaction which have led many researchers to develop cultural-models to describe and understand the differences. These cultural theories include the Onion model [25], the iceberg model [19], and the pyramid model [9]. Amongst all available cultural models, Hofstede's cultural dimensions theory is one of the most widely used in the field of HMI design and automotive industry [10]. The model describes cultures in terms of six dimensions (Power distance; individualism vs collectivism; masculinity vs femininity; uncertainty avoidance; long term orientation vs short term normative orientation; indulgence vs restraint). These cultural dimensions help us to understand and explain how and why orientations on various cultural dimensions may contribute to, or account for, differences in users' needs, preference and expectation of technology or artefacts cross cultural groups.

However, this theory is not specifically developed for the purpose of ADAS HMI design. In this particular domain, environmental constraints plays an important role, e.g. traffic regulation, traffic situations and infrastructures. Those factors influence how drivers interact: with other road users outside of car; and with the information system inside. This brings us to the concept of Traffic Safety Culture (TSC), which has been defined [3] as "*the assembly of underlying assumptions, beliefs, values and attitudes shared by members of a community, which interact with a community's structures and systems to influence road safety related behaviours.*" This definition addresses that TSCs consist of common practices, expectations, attitudes, and informal or hidden rules that drivers learn from society regulations and by observing others in their communities. This in turn motivates driving behaviours and strategies [17]. (Do note that a TSC is not the same as a national culture; several countries could have the same TSC, or one country could display several TSCs.) A number of researchers have studied differences in traffic incidents and fatalities between national cultures. Lund and Rundmo [18] have identified differences in risk perception and attitudes towards traffic safety and risk between Norwegian and Ghanaian drivers, finding that there were major differences between nations in perception of risks. In a similar study, Ozkan et al [22] concluded that cross-cultural differences exist in driving skills, after having compared drivers' self-assessed skills with accident data and fatality rates in six different European countries.

Moreover, a number of regional difference studies have tried to explore possible culture elements in the automotive field. A study carried out by Khan and Williams [12], aimed to identify the elements within infotainment HMI that are culturally specific – for instance perception of ease of use; and acceptance. They identified a strong correlation between usability issues and regional differences. Other studies by Heimgärtner and his colleagues have also highlighted a number of cultural differences regarding user preferences, system navigation and driving styles, which are relevant to cross-cultural in-vehicle information system design [6,7]. E.g. they found out that Chinese drivers preferred greater information density and a faster flow of information than German users for the navigation system tested.

In another study regarding regional issues with ADAS designs [5], a number of focus group discussions and an online survey were conducted to identify different types of constraints occurring in the relationship between Brazilian drivers and ADAS. The conclusion pointed out that the problems and characteristics of the Brazilian traffic environment had not been addressed in the current design of the systems in Brazilian market, which affected the drivers' low acceptance to ADAS. Unfortunately the study did not clarify how to take traffic environment constraints into account during design.

As for Sweden vs China specifically, Lindgren et al [16] compared Swedish and Chinese drivers in terms of preferences towards ADAS system, given driving experience in common traffic situations. Their results showed that even though Swedish and Chinese traffic regulations are similar, driver behaviours are highly culturally mediated. In particular, they found that Chinese drivers tended to drive more aggressively, and obey rules less than the Swedish drivers.

In summary, the results from these studies demonstrate that introducing Western-style in vehicle information systems into developing markets like China with little or no adaptation to meet the requirements and cultural preferences of this region is unlikely to be successful. Currently, there is still a limited understanding of what factors and reasons underlie these differences. Moreover there are no suitable models to describe culture from other domains (e.g. the Hofstede's dimensions) that can fully be utilized when studying automotive HMI designs; the subset of traffic safety cultures (which may differ within countries) must be taken into account.

Advisory Traffic Information Systems (ATIS) and the Use of Sounds

Designing a good ATIS means designing for Situation Awareness [4] which in short means supporting all three levels of awareness: firstly perceiving the ongoing situation (e.g. the conditions of the road, current traffic regulations, situation in relation to one's own driving, seeking out potential hazards; and thirdly extrapolating the events to be prepared to act, i.e. "thinking ahead". In summary, drivers' utilize information from all three levels to assess the situation, anticipate how it will change, and make a correct decision *in advance*, in which case warnings and critical signals can be avoided.

A few studies have investigated drivers' performance under advisory visual warnings. Lindgren [15] compared visual advisory information with critical warnings and revealed a significantly higher preference for advisory information than warnings. Stanton [24] compared brake warnings and graded deceleration displays in a simulated test, and found that in the latter, more advisory case, drivers performed significantly better in terms of car following distance, brake grain, and collisions. Most recently, Naujoks [20,21] conducted a series of studies on drivers' reactions towards different timing levels of hazard warnings in various traffic conditions and found that compared to urgent warnings, early/advisory warnings improved drivers' anticipation rates of the hazard.

Recently, several studies have also proposed an approach using looming sound cues. Here, the looming aspects of the sound indicated the distance between the driven vehicle and other road users, whereas the intensity of the sound increased when the distance between the driven vehicle and that in front was shrinking. In these studies, the timing-aspects of sound activation were tested. The results showed that the sound cues activated earlier resulted in faster brake response time [8], better perception of urgency [23], attention capture and fewer false alarm conditions [13] than the later ones.

To sum up, previous studies have primarily focused on drivers' reactions to advisory warnings and on system design perspectives. However there are no studies on drivers' information requirements in relation to specific traffic scenarios. In addition, it has not been considered how information requirements may differ between different Traffic Safety Cultures. In this study, we have aimed to explore these issues in detail.

METHOD

Our methodology will be described in detail below, but in short, focus groups from Sweden and China were shown a carefully selected set of traffic situations in the form of naturalistic video recordings. Simultaneously, a low-fidelity prototype of a 3DAATIS presented sound-based indication regarding locations, movement, and distance of other road users in relation to the participants. Questionnaires and focus groups discussions were used to collect user data. The aim was to collect information requirements as well as understand the participants' attitudes to a 3DAATIS-system in general, and their attitude towards, and understanding of, the sounds given in the study.

Participants

In all, 13 focus group sessions were conducted. Each group consisted of 3 to 4 participants. In total, 47 participants took part in our study. In Sweden there were 24 (19 male and 5 female) making out 7 focus groups. In China there were 23 (16 male and 7 female), making out 6 groups. The selection criteria for participants were as follows: 20-60 years old; and had a driver's license for at least two years; and no hearing deficiencies. They were also required to have a basic knowledge of Advanced Driver Assistance Systems (ADAS) and how they function during drive. Each participant was given 2 movie tickets as a reward for their participation.

Selecting Naturalistic Driving Videos

We used four naturalistic drive videos which were chosen from two naturalistic field operation test (FOT) projects that the research groups had access to, namely, the Sweden-Michigan Naturalistic Field Operational Test [26] and a Chinese naturalistic drive videos database which had been developed by the authors' research group. Over 100 hours of naturalistic drive and near crash/crash video records were observed. From this, we selected four videos[1] which depicted what we had found to be the most frequent and typical traffic situations when driving on city roads, on highways, in roundabouts and in residential areas. Moreover, they also

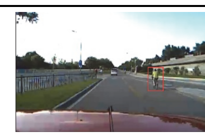
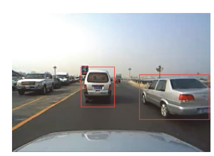
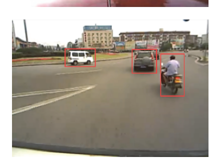
Scenario categories	Samples scenario
Interactions with a single road user *Only one road user has potential conflicts with the driver*	
Interactions with multiple road users *More than one road user has potential conflicts with the driver*	
Interactions with a single road user in special road situations *Traffic regulations are unspecified, e.g., roundabout, intersection*	
Interactions with multiple road users in special road situations *Traffic regulations are unspecified, e.g., roundabout, intersection*	

Table 1. The categories and samples of scenarios

[1] https://youtu.be/Vr_9LeDTtBY

involved different types of road users and levels of traffic density. The rich information from the videos provided a good starting point for focus group discussions. Each video was approximately 25 seconds long, and contained 3 or 4 interesting incidents, which were categorized as listed in Table 1

The Selection of Sounds

To better understand what types of sounds drivers prefer in advisory information systems, two different sets of sounds were tested: auditory icons (i.e. "natural" sounds) and synthesized sounds – see Table 2. E.g. one auditory icon was the sound of footsteps representing a pedestrian. For synthesized sounds, the rhythm of the sound was used to match the frequency of the road users' movement. All sounds communicated emergency level via increased volume. All samples were retrieved from Adobe's royalty-free Audio Message database and free Sound Effect database.

Road Users	Auditory Icon	Synthesized Sound
Vehicle (parking)	Car engine sound	Drum
Vehicle (driving)	Car passing sound	Melody swells with delay
Motorcycle	Motorcycle engine sound	Sweeping melody
Bicycle	Belling	Panned high frequency melody
Pedestrian (standing)	Human whistle	Same as auditory icon set
Pedestrian (walking)	Footsteps	Long melody with delay

Table 2. Descriptions of sound samples used in the experiment

Apparatus and Materials

In order to simulate how the sound cues would correspond to traffic events and how the system would work, the four selected videos were pre-programmed into the prototype by using the software soundtrack Pro, so that the 3DAATIS prototype could signal every event in each naturalistic drive video. For instance, if a vehicle overtook the drivers from the left side, the prototype presented this other vehicle's movements in relation to the participants as 3D sound information. There were two versions for each video; one with auditory icons and one with synthesized sounds, and these two versions were presented to the focus group in a randomized order. A small $3.5 \times 3.5\ m^2$ test area was set up in which the naturalistic drive videos were projected on a front projector screen. There, four seats were positioned in the center, similar to the seats in a car. A 5.1-channel surround-sound system was used to emit the auditory information in the 3DAATIS prototype. The arrangement of the loudspeakers and the seating positions of the participants were calibrated according to Dolby 5.1 home theatre speaker guidelines. The speaker system used was a Logitech model Z-5500. Sound-absorbing curtains were installed on three sides of the test area to ensure a good surround effect.

PROCEDURE

Each focus group consisted of 3-4 participants. When they came to the focus group session, the purpose of the study was first introduced to them, and then they were asked to fill out a personal profile questionnaire. Thereafter, they were asked to sit in the central area of the sound surrounding system. In a mapping test, all sound samples listed in Table 2 were played twice to the participants, who were asked to match each sound sample with a road user in a questionnaire. After the mapping test, the correct mapping was introduced to the participants, and a training sections of 3D sound system was carried out as preparations for the next step.

In the second part of the study, the four videos were played one by one together with sounds provided by the 3DAATIS prototype; once with auditory icons, one with synthesized sounds. The order was randomized for each focus group. Participants were asked to observe the traffic events in the video and reflect on the design of the 3DAATIS. Every traffic video was played twice; during the second round, the facilitator paused the video at particular events and followed up with questions. Since each video represented different traffic scenarios, several questions were discussed for each video. Some general questions were asked in all scenarios, e.g. what are your general opinions and attitude regarding the auditory information system? Which types of sounds do you prefer? Under each event, specific questions were asked: e.g. *what information is interesting to present in sound and why? Should the sound information present any attributes of each road user (e.g., distance to your car, speed, size)?*

Data Analysis Procedure

The data analysis method utilized a combination of question-based structural code and thematic analysis [1]. The data analysis was based on the notes taken during the focus group sessions and video transcripts of the discussions. The details of the data analysis procedure are as follows.

1. Video transcripts. The videos from the focus group discussions were not directly transcribed word-for-word; the researchers instead summarized and harvested the comments related to: the sounds, the 3DAATIS system in itself, and information requirements. In the original transcript charts, the individual transcriptions were aggregated into one set of notes for each focus group, which were categorized into the four traffic scenarios (city, highway, roundabout, residential area). The aggregated notes for the 13 focus groups contained more than 1600 statements. To avoid individual participant misinterpretation, two people performed the transcription work together. **2. Code sorting and grouping.** Four members of the research team were involved in this task. Similar quotes were coded into different categories according to focus group questions, traffic scenarios, and interesting points raised during the discussion. This was an iterative process, and the sorting process was accomplished using a Microsoft Excel spreadsheet. **3. Summary.** After the sorting, the researchers summarised and analysed each coded category and came up with different themes based on the questionnaire, the perceived importance, and how often the opinions or statements were raised in the discussion.

RESULTS

Both similarities and differences in preferences were found; we will start with similarities and move on to the differences last. The findings are based on the input from questionnaires and focus discussions (as per described above).

Same: Similar Sound Preferences

Both cohorts demonstrated a **high mapping rate for auditory icons.** Swedish participants had a high accuracy rate when mapping auditory icons to the corresponding road users: for cars it was 91.3%, for motorcycles 95.7% and for pedestrians walking and stopping 91.3%. The Chinese participants' mapping was perfect; all correctly mapped these four auditory icons correctly.

In contrast, both cohorts demonstrated **low mapping rates for the synthesized sounds;** almost no mapping between sound samples and respective road users was found. All participants claimed that it was hard to associate synthesized sounds with road users and that they perceived the synthesized sounds as music or phone tones.

However, this otherwise clear finding was disrupted in one particular case: The bicycle sounds. The auditory icon scored particularly low: only 56,5% of the Swedish participants and 78,2% of the Chinese understood it. As for the synthesized sound, the mapping was very good in comparison with the other synthesized sounds: 43,3 % of the Swedish participants and 60.8% of the Chinese participants mapped this correctly. Why was this? It was all related to the nature of the sounds. In both groups, participants pointed out that the auditory icon sounded more like a cow bell than a bicycle bell. As for the synthesized sound, participants stated that it had characteristics quite similar to a bicycle bell.

Both cohorts expressed **similar preferences regarding sound types:** they chose auditory icons as their preferred sound type, pointing out that these contained meaningful information and were easy to associate with different road users. Warning sounds (e.g. warnings from other ADAS) were selected as their second choice: e.g. participants would refer to the "beeping" signals in parking systems, where the frequency of the sound represents the level of emergency and the distance to the obstacles. A participant commented that *"As soon as my sight matched the sound information, it was possible for me to decode and understand the sound information even if the sound designs are ambiguous sometimes." Another participant said "I react differently when a truck approaching, it would be good to know whether a car or truck is."* The synthesized sounds used in the study had a low preference; participants thought that the synthesized sounds used were distracting and dissonant, some participants said, *"The sound information should be intuitive and simple; complex sound is irritating."*

In general, both Swedish and Chinese participants expressed **positive attitudes towards the use of sound** as carrier of information in the form of a 3DAATIS. In total, 41 out of 47 participants (87.2%) from post-questionnaire showed a positive attitude towards the concept, and some of them wanted a similar system in their cars. The typical comments were that the system could provide drivers with attention support and situation awareness and that such information would give the participants better control of a situation. A Chinese participants said: "*If the sound design can provide the driver with a smooth lane change without the shoulder check, then the sound design is very successful.*"

During the discussions, participants also pointed out the limitations of the current prototype, such as an excessive number of information cues or that the current sound design was **not pleasant to listen to for longer stretches of time.** The current 3DAATIS prototype did not filter out any of the objects in the road; every road user that appeared within certain distance of the own vehicle was represented by one type of sound, all sounds being of equal length. *"During the drive, drivers already have really high cognitive workload; if the sound information is too frequent or distracting, the driver will easily be overloaded with information cues."* a Swedish participant said. This prototype served to set up the discussion points; therefore, these comments were expected. A small group of participants (two Swedish and four Chinese) expressed that they were interested only in visual information cues and that they found sound information to be obtrusive.

Same: Similar Information Priority Preferences in Less Complex Situations

When the traffic situations involved only one other road user, the cohorts shared similar information requirements. One information requirement discussed consistently among the focus groups was the high risk and unpredictable movements of vulnerable road users such as pedestrians, cyclists, and children. Both cohorts suggested that **information about vulnerable road users should be designed as the highest priority level**. Some Chinese participants pointed out that "*cyclists' behaviours are more difficult to predict than pedestrians because they move fast and mix with vehicles in the street*".

Both cohorts also mentioned that sound information provides certain support to enhance drivers' **awareness about an upcoming hazard.** Some typical comments were *"sound information should notify me about incoming irregular, or extreme situations to especially in situations such as pedestrians crossing, emergency braking." "Within the front meeting points, if there are a very fast-moving road users or dramatic acceleration or deceleration situations, notifying me is useful.*" One noteworthy result was that the participants preferred sound for emergency braking but not normal braking.

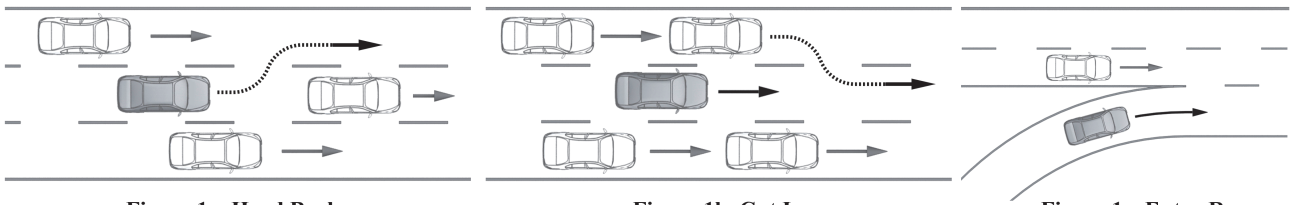


Figure 1a. Hard Brake Figure 1b. Cut In Figure 1c. Entry Ramp

In line with this, both Swedish and Chinese participants stated that in *non-critical situations* with only one road user in front of the car, information presented about the front road user would be irritating and distracting. They believed that they as drivers already have their attention targeted forwards. One of the most typical comments was: "*Within the visible area, the driver has already detected the information; sound information will be redundant and distracting.*"

Auditory **information on blind spots was highly appreciated** among all participants. They claimed that blind spots (A-pillar blind spots and side blind spots) were the areas that created visual disadvantages and higher risk of dangers; auditory information in regards to these zones could increase their awareness and reduce their uncertainty about critical situations. Examples of participants' opinions were. "*A-pillar blind spot information is good, especially in turning situations." "Blind spot information should be provided in advance, and information should be provided for unanticipated events such as a large truck on the other side*."

….But Different: Diverse Information Priority Preferences in Complex Situations

When interacting with multiple road users or under special circumstances like ramps, roundabouts, dense traffic etc. (e.g. the last three scenarios in Table 1), Swedish and Chinese drivers clearly showed different motivations and hence wanted different information, despite the fact that both countries have the same traffic laws and regulations. Here, we will discuss three typical scenarios identified in this study, as shown in Figure 1. In all cases the grey car represents the own car.

Hard Brake Scenario

The hard brake scenario (see Fig. 1a) is one of the situations in which crashes are most likely to occur. The own car intends to change lanes from right to left, the front vehicle makes a hard brake and another car in the left lane approaches without decelerating. In this situation, most Chinese participants' requirements differed from those of the Swedish participants. Many Swedish participants expressed interest **only in information about the front car**—e.g., its brake light—in order to avoid a collision. In contrast, Chinese participants preferred **information from the front, rear, and side areas**.

Cut-in Scenario

In this scenario (see Fig. 1b), the own car has to interact with multiple road users simultaneously. The vehicle in front intends to change lanes and cuts into the own cars' lane while the vehicle in the right lane maintains the same speed. In this particular situation, most of Swedish participants wanted **information about the upcoming lane change, and whether the overtaking car would brake** once it was in the new lane. Some of comments were *"According to Swedish laws, I am obligated to give way to the drivers from left lane, therefore, in this situation, I want to make sure I don't miss the brake light from the front vehicle, keeping a safe distance from the front vehicle is important in this case."* The Chinese participants had the same requirements but in addition they **also required information from the rear and side areas**, since they wanted to assess whether it was possible to change lanes instead of braking. *"The traffic is dense and other cars are close to me […] if I brake hard, it may start a chain effect of brakes or crashes. Therefore, if someone suddenly brakes or cuts in, I often switch lanes or try to overtake the front vehicle."* Some Chinese drivers also mentioned that if they give way to one vehicle, switching lanes, they will have to give way to several other coming vehicles, risking to get stuck in the middle of the traffic, especially in rush hours.

Ramp Entry Scenario

In the ramp entry scenario (see Fig. 1c), the own car is entering a ramp, and a car is approaching from the rear in the lane the own car intends to enter. In both Sweden and China, the traffic law states that the car entering the lane (i.e. the own car in this scenario) must give way to the cars on the highway, and is responsible for merging into the traffic on the highway without causing any danger.

Here, most Swedish participants showed no particular auditory information, this since drivers in Sweden are being taught to always perform a shoulder check before entering a highway lane. Chinese drivers however highly appreciated the information about oncoming traffic from the main road. Some participants said that *"the entry ramp-situations are often high-conflict ones. Because of the high traffic density, I must find my best chance to get into the main road and therefore must keep eyes on vehicles in both the front and side areas. Information from the side would help a lot in such situations."* In highway situations, the participants mentioned that the information from the side regarding coming vehicles would be even more important because the driver cannot depend on other vehicles to give way.

DISCUSSION

In all, we have drawn three major conclusions from this study, as will be discussed below.

Using Sounds: Yes, But Designed With Care

The study shows that Swedish and Chinese participants have much in common in terms of sound mapping rate, sound type preferences, and attitudes towards the design of 3DAATIS. These were very positive findings for us. However, the study does not necessarily indicate that auditory icons are the best, despite the participants' opinions.

There are several things that indicate this. Firstly, "the bicycle incident" that indicated that a synthesized sound might well be used to give a certain association, if well-chosen. Several participants stated that the cyclist synthesized sound was pleasant to hear. In general, it may be difficult to find a suitable match between different events or road users and sounds. This may indicate that a brief synthesized sound imitating road users may be an appropriate approach to design advisory traffic information. Secondly, this study did not consider long-term use; the tolerance level to the sound information might change over time. Naturally, learning rates for auditory icons were higher, however the quick learning effect would diminish over longer use. Lastly, explicit auditory icons might result in an unpleasant long-term user experience due to their characteristics, whereas well designed synthesized sound might be a good alternative.

Moreover, participants wanted fewer sounds. We used six different sounds for: driving vehicle; parking vehicle; motorcycle; bicycle; stopping pedestrian; and walking pedestrian. In hindsight these were too many. Instead, limiting the categories in relation to expressed information needs is worth exploring.

Traffic Safety Culture Affects Information Needs

As for information preferences it was useful from a design perspective to find that even though both countries have different traffic situations and driving behaviours – i.e. different Traffic Safety Cultures – some of the information needs were overlapping, especially in less complex situations with only one other road user involved. E.g. participants were in unison that vulnerable road users such as pedestrians and cyclists should be given a high information priority; and blind spot information and urgent information in the front are generally appreciated. While driving, visual attention is still the primary information source channel, and auditory information was considered to be a supplementary information source to compensate for the shortcomings of the visual channel.

However, the differences between the two cohorts was obvious in more complex traffic scenarios, e.g. when interacting with multiple road users and/or under special road situations. Here it is important to note that the traffic regulations are the same in both countries in the situations we studied. Regardless of this, Swedish participants require information mostly from the front, while the Chinese participants often seek for information not only from the front but also from the rear and side areas. These identified differences can be coupled to the countries' respective Traffic Safety Cultures. Drivers in Sweden respect and follow traffic regulations; hence they trust and rely on other drivers to also obey the rules. Conversely, in China, as in other industrial developing countries with high-density traffic, road users (not only cars but also other types of road users) fill all possible space on the road. In such situations, road users must not only consider the traffic regulations but also coordinate with one another. Therefore, each driver needs to be aware of the traffic *everywhere* around the car, in order to be able to manoeuvre in traffic. The differences found in these scenarios imply how drivers from different regions expect the system to support their driving.

Scenarios are Useful for Finding Differences

In order to make the design successful cross regionally, it is important to *actively involve the users from the target cultural populations* into the design process. Secondly, in our study, we found that Swedish and Chinese drivers have similar information requirements in less complex situations, for instance in regards to emergency and vulnerable road users. For this type of scenarios, adaptation design can focus on *understanding the risk perceptions in order to adjust system parameters*. For instance, the braking distance of the Automatic Emergency Braking (AEB) system can be varied between Swedish and Chinese markets, since the risk perception between these two groups varies a lot. However, when the situations are complex, and multiple road users are involved, Swedish and Chinese participants expressed *different strategies* when handling the situation, as per dependent on their respective Traffic Safety Cultures. In conclusion, *adaptive design for complex traffic situations must look into information requirements related to Traffic Safety Culture*.

CONCLUSIONS

Our study shows that bringing both less complex (single road user scenarios) and complex (multiple road user scenarios) traffic scenarios into the ADAS design process is highly beneficial. This since it will help the designers to have a better understanding of the drivers' underlying motivations. In future work, more traffic scenarios need to be studied to verify the validity of the results.

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