Requirements for the Design of Advanced Driver Assistance Systems – *The Differences between Swedish and Chinese Drivers*

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In order to decrease the amount of accidents or mitigate the consequences of them, today's vehicles are being equipped with Advanced Driver Assistance Systems. The functionality and design of these systems is almost entirely based on research related to the driving concerns in Western countries. However, with the rapid motorization in developing countries such as China, there is an increasing need to investigate how these systems should be designed for new and growing markets. In order to address this need, research was conducted to discover the most common traffic problems facing Chinese drivers, how those problems differ from those for drivers in a country with a more developed driving culture (Sweden), and what consequences these differences will have for the design of Advanced Driver Assistance Systems. Results show that, even though Swedish and Chinese traffic rules and regulations are similar, driver behavior is highly culturally mediated. Results also indicate that the type of assistance drivers need in different traffic situations depends a great deal on driver behavior. The observed differences between Swedish and Chinese drivers suggest that Advanced Driver Assistance Systems designed for roads in Sweden may not necessarily be optimal in other markets.

Keywords **–** ADAS, Cross-cultural Differences, Driver Assistance, Driver Behavior, Traffic Safety.

Relevance to Design Practice **–** Driver behavior differs from one culture to another. Not taking these differences into account when designing a system increases the risk of ending up with a product that is not only unusable but also potentially dangerous.

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Introduction

Over the last few decades, safety has become an increasingly important concern for the automotive industry. Safety testing organizations such as the European New Car Assessment Programme provide customers with information about the safety ratings for different makes and models. Today, these rankings are based on a vehicle's *passive safety*, taking into account things such as airbags and crumple-zones. Over the last few years, however, automotive manufacturers have been putting much effort into *active safety*. Active safety systems, also known as Advanced Driver Assistance Systems (ADASs), are a variety of independent electronic systems designed to help the driver maneuver through demanding traffic situations. Their overall aim is to reduce traffic accidents and to make the driving experience easier and more efficient.

ADASs can offer support to the driver at four different levels. At the most basic level, they present drivers with information which enables them to make more informed driving decisions, for example information about pedestrians not visible to the driver during night driving. At the next level, ADASs can give the driver warnings of an imminent and possibly perilous situation to give them more time for decision making and reaction. The third level of intervention involves the system not only warning the driver but also advising or guiding them through the situation. At the highest level of intervention, ADASs either take action independently or override the action of the driver. Regardless of level of intervention, manufacturers who implement these systems hope to increase driving safety by assisting the driver before a critical situation arises (Lindgren & Chen, 2007) or, at least, to reduce the consequences of driver error. The design and development of these systems, though, has concentrated on the needs of motorists in Western markets. A question remains as to whether those currently available can offer similar benefits to drivers in other areas of the world.

Looking, then, at how best to go about designing for a global market, Shneiderman and Plaisant (2005) emphasized the importance of all design beginning with an understanding of the intended user's attitudes, needs and requirements. When designing products for global use from this user-centered perspective, it is important to understand how needs differ around the world. This may be particularly true for ADASs as not only the rules of the road, but also social environments, norms, and driver behavior may vary significantly from country to country and have a notable influence on the attitudes and behaviors of drivers (Zeidel, 1992).

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Consequently, an ADAS that is of great value to drivers of one country may be of less value to those in another (Lindgren, Broström, Chen, & Bengtsson, 2007).

Today, automotive manufacturers take into account the different markets when it comes to design. For example, manufacturers such as Toyota have different in-car control and display designs depending on whether the vehicle is bound for the Asian, American or European market. With respect to ADASs, the work with making adjustments for particular markets still seems to be in the early stages (Krum, Faenger, Lathrop, Sison, & Lien, 2008). With the Western world being the most dominant market, the development of ADASs is generally based on perceptions about the needs of drivers in those countries. Recently, there has been an increasing amount of research published on the technical aspects of ADASs' development, with many of these publications coming from China (Gong et al., 2008; Zhao et al., 2008; Wu et al., 2008). There is scant information, however, from a user-centered design perspective targeting Chinese drivers.

In the face of this dearth of research, the Chinese automotive industry is truly booming, and the Chinese government is beginning to introduce intelligent transportation systems in the infrastructure to prepare for new generations of vehicles to come (Zhang et al., 2005). In just over 20 years, the production of passenger cars in China has increased from 220,000 to 2.34 million units (China Statistical Yearbook, 2004). By 2003, approximately seven percent of the 530 million vehicles in the world were being driven in China (World Watch Institute, 2003). At the same time, the composition of the Chinese driver population has quickly changed from having a majority of professional drivers, like taxi drivers, to more than half being private drivers. This rapid increase in the number of novice drivers is becoming a major challenge to traffic safety, as seen in the resulting problem of traffic fatalities increasing (Zhang, Huang, Roetting, Wang, & Wei, 2006), with almost 110,000 people being killed every year (China Road Traffic Accident Statistics, 2003). This accounts for about 20 percent of the total annual number of traffic fatalities in the world.

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With China's rapid economical development, predictions are that this problem will increase. It has been projected that the number of vehicles per capita will increase faster than the fatalities per vehicle will decrease (Zhang et al., 2006), which forecasts a worrisome future.

In considering these high numbers of fatalities, the general dangers on Chinese roads should be illuminated. One issue drivers face is a chaotic driving environment that includes many vulnerable road users such as pedestrians and bicyclists (Huang, Zhang, Roetting, & Melton, 2006; Lindgren et al., 2007). China also struggles with infrastructural issues, including poorly designed road signs or even a lack of them at road construction areas (Lindgren, Chen, Jordan, & Ljungstrand, n.d.). In addition to the complex driving environment and infrastructural issues, driver behavior is considered a major safety problem. Huang et al. (2006) found Chinese drivers to be more aggressive than drivers in the USA, as the Chinese drive more offensively and disobey traffic rules. A study by Xie and Parker (2002) showed that these aggressive violations significantly contributed to traffic accidents in China. Moreover, they asserted that this deliberate behavior may be a result of culturally specific norms, such as a sense of social hierarchies or challenging legitimate authority. In further emphasizing the role culture plays, Lee (2006) criticizes past research done solely on driver behavior as it focused only on individual differences of drivers as contributors to traffic dangers. He claims that the extreme difference in the rate of fatalities between countries suggests that culture has an important influence on driving behavior, as well as plays a critical role in general driving safety. Assuming this is true, before launching into an exploration of culture as a factor involved in traffic safety, it is important to first establish an understanding of the concept of *culture*.

There are hundreds of ways to define the concept of culture. As it pertains to the present discussion, culture will be understood as being the characteristics common to a particular group of people that are learned and not given by nature. We can differentiate the concept of culture into the following four primary dimensions (Allwood, 1985):

1. *Patterns of thought* – common ways of thinking, including factual beliefs, values, norms, and emotional attitudes.
2. *Patterns of behavior* – common ways of behaving, intentional/unintentional, aware/unaware or individual/interactive.
3. *Patterns of artifacts* – common ways of manufacturing and using material things.
4. *Imprints in nature* – the long lasting imprints left by a group on the natural surroundings, including agriculture, waste, and roads, which give us a basic understanding of the culture.

According to Allwood, all human activities can be encompassed by the first two dimensions. Most activities also involve the third dimension, while ecologically important activities also involve the fourth. When a particular activity combines several of these dimensions over a period of time, it can be said that this activity has become institutionalized and transformed into a socio-cultural institution, which is a type of institution that differs around the world. As a pertinent example, in Turkey the traffic flow speed tends to be much higher than

the speed limit (patterns of behavior), while Turkish drivers do not see speeding as serious an offense (patterns of thought) as compared to what Western Europeans might (Özkan, Lajunen, El Chliaoutakis, Parker, & Summala, 2006).

With huge cross-cultural differences, it is remarkable that automotive manufacturers continue implementing new safety technologies without considering different markets. Some ADASs produce what are known as 'imminent warnings' presented to the driver just prior to a potential accident. With such short reaction time, cross-cultural differences may be negligible. However, more and more research in the area points toward a need for multi-level ADAS warnings. To better estimate upcoming situations and drive more safely, drivers need to be more aware of the current traffic situation (Endsley, Bolté, & Jones, 2003). Studies of collision avoidance (Lerner, 1993; Shutko, 1999); driver drowsiness warning (Bekiaris & Nikolaou, 2004); lane drifting and dangerous curve warning (Brunetti-Sayer, Sayer, & Devonshire, 2005); and reduced visibility (Cacciabue & Martinetto, 2006) all show that, besides the imminent warning that should be activated when immediate evasive actions are needed to avoid a collision, a cautionary warning should be given whenever a critical situation is recognized, though no immediate action is necessary. These cautionary warnings even further necessitate designing a culturally sensitive ADAS.

With cautionary warnings, the driver can be made better aware of traffic situations and take proper actions before a critical event arises. The result could be fewer incidents and fewer imminent warnings that need to be activated. However, since precautionary situations occur more often than imminent ones, advisory warnings will also be presented to the driver frequently resulting in a danger of information overload and reduced alertness to warnings (Gupta, Bisantz, & Singh, 2002), as well as a less positive attitude towards the system (Lee, Hoffman, & Hayes, 2004). This problem could be exacerbated when introducing an ADAS created for a Western country to a market such as China where infrastructure, traffic situations and driver behavior are very different (Huang et al., 2006). To illustrate, situations that might be considered dangerous in a Western context might be seen as quite typical to drivers in China. There is a danger that these Chinese drivers would become annoyed by such constant "Western" information or warnings. In addition, different ADASs that a single car may use are developed and evaluated independently (Lee et al., 2004; Ma, Sheik-Nainar, & Kaber, 2005; Piao, McDonald, Henry, Vaa, & Tveit, 2005; Stanton & Young, 2005 etc.). This means that there is no clear concept of how these systems will work together and how the driver will understand them as a whole. This issue is emphasized by Hollnagel (2006), who brings up a potentially dangerous situation where a number of systems may be competing for the driver's attention. This may possibly distract or even misguide the driver and, in a worst case scenario, contribute to an accident. By adding precautionary warnings on top of this, the issue may become even more troublesome.

Today, there is an enormous lack of understanding of how drivers interpret traffic situations while driving, as well as in the differences of those interpretations by Western drivers and those by drivers in emerging markets. Nevertheless, systems developed in Western countries are introduced into these emerging markets without significant changes. The ultimate question that still looms is whether or not ADAS research from Western countries can be directly applicable to the Chinese traffic situation. This question is addressed in the three studies presented in this article. Study 1 investigates the most common traffic problems for Chinese drivers, and what Chinese drivers think about the introduction of ADASs to their automotive market. Study 2 compares the different needs for ADASs that people have in Sweden and in China by employing a naturalistic video presentation of possibly dangerous driving situations, and then compares Chinese and Swedish drivers' interpretation of the situations. Finally, Study 3 focuses on trying to determine what complications these differences may give rise to when developing and designing ADASs.

Study 1: Shall We Introduce ADAS to Cars in China?

For whatever reasons, it is very difficult to find internationally published reports of detailed accident analysis from China, inside or outside of the country. The Chinese City Traffic website (http://www.chinautc.com/information/newsshow.asp?newsid=1090) did, however, publish some data relating to accidents, fatalities and injuries from 1970 to 2005. Over those 35 years, the number of traffic accidents increased by ten times (from 55, 437 cases in 1970 to 450, 254 cases in 2005). During that time, the number of fatalities increased by roughly the same degree, from 9,654 to 98,738. Some limited accident analysis reports published in the China Insurance Report (July 2nd, 2006) showed that accidents were most likely to occur on low quality roads and on country roads. Multiple car collision rates were high as well. In February 2008, the traffic police office in Zhejiang province conducted a questionnaire with over 90,000 road users about dangerous factors on highways, The report (refer to http://www.zjol.com.cn/05car/system/2008/02/27/009246590.shtml) listed ten main factors that included speeding, driver fatigue and drowsiness, tailgating, drunk driving, use of safety belts and lane changes. Results showed that bad driving habits and poor understanding of and respect for road and safety regulations were the obvious problems.

There are very few studies that have investigated what kind of ADAS is needed for drivers to cope with the traffic problems in China. The purpose of this first study is therefore to identify the most common traffic problems Chinese drivers face, and what Chinese drivers' opinions are about the introduction of ADASs into their cars. In order to keep the study to a manageable size, seven systems were selected for this study. These systems are: Blind Spot Information System (BLIS), Forward Collision Warning (FCW), Night Vision System (NVS), Driver Alert System (DAS), Adaptive Cruise Control (ACC), Tyre Monitoring System (TMS) and Lane Departure Warning System (LDW). These systems were selected as they were among the first ADASs introduced on the commercial market.

Blind Spot Information System (BLIS)

The BLIS is a sensor or camera-based system used to provide the driver with information about vehicles, pedestrians or cyclists

in areas not visible in the rear-view mirrors (Floudas, Amditis, Keinath, Bengler, & Engeln, 2004).

Forward Collision Warning (FCW)

The FCW uses sensor technology (laser or microwave radars) that measures distance, angular position and relative speed of the car and obstacles ahead. If an obstacle is found, the system decides whether or not the vehicle is in imminent danger of crashing. If there is a risk of crashing, the system provides the driver with a warning (Floudas et al., 2004).

Night Vision System (NVS)

Night vision systems use cameras and near or far infrared lights to flood the area in front of the vehicle. Thermal maps of the environment are then used to create an image and present this to the driver with the purpose of improving vision at night and in bad weather (Siemens VDO, 2005).

Driver Alert System (DAS)

DAS use vehicle sensors or in-vehicle cameras to monitor driver behavior and provide the driver with a warning, for example when the vehicle's lateral position changes in an irrational pattern or when eyelid movements lessen (Floudas et al., 2004).

Adaptive Cruise Control (ACC)

Using radar technology, the ACC automatically adjusts the vehicle's speed to maintain a safe distance from a vehicle ahead in the same lane (Siemens VDO, 2005). If the vehicle ahead slows down or accelerates, the system either makes the car decelerate or accelerate to maintain the preset distance. The ACC is expected to ensure that there is enough distance from the car in front, even if that driver unexpectedly reduces speed (Ford, n.d.).

Tyre Monitoring System (TMS)

The TMS measures a wheel's rotational speed relative to the other wheels. This allows the system to detect dangerously low air pressure in the tires. If there is a critical air pressure loss in one or several tires, the system notifies the driver (Toyota, n.d.).

Lane Departure Warning (LDW)

LDW is a camera based system that recognizes lane markings and is activated when a driver is about to leave a lane without using the turning signal (Siemens VDO, 2005).

Method

60 participants in Beijing were asked to complete questionnaires. The 60 participants (56 male, 4 female) included 45 private car owners, 10 taxi drivers, and 5 car salespersons. The questionnaire was based on the Manchester Driver Behaviour Questionnaire (originally developed by Reason, Manstead, Stradling, Baxter, & Campbell, 1990) and contained questions about traffic problems. Participants were asked how often they face certain types of problem, and answered by choosing between the alternatives *often*, *occasionally*, and *never*. After the questionnaire was completed, a follow-up interview was conducted where the participants were asked to comment on those traffic problems in order to get a broader view of them. Finally, the participants were asked, based on the traffic problems encountered, to discuss each ADAS's perceived usefulness.

Results

Traffic Problems

The results showed that there were 9 traffic problems that most participants considered serious. These problems are presented in bold text in Table 1, and some are described in more detail below.

Table 1. Traffic Problems encountered by the participants (n=60)

Problems	Often	Occasionally	Never
1. Adverse weather conditions, slippery	0%	67%	33%
2. Bad visibility (fog, rain and darkness)	**17%**	**62%**	27%
3. Blind spot invisibility	0%	**55%**	45%
4. Punctured tire	0%	39%	61%
5. Driving on hard shoulder	**33%**	**50%**	17%
6. Pedestrians not crossing road at crosswalk	**73%**	**27%**	0%
7. Bicycles do not cross road at crosswalk	**71%**	**29%**	0%
8. Drinking and driving	6%	33%	61%
9. Fatigue	0%	39%	61%
10. Illegal overtaking	**17%**	**50%**	33%
11. Driver distraction (e.g. cell phone)	**85%**	**15%**	0%
12. Speeding	**57%**	**26%**	17%
13. Difficulties detecting obstacles on the road	3%	23%	74%
14. Congestion	**87%**	**13%**	0%

Bad Visibility

The drivers found these problems to occur in foggy and rainy conditions, or at night. Many of the drivers believed that street lights are insufficient and, as many cars are parked along streets, there may be problems in detecting pedestrians and cyclists suddenly appearing between two vehicles.

Driving on the Hard Shoulder

The problem of drivers using the hard shoulder (emergency lane) was considered a big problem. This type of driving often occurs in heavy traffic when people are impatient and try to save time getting to the next road exit.

Pedestrians and Bicyclists not Using Crosswalks

This problem was considered one of the main traffic issues in China. On smaller roads, there is always a mix of vehicles, pedestrians and bicyclists. Many of these vulnerable road users are either not used to vehicles or are not aware of the danger, and may therefore cross the road without paying attention to other traffic.

Illegal Overtaking

Other situations that the participants found problematic were those in which drivers overtake vehicles from the inside, or overtake a vehicle that is already overtaking another vehicle.

Driver Distraction

In China it is very common that people use their cell phones while driving. Almost all participants admitted that they often use their phones while driving even though they know that it may distract them.

Speeding

With congestion and speed cameras, speeding is seldom a problem during the daytime. However, the problem escalates after dusk and, during the night, speeding may also be a result of drunk driving.

Congestion

Congestion is one of the most rapidly increasing problems in Beijing. The participants found this problem to be very common on the ring roads surrounding Beijing. Looking at earlier research, this problem is obvious. Huang and Wu (2006) found that the average speed on the ring roads around Beijing is about 35 km/h during the daytime.

Attitudes towards ADASs

Summarizing the participants' ratings of the seven ADASs, it can be seen that the four systems considered most useful are the BSI, FCW, NVS, and the TMS. The participants generally believed that these systems could help prevent accidents if properly designed. In contrast, they were not as interested in ACC or the DAS, as the majority of the participants felt that the traffic situation in China was too complex for the systems to work. Further, they believed that, with only a few cars equipped with ACC, the system would not help very much. In the case of the DAS, participants were of the opinion that they could handle the driving themselves. Some even thought that this type of system could be misused as tired drivers could go on driving further without taking a break. In discussing the LDW, most participants found no use for the system in China as many roads lack lane markings.

Discussion

Study 1 provides a series of insights into the driving culture in China, the key safety issues that Chinese drivers face, and their attitudes towards ADASs. The traffic problems identified in China indicate strong cultural factors regarding pattern of thought and pattern of behavior. The participants found problems with drivers using the hard shoulder (emergency lane), illegal overtaking, and speeding to be the main factors causing accidents. These results agree with results showing that unsafe behavior is the sole or a contributing factor in more than 90% of accidents world-wide (Rumar, 1985). Illegal overtaking and speeding are also evident problems in the Western world. On Swedish roads, for example, 37-85% of drivers drive faster than the posted speed limits, depending on road conditions (Nilsson, 1991).

What is a more unique and severe problem for China is the complex traffic environment with congestion, where pedestrians and bicyclists do not use crosswalks. One could argue that this is due to the higher population and traffic density, but it also reflects the social pattern of thought. When deciding between following regulations or social norms, people in China often tend to select the latter. In Sweden, on the other hand, a law forcing drivers to stop at crossings at all times, where earlier drivers only had to stop if a person at the crossing made it clear that he or she was about to cross the road, actually increased the number of rear-end collisions due to sudden braking (Thulin, 2007). Thus, it is clear that attitudes towards traffic rules differ with respect to their social acceptance in the population (Åberg, 1998). These types of cultural differences of course affect the usefulness of and preferences for ADASs. In order to reach optimal utility of the ADASs, it is necessary that all drivers and the majority of other types of road users follow traffic regulations. In a country where people do not consider following traffic regulations to be obligatory, but rather follow social norms and behavior, the utility of the ADAS will be greatly diminished.

Nowadays, most automotive manufacturers provide vehicles with some type of ADAS. It seems that the automobile industry has reached a common understanding of the importance and usefulness of these systems in Western countries. Overall, the Chinese drivers in this study were fairly positive to the introduction of ADASs to the Chinese market. It was also evident, however, that the participants' perceptions of the systems' comparative usefulness were culturally mediated. For example, the discussions revealed that continual lane switching and tailgating are very engrained in Chinese driving culture. The reason that ACC and the LDWS scored comparatively low could therefore largely

depend on the participants' beliefs that they would constantly be given warnings and would either be distracted by them or simply ignore them. This creates a vexing problem in that the systems created to make the roads safer may actually add to the danger on the roads due to an ingrained driving culture.

To illustrate this problem, look at the situation where even though drivers in China know how to keep safe distances and to use turn signals when changing lanes, many deliberately choose not to. According to Reason et al. (1990) this type of deliberate violation is often what causes severe accidents. This creates the situation where the ADASs most needed will also be the ones that are least accepted. At the same time, selection of the BLIS as the most preferred ADAS by the questionnaire participants reflected an appreciation of a real solution to another culturally specific problem – in this case bicycles which are often in the driver's blind spot when making turns in urban traffic. Although participants' reactions show a positive response to a serious issue, it is once again clear that the drivers' preferences and attitudes towards ADASs were highly culturally mediated. The cultural influences are not necessarily straightforward, however, and there is a danger that local driving norms may lead to drivers resisting the systems that would actually be most beneficial to them.

In considering the accuracy of this study, it would be a stretch to claim that the sample was statistically representative of Chinese drivers as a whole. Participants were largely sampled on a pragmatic or opportunistic basis, and professional drivers and male drivers were overrepresented. Nevertheless, the outcomes of the study gave some important insights into the Chinese driving culture and attitudes towards ADASs.

Study 2: Are There Differences In How Chinese and Swedish Drivers Interpret Possible Incidents?

The purpose of Study 2 is to get a deeper understanding of the traffic problems brought up in Study 1, and to compare Chinese and Swedish drivers' interpretations of the situations in question in order to better understand the role of cultural differences. In this study, we tried to capture a real-life example of the traffic problems that were identified and discussed in Study 1. To accomplish this, driving sessions with five participants were held in the Chinese cities of Beijing and Dalian. The sessions were videotaped, and 30 hours of real-life driving footage were captured. The reason for only using videos of driving in China was to exemplify the problems there that are not found in the Western world. Initially, some pilot video recordings were made in Sweden, but they showed very few problems and no incidents that were understood as problems by the Swedish pilot testers and would probably not have been understood as problems by the Chinese participants.

Several naturalistic driving studies have been and are being carried out in the USA and other countries, with the 100-car study being the largest and most well known (Neale, Dingus, Klauer, Sudweeks, & Goodman, 2005). These studies have provided us with a deep understanding of drivers' behavior, but there is little or no video data available in the published literature. With ADASs being developed and tested in the Western markets, research of this kind has long focused on these markets while only a handful of studies have concentrated on the rapidly developing markets, such as China. If focusing research on the Chinese market, it would be important, then, to compare Chinese drivers' understanding of driving conditions and specific traffic conditions with those of drivers in a Western country with a long history of vehicle and traffic safety. A comparison of this kind can expose the cultural differences regarding pattern of thought (Allwood, 1985) and may further be used to judge whether results of Western countries' driver behavior studies are applicable to other countries. A further intent of Study 2 was to develop and test appropriate methods to elicit Human Machine Interaction (HMI) design requirements for ADASs on the Chinese market.

Before analyzing the videos, some alterations were made to the problem categories presented in Study 1. The category of *bad visibility* was excluded as no foggy or rainy conditions occurred during the recordings, and because the cameras used to film the driving were not suitable for recording at night. The category of *driver distraction* was also excluded as the drivers did not use cell phones or distract themselves with secondary tasks while driving. Measuring driver distraction in other more obtrusive ways, for example eye-tracking, was not practical as this would have required special permits from the Chinese government. Finally, the category of *congestion* was excluded as this was considered more an environmental and infrastructural issue than a traffic safety problem.

Method

The naturalistic driving data was analyzed, and driving situations found potentially dangerous were extracted and made into 15 to 45 second long video clips. For a situation to be considered potentially dangerous, it had to include driving behavior (participants' or other road users') that interfered with other motorists and could have eventually resulted in an accident. These situations were then categorized into subcategories and a total of 13 video clips were placed into the four categories of city driving, lane changing, road obstacles, and vehicle drifting. Videos in these categories were then compared to the traffic problems revealed by the participants in the first study to see how well they correlated. To study drivers' needs and requirements of ADASs in the situations extracted, two series of semi-structured interviews were conducted with drivers from the Chinese city of Dalian and the Swedish city of Gothenburg.

Participants

For the Chinese interview sessions, 20 participants (12 male and 8 female) were recruited through the Dalian Maritime University. The average participant was 37 years old and has held a driving license for nine years. The Swedish participants (10 male and 10 female) were recruited through local advertisements, had an average age of 44, and had been a licensed for an average of 25 years. The average yearly driving mileage for the Chinese drivers was 28,000 km, while for the Swedes it was 14,000 km. The criteria for selection into the study included the participants

having a valid driving license, and having had most of their driving experience in their native country.

Procedure

The interview sessions were divided into two parts. In the first part, the participants were asked to complete a questionnaire with demographic information (age, annual mileage, driving experience, etc.). In the second part, participants were presented with video clips of potentially dangerous traffic situations. After each video they were asked questions about what possible traffic safety problems they found in the videos, how common they found this type of situation to be, and whether they thought it would be stressful if they encountered the situation. The order in which the videos were shown was rotated in order to compensate for potential biases. In total, the interview session took about 1 hour to complete.

Data Analysis

The raw interview data from Dalian was translated from Chinese to English and then analyzed together with the Swedish data. Responses were categorized, and a content analysis was performed on the basis of the number of responses in each category. Categories with only single statements were excluded, and only categories including multiple statements are presented in this paper. This delimitation was made so that there would be a foreseeable amount of data to compare, and because the main focus of this study was to investigate cross-cultural differences, and individual differences would not assist in that goal. Last, the traffic safety problems found in the driving videos were compared to the problems defined by the participants in Study 1.

Results

The following is a presentation of the interview results and related videos used for the study. As every category included two or three video clips, the problems and opinions brought forth by the participants were in many cases found redundant. Therefore, only one video of each category was selected and presented here. The results are reported category by category and are followed with a comparison to the results presented in Study 1. In the tables, the number of answers given differs for many of the questions, especially in the Chinese part of the study. Questions with answers such as *9/14* mean that only 14 participants answered the question. This problem is further discussed in the next chapter. To see the video clips discussed, click the hyperlink or visit the following web addresses:

- City Driving: http://www.youtube.com/watch?v=xwwFAlj4u_U
- Lane Changing: http://www.youtube.com/watch?v=qMXsI7rF52U
- Obstacles along the Road: http://www.youtube.com/watch?v=6oNZaOgXtgQ
- Vehicle Drifting: http://www.youtube.com/watch?v=uOG8wJ37U1s

City Driving

In the city driving video, the Swedish drivers found pedestrians and bicyclists to be the major problems (Table 2). In addition, they believed that the high driving speed of the camera equipped car (cam-car) and other vehicles, combined with not stopping at crossings, to be very stressful. When asked about how common they found this type of scenario to be in Sweden, all participants reported this to be very unusual. Looking at possible accidents, all Swedes found accidents involving vulnerable road users to be the most likely. The Chinese participants also found pedestrians and bicyclists to be two major problems in the video. Just as the Swedes, the Chinese found the cam-car's speeding to increase the risk of an accident, with accidents involving vulnerable road users to be most likely. A majority of the Chinese participants found this type of situation common, but the majority of them did not consider this type of situation stressful. When comparing this type of situation with the results of Study 1, the problem of pedestrians & bicyclists not using crosswalks can be included as a problem in this specific video as well.

Lane Changing

In the lane changing video, the Swedish participants all found two major problems: drivers overtaking on the hard shoulder, and a near collision with a white minivan suddenly turning back into the cam-car's lane (Table 3). They also believed the heavy truck traffic and poorly displayed road construction area on the innermost lane of the road were two potential issues. These two major problems mentioned by the Swedes were also the two major issues brought up by the Chinese participants. Heavy truck traffic was considered a potential issue, while three participants did not see any problems in the video. When asked how common they found this type of situation, 19 out of 20 Swedes believed this to be unusual, while a majority of the Chinese found the situation quite common. In the question regarding stress, most of the Swedes found this type of situation stressful while approximately half of the 15 Chinese (five chose to not answer this question) shared this opinion. Looking at

Table 2. Results in the category 'city driving'

	Sweden	Answers	China	Answers
Problem(s)?	Pedestrians	90%	Speeding	80%
	Bicyclists	80%	Pedestrians	55%
	Not stopping at crossing	70%	Bicyclists	55%
	Speeding	45%		
Common situation?	No	100%	Yes	64% (out of 14)
Stressed?	Yes	70%	No	59% (out of 17)

Table 3. Results from the category 'lane changing'

	Sweden	Answers	China	Answers
Problem(s)?	Overtaking on verge	100%	Overtaking on verge	65%
	White van	100%	White van	35%
	Trucks	45%	Trucks	20%
	Poorly displayed road work	40%	No problem	15%
Common situation?	No	95%	Yes	77% (out of 13)
Stressed?	Yes	80%	Yes	53% (out of 15)

the problems in Study 1, the issue of illegal passing is also evident in this video. In addition, without knowing the actual speed of the cam-car, it can also be assumed that, although the driving was done in daylight, the speed is high relative to the traffic density on the road in question.

Obstacle along the Road

The video in the category road obstacles shows a scenario where the cam-car is overtaking a bus on the right side as a slow-moving, motorized three wheeled vehicle appears up ahead in the same lane. Both the Swedish and the Chinese participants agreed on three major problems in this situation: the slow vehicle on the roadway, the cam-car overtaking on the right side, and a black car coming into the same lane the cam-car is turning into when overtaking the three-wheeled vehicle (Table 4). When asked how common they found this type of situation to be in their country, a vast majority of the Swedes believed this situation to be uncommon, while six of the ten Chinese participants answering this question found this type of situation quite common. The majority of the Swedes also reported this type of situation to be stressful, while only two of the eight Chinese answering this question felt stressed. Compared to the results from Study 1, the problem of illegal overtaking was also present in this video. Further, although many of the Chinese participants in Study 2 did find the slow three-wheeled vehicle to be a problem, they did not mention having problems detecting it. This also agrees with the results of Study 1, where only 3% of the participants considered themselves to face that problem often.

Vehicle Drifting

In the category vehicle drifting, the cam-car driver is trying to overtake another car on the right while on a two lane roadway that merges onto a larger road, as the driver of the car being passed steers back into the same right lane. At the same time, a truck on the roadway is coming up from the right. Both the Swedish and Chinese participants believed that the biggest problems in this situation were the truck coming in from the right, and the incorrect lane markings that possibly mislead the driver of the vehicle in front of the cam-car compelling that driver to go back into the lane occupied by the cam-car (Table 5). A majority of the Swedes believed that this type of situation was quite uncommon in Sweden, as they considered lane markings in Sweden to be better designed. On the other hand, a majority of the Chinese believed that this was a quite common situation and wanted more easily understood lane markings on Chinese roadways. Comparing this situation to the problems in Study 1, it is clear that the problems in that study, except for the illegal overtaking mentioned by a minority of the Swedes, were not comparable to the problems here. This video was thus of extra interest in the expert evaluations that were to follow in Study 3.

Table 4. Results in the category 'road obstacle'

	Sweden	Answers	China	Answers
Problem(s)?	Slow vehicle in same lane	95%	Slow vehicle in same lane	30%
	Car coming in from left lane	95%	Car coming in from left lane	35%
	Overtaking on right side	60%	Overtaking on right side	35%
Common situation?	No	85%	Yes	60% (out of 10)
Stressed?	Yes	75%	No	75% (out of 8)

Table 5. Results in the category 'vehicle drifting'

	Sweden	Answers	China	Answers
Problem(s)?	Truck from right	90%	Truck from right	30%
	Incorrect lane markings	85%	Incorrect lane markings	30%
	Car from left lane	65%	Car from left lane	35%
	Overtaking on inside	25%		
Common situation?	No	65%	Yes	70% (out of 10)
Stressed?	Yes	80%	No	64% (out of 11)

Discussion

Considering the results in Study 2, it is apparent that expectations of proper driving behavior are similar in Sweden and China. Participants in both countries found problems in illegal passing, vulnerable road users, speeding, and highway infrastructure. However, after all had watched the videos, it was clear that their major differences lie in their responses to the situations. This can be shown by summarizing participants' answers to how common they found different situations to be, and whether they felt stressed in these types of situations. For example, results of Study 1 showed that the Chinese participants found vulnerable road users to be a major traffic safety problem. This was also the case in the city driving videos, where both the Chinese and Swedish participants found pedestrians and bicyclists to be the greatest problems. The interesting finding here is that almost 70% of the Swedish participants found "not stopping at crossings" to be a big problem, while no Chinese drivers gave this any thought. To slow down the car and stop at a crossing can be inconvenient for the driver, but, in most Western countries, this type of behavior has developed from a simple traffic rule into a social norm of respecting pedestrians. This is, however, the opposite of the situation in China. There, pedestrians must take a very careful look before crossing the road, even though there is a regulation stating that drivers must slow down or stop when a pedestrian is crossing.

Generally, looking at the other problems identified, it can be concluded that most of the problems identified by the Swedish participants were also identified by the Chinese. However, looking at the percentages of answers, it is evident that these situations are much more commonly recognized in Sweden as problems than in China. The explanation can be found by looking at patterns of thought and patterns of behavior that seem to be connected more with laws and regulations among Swedes than among Chinese. The only contrary example is the problem of speeding in the city driving scenario, where 80% of the Chinese found speeding to be a problem while only 45% of the Swedes shared that opinion (Table 2). This may, however, stem from the Swedish participants finding three problems to be more severe than speeding and focusing more on those issues. Another interesting result concerns the question of how common they found this situation to be, where a majority of the Chinese found the situations very common while the Swedish answered the opposite. This was evident in all categories of incidents and clearly reflects the differences in patterns of thought and patterns of behavior between the two countries. It also shows the strong cultural differences between China and Sweden as, even though the traffic regulations are similar, social norms and institutions differ extensively.

In general, in HMI design, social and cultural factors are important in the development of products (Preece, Rogers, & Sharp, 2002; Shneiderman & Plaisant, 2005). In the area of ADASs, however, little consideration has been given to these fundamental questions. The outcomes of this study suggest that a system designed to give the driver warnings about pedestrians and bicyclists should have different settings depending on whether it is to be used in China or Sweden. A system designed for the Swedish market, with these types of incidents seldom occurring, is unlikely to be accepted in China where warnings would trigger several times a day, and are situations not found very stressful or dangerous by Chinese drivers. Similar problems may also occur on bigger roads. A FCW system optimized for the Swedish market may warn the driver perhaps a few times a month as distances between vehicles on rural roads and highways are often quite extensive. In China, with shorter distances between vehicles, this system might trigger far more frequently, and probably often in situations that drivers do not find dangerous. This may cause irritation and could ultimately end in drivers either ignoring the systems or shutting them off.

Discussing the validity of this study, it must be taken into consideration that the interviews in Sweden were conducted by Swedish researchers, while the Chinese interviews were carried out by Chinese researchers. The questions asked to the participants were originally written in Swedish and, though professionally translated, there may be semantic differences in words and phrases that could have affected the way the participants understood the questions. Also, with semi-structured interviews, there is also a risk that the test administrators may have used different wordings and highlighted different parts of the questions. This problem was evident in that the number of people that answered each question varied substantially in the Chinese sessions. The reason for this could also partly be due to cultural and hierarchical differences. While the Swedish participants were very positive toward giving information and discussing problems, the Chinese participants may have felt less open about sharing their thoughts and opinions, especially as the interviewers in most cases had a higher level of education and greater expertise in the area. Finally, the interviews in China were translated into English. When discussing the participants' answers, some Chinese words and expressions were difficult to translate.

Study 3: How Should an ADAS Be Designed?

After investigating driver attitudes towards ADASs and traffic safety problems, expert evaluations were conducted. The purpose of these evaluations was to investigate the specific cultural factors that may affect the type of assistance that drivers need, and to compare these needs with the problems brought up by the participants in Study 2. A further focus was on studying what possible problems may have occurred in these situations if the vehicles had been equipped with one or several ADAS.

Method

Participants

The five people participating (4 male and 1 female) were all Swedish and connected to the automotive industry. Four of them had over ten years' experience working in the area of HMI and vehicle safety. Two were researchers that focused on driver information and interaction design, while the other two worked with HMI issues and interface development. The last participant was an Engineering Psychology PhD candidate with interface development and human factors methodologies as her main research areas.

Procedure

Before beginning the expert evaluations, two separate pilot evaluations were held with human factors researchers. These two researchers had a background in evaluating in-vehicle technologies and had both worked with methodological development in the automotive industry. After the pilot evaluations, some questions and video examples were revised, and five separate expert evaluations were made. The evaluations were based on the Delphi Method (described in detail in Linstone & Turoff, 1976). The procedure for this method was begun by eliciting initial evaluations by the pilot evaluators, and then providing those evaluations to the expert to be either opposed or further validated. The information from the two pilot evaluations was presented to the first expert being interviewed to either support or to contradict. During the subsequent evaluations by the other experts, the experts were encouraged to discuss issues brought up by both pilot evaluators and the previous experts. This information was then summarized by the test administrator.

Results

Below, the results of the expert evaluations are presented and compared with the results from Study 1 and 2.

Infrastructural Issues

The evaluators found a great need for infrastructural improvements. In several videos, lane markings were found to be vague or poorly designed, and could therefore easily be misunderstood. These results agree with the results of Study 2 where both the Swedish and Chinese participants found the poorly designed lane markings to be a problem in the vehicle drifting situation. The experts pointed out possible problems with several ADASs, such as the camera-based LDW which is dependent on correct lane markings. On roads with incorrect markings, this system would malfunction and not be of any help to the driver. If an infrastructural improvement should be made, the experts found use of more feed-forward ADAS information that could help drivers plan their driving more effectively and to be of special help in situations with bad visibility, such as rain or fog.

Problematic Situations for ADASs

The evaluators found two driving situations to be particularly troublesome when predicting the impact of using ADASs when encountering them: road obstacles and vehicle drifting. In the first situation, as seen in the video sample, the cam-car driver was able to overtake the three-wheeled vehicle before the car on the left had completely changed into the cam-car's lane. In the second situation, the driver noticed the car ahead turning back into the lane, and was therefore able to make a maneuver to the right. By doing this, he avoided a collision with that car and luckily was not hit by the truck to the right. However, the evaluators pointed out that different ADASs could have turned both these situations into actual accidents. In the road obstacle situation, a future ADAS such as a lateral collision warning might have sensed the vehicle steering in from the left and warned the driver about that danger. This would be a problem if the driver moved his attention to that vehicle and neglected the three-wheeled vehicle in front. In the second situation, an ADAS such as FCW could have reacted to the car coming in from the left and provided the driver with a warning to capture his attention. Consider, however, a situation in which the cam-car driver made the same type of maneuver that he made, but turned into the right lane. He would then have created a situation in which a LDW system would warn him about drifting out of his original lane. What would then have been the correct action to take? Ignore the LDW and change lanes, or react to the LDW and probably get hit from the side by the car on the left? Without any ADAS, the driver in this situation solved the problem by making a correct maneuver, but the experts all believed that he made that maneuver without being aware of the truck coming up from behind in the right lane. As one evaluator put it, "It isn't a problem to technically prioritize what system should overrule another. The problem lies in getting the driver's attention and making him take a correct action".

Another issue discussed by the evaluators came from supposing the other vehicles in the videos were equipped with an ADAS. One expert gave an example in the vehicle drifting situation where the driver of the car that steers into the cam-car's lane could have received a warning about the cam-car occupying that lane. This may have resulted in that driver steering back to the left lane and avoiding the cam-car. However, as the lane was closing, the driver may have hit the curb and lost control of the vehicle. As one solution to this problem, the experts recommended providing early information to the driver about the road infrastructure. This would have allowed him to better prepare for this situation to avoid changing into that lane in the first place.

Driver Behavior

Infrastructural issues and warning priorities were both considered major issues for the implementation of ADASs. However, the experts all agreed that the biggest problem that must be overcome is that of driver behavior. In all videos, the experts noticed several cases where driving behavior was aggressive and risk-taking. They found this type of behavior frequently in situations involving lane changes, with drivers overtaking on both sides and sometimes using the shoulder of the road to get through. The evaluators emphasized that this type of driving behavior differed extensively compared to the behavior of Scandinavian and Northern European drivers. With these large differences, the evaluators found problems when considering the type of assistance that would be useful for drivers in both areas as they saw no clear patterns of how risk-taking maneuvers, such as lane changes and overtaking, were performed. The evaluators also agreed on these differences affecting drivers' trust in and acceptance of an ADAS. A driver used to driving more aggressively, with shorter headways and deliberate violations of traffic rules, would certainly have problems accepting ADAS warnings if they interfered with a driving style that he or she finds normal and safe. Looking at the problem from the other side, a system optimized for the Chinese market would most probably not be appreciated in Sweden, where drivers would consider warnings and information as being presented too late. Therefore,

a majority of the experts stressed the importance of designing ADASs in a way that information is not presented obtrusively or too late to the driver, as this may result in irritation and a lack of trust in the system.

Discussion

Summarizing Study 3, it is evident that there are several factors that must be considered when implementing ADAS in order to enhance driving safety. To start with, differences in infrastructure between countries and continents obviously affect people's driving and, as a result, the type of traffic situations that occur. The experts found these infrastructural differences to be a significant issue in designing ADASs. Besides a great need of improving road and lane marking, they found warning signs near roadwork insufficient and difficult to notice. Besides improving lane markings and warning signs, the experts suggested using ADASs to provide drivers with feed-forward information about upcoming roadwork areas. This could help them to plan their driving more effectively and could be of special help in situations with bad visibility and weather conditions that the participants in Study 1 found problematic. This type of precautionary information has been proposed for systems that detect possible dangers but where no urgent action is necessary (Lerner, 1993; Shutko, 1999; Brunetti-Sayer et al., 2005), and could also be implemented to warn of vehicles ahead traveling at low speed in the same direction, such as the road obstacle situation. Today's imminent collision avoidance systems are set to give a warning based on the distance and relative speed between two objects. It could therefore be useful to complement these systems by having a more precautionary system that provides the drivers with feed-forward information, giving them more time to think and react.

With respect to driver behavior, all experts considered the driving in the videos to be much more risk-taking and aggressive as compared to driving in Sweden and Scandinavia. These large differences in driver behavior are problematic when designing ADASs such as LDWS and lane changing assist systems, as they may be of limited use in the Chinese market, especially with Northern European system settings. With formal and, in particular, informal traffic rules influencing every individual driver in a social environment, the question is in what direction the automotive industry should take. Should they strive towards creating systems based only on formal rules and legislations, or should drivers be allowed to drive illegally and still get assistance from the systems? As an example, should the driver in the changing lanes situation be given information about upcoming road work on the hard shoulder even though he is violating traffic rules by overtaking in an illegal manner?

Another issue brought up by the experts was situations in which several incidents take place around the vehicle more or less simultaneously. The experts were all of the opinion that it is difficult to discern which of these incidents may be the most problematic ones. As there are no standard actions to take in these types of situations, it was concluded that situations such as these would make it extremely difficult to decide what systems need to be given priority, and what possible danger a driver will face if one ADAS is overruled by another. The extent of this problem is clearly exemplified on numerous occasions even in this small-scale study. Larger scale naturalistic studies of this kind are be needed, then, to include a number of incident types not covered here.

With only five participants and 30 hours of recorded naturalistic driving, it is difficult to say how representative the driver behavior in these videos is. China is a huge country with 1.3 billion citizens and numerous subcultures. In addition, there are of course common causes of accidents (such as falling asleep at the wheel or drunk driving) that cannot be assessed in this type of study. Continuing with methodological issues, the choice to use expert evaluations can be questioned. Experts are, owing to their experience, good at making comparisons between systems and user groups' requirements, and these types of comparative evaluations are important parts of automotive product development (Ross & Burnett, 2001). This was found very useful in evaluating the video clips, as differences in observations on driver behavior and infrastructure could be compared. However, it could be questioned whether or not the method of providing the experts with the opinions and analyses given by the others affected the results. Still, the aim of this study was to gather as much useful information as possible and not to investigate individual differences between evaluators. It was found very useful to have an expert agree with or oppose the previous expert(s) analysis as this gave further depth to the questions and opinions brought forth.

General Discussion and Conclusions

The three studies presented in this paper provide a series of insights into the Chinese driving culture, the key safety issues that Chinese drivers face, and their attitudes towards ADAS. Further, the interview studies with Chinese and Swedish drivers make it evident that traffic rules and regulations are very similar in Sweden and China, and that the major cultural differences are in terms of infrastructure and driver behavior. One major issue is the differences in vehicle standards and driver skills. In China, luxury sedans, small, inexpensive cars, trucks, mopeds and rickshaws all share the roads. Compared to the Western world, many of these road users are novice drivers not used to heavy traffic and vehicles (Zhang et al., 2006). Further, Chinese drivers put more trust in their own driving skill, experience and capabilities, even though they lack driver training and an understanding of safe driving guidelines (Zhang et al., 2006), With more and more novice drivers trusting their own skills while neglecting driving guidelines, traffic problems will no doubt escalate even further.

Overall, many cultural differences were exposed in these studies. They may have been made even more clear being that in these studies the drivers came from one of the world's most dangerous driving cultures, China (China Road Traffic Accident Statistics, 2003), while the experts came from one of the world's safest driving cultures, Sweden (Marell & Westin, 1999). The exposed differences lead to an important conundrum regarding cultural differences and safety. If ADASs do not take cultural differences into account with respect to driving, they may not be accepted. Instead they will simply be regarded as being too

intrusive and therefore as more of a nuisance than a help. On the other hand, if they take too much account of cultural differences, there is a danger that they will simply reinforce the bad driving habits of a particular culture. A key question is therefore to what extent ADASs can try to encourage a safer form of driving behavior in a dangerous driving culture. Presumably, there is somewhat of a 'golden point' in the settings of the systems that will gain acceptance, but at the same time can bring about some important changes in driving style to make it safer. This would be the point at which maximum safety benefits are realized.

In terms of the methodologies used in these studies, it can be questioned whether they were suitable for the purpose. The questionnaires and complementary interviews in Study 1 gave good insight into what traffic problems Chinese drivers find most problematic. This was considered to be very important when conducting the naturalistic driving sessions in Study 2, as it gave clear objectives in terms of what type of driving was needed to be captured to address the problems brought up by the participants. In addition, Study 1 provided us with interesting thoughts and opinions about ADASs and their perceived usefulness. However, it could be difficult for participants to assess the functionality of ADASs based only on descriptions of the systems. Presenting video examples of the systems in different situations could have improved the participants' understanding of them and, therefore, to have lead to different thoughts and opinions. In Study 2, videos of traffic situations were used as a tool to enhance the participants' understanding of the situations. This tool seemed to work well, as most participants entered enthusiastically into the situations. This also reinforced the idea that that it would have been a good idea to include video sequences of ADASs and how they function in Study 1. With different manufacturers using different warning modalities, this could also have biased the participants' opinions. In Study 3, expert evaluations were chosen as a method to further investigate the specific cultural factors that determine the type of assistance that drivers need and how this information should be presented. As mentioned above, most ADASs are new products on the market and drivers therefore have little or no experience with driving with them. Using experts in the area provided a sharper focus on how these systems could actually be implemented in order to enhance driving safety. As the expert evaluations in Study 3 were preceded by the driver interviews in Studies 1 and 2, issues that may have been overlooked in the expert evaluations were possibly due to the range of drivers interviewed who varied in areas such as age, technology experience, and driving behavior, which are factors that may color what they see on the road (Ross & Burnett, 2001).

In conclusion, these studies have shown that transferring ADAS technology from one culture to another can problematic. If the full benefits of this technology are to be realized, it is important that the systems be adapted to take into account local issues, in particular infrastructure and driving behavior.

While they should not reinforce dangerous driving behavior, it is also important that the drivers regard the information the systems present as meaningful and worthy of action. Getting this balance right is the key to creating an ADAS that will enhance road safety and save lives all around the world.

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