Towards Cultural Adaptability in Driver Information and -Assistance Systems

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Abstract. This paper elucidates and discusses some aspects of cultural adaptability. It describes the concept, influence and Use Cases of cultural adaptability in driver information and assistance systems exemplified by driver navigation systems. Thereby, the reasons, advantages and problems of using adaptability regarding driving safety and driver preferences will be addressed. The results of two online studies concerning use cases of navigation systems revealed differences in interaction behavior, which depend on the cultural background of the users (e.g. attitude, preference, skill etc.). Furthermore, cultural adaptability can improve usability and share in universal access.

Keywords: cultural adaptability, cultural user interface design, adaptive HCI (Human Computer Interaction/Interface), adaptive HMI (Human Machine Interaction/Interface), driver navigation systems, driver information systems, driver assistance systems, tool, cross-cultural HCI analysis, cultural adaptability, cultural user interface design, intercultural usability.

1 Cultural Differences in User Interfaces

Culture influences the interaction of the user with a computer system or a machine because of the movement of the user in a cultural surrounding [13]. Cultural dimensions are models to describe the behavior of the members of different cultures. They allow to analyze and to compare the means of the characteristics of different groups quantitatively [6]. For HCI the cultural dimensions are interesting that are directly connected to communication, information, interaction and dialog design, e.g. those cultural dimensions concerning the culturally different concepts of space, time and communication [2]. Space and time are physical variables influencing the communicative behavior of human beings, which form the social processes of a group of humans and their culture: by learning of certain kinds of behavior, the human being matures according to his cultural surrounding. Basic patterns of such kinds of behavior are time handling, density of networks of information, communication speed and the time behavior of action chains. In this respect, it is also reasonable to assume that *variables connected to information science* like information speed (distribution speed and emergency frequency of information), information density (number and distance of information units) or information order (appearing sequence and arrangement of information) *correlate with cultural different basic patterns of kinds*

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of behavior. Therefore the differences that Hall [2] found in communication speed between cultures imply differences in information speed ("duration of information presentation"), information density ("number of parallel pieces of information during information presentation") and information frequency ("number of information presentations per time unit").

To be able to design user interfaces for the global market that can adapt to the cultural needs of the user automatically, the first step is to find out the differences in the cultural needs of the users and hence the cultural differences in HCI on all levels of HCI localization (surface, functionality, and interaction) concerning Look & Feel [3], [5]. In this context, topics such as presentation of information (e.g. colors, time and date format, icons, font size) and language (e.g. font, writing direction, naming) or dialog design (e.g. menu structure and complexity, dialog form, layout, widget positions) as well as interaction design (e.g. navigation concept, system structure, interaction path, interaction speed) are affected [13], [4].

One promising method to accomplish this task is to observe and analyze the interaction behavior of users, from different cultures, with the system by an appropriate automated analysis tool to determine different interaction patterns according to the cultural background of the users (if any).[1] From this, cross-cultural usability metrics can be derived, which can be used for cultural adaptability.

2 Adaptive Driver Information and -Assistance Systems

Today, driver information and assistance systems are very complex both in functionality and in usage, which tend to need strong mental power of the drivers. The mental workload of the driver has to be as low as possible for the sake of preventing accidents in traffic. Hence, especially when the driver is becoming mentally overloaded (e.g. in dangerous traffic situations) the characteristics of the interaction between the system and the driver must be adapted automatically to reduce mental workload or at least to prevent mental *overload*.

According to the Use Cases, there are several areas in driver information and assistance systems where adaptability is reasonable, e.g. maneuver generation, voice guidance (instructions and timing), guidance pictograms, map display, dynamic routing / traffic message data handling, multimedia / multimodal HMI in general, destination input, speech recognition, help concept controlled by speech, interaction management and dialog management. Therefore, cultural adaptability does not only concern the look and feel of the user interface, but also the interaction devices as well as the number and the kind of system functions that can dynamically change according to the driver preferences, the driver state and the driving situation.

Within the infotainment systems of a car, alongside other components – including radio, telephone, CD or DVD player and telematics unit – especially the car navigation system demands many interactive activities from the driver. Furthermore, it also provides many important and calculated pieces of information together with vehicle data to other devices (e.g. data about the driving situation). In this sense, the

[1] For information about such a tool in more detail, see [3], [4] and "A Tool for Cross-Cultural Human Computer Interaction Analysis" in this conference proceeding.

driver navigation system plays a prominent role of intersection within the round dance of driver information and assistance systems. Therefore, it will be used as an exemplary system in this paper to elucidate cultural adaptability.

Use Cases, which need massive interaction in navigation systems, are e.g. destination input, map interpretation and maneuver guidance [3]. To be able to take into account these complex information structures simultaneously and to let the driver's mental workload be as low as possible at the same time, it is necessary to employ adaptability additionally to pre-settings or profiles. Adaptability is an appropriate solution for this because the driver does not have the opportunity to adapt manually the setup of the information presentation according to the special requirements depending on the situation. Especially for stressful situations, the HMI of the driver information system has to be adaptive to reduce the mental workload of the driver [12], depending on the driver's cultural background [15].

According to the principle of cross-cultural adaptation of HMI [3], the culturally dependent behavior of the driver has to be measured and recorded over time in order to obtain information about the parameters necessary to be able to culturally adapt the HMI. Either the system suggests the adequate form of information presentation to the driver (Computer Supported Adaptation) or it adapts it automatically (Automatic Adaptation) whilst the driver is actually concentrating on driving [10]. E.g., difficult routes with high rate of accidents can be avoided most notably for beginners by analyzing the routes as well as the driving behavior and by adapting the route calculation and the information presentation according to the recognized facts.

3 Cultural Adaptive Driver Information and -Assistance Systems

If a driver information or -assistance system knows the culturally influenced preferences of the driver, it can adapt its behavior to the expectations of the driver to reduce mental workload, to prevent mental distress and to increase driving security [11]. The objective of cultural adaptive HMI in driver information and assistance systems is the situation-referential adaptation of cultural aspects of the Graphical User Interface and Speech User Interface. For cultural adaptive HMI user models are employed, which are averaged over all users of a cultural group (e.g. information dimming or multi-modal dialogs according to the different requirements in China and Germany respectively, according to the current situation and context) [5].

There are some target user groups of drivers which have their own characteristics of using driver information or -assistance systems in vehicles depending on their preferences (e.g. driving beginners vs. experienced drivers, old vs. young people, female vs. male users) that are influenced by their primary culture. In this sense, the meaning of the usual conception of *culture* as ethnical determined is extended to the *individual culture* of the driver (e.g. individualistic but culturally influenced style of using a device, interacting, driving, etc.). E.g. the individual driving behavior, including aspects such as fast, stressed, hectic, sporty, or unsteady driving, depends on the kind of cultural influences to the driver by the group he belongs to (beginners, intermediates, professionals, experts), or gender and on the cultural background (using bumpers for parking, buzzer frequency, interaction times, interaction frequencies, etc. cf.

e.g. [15]).[2] The data collected about driving contains important information about the preferences of the driver such as the preferred type of routes, average speed, default tours, short or long tours, along rivers or hills, etc. Moreover, the interaction styles can vary strongly (e.g. reasonable, rational, arbitrary, sequen-tially fast, well-considered, haptic, visual, auditory, linguistic, etc.). By associating these aspects with the cultural models, implications can be made to culturally adapt the HMI and the functionality of such systems.

To make driver information and assistance systems culturally adaptive, at least three steps are necessary, determine the differences in the HCI of the cultural different users (cultural preferences), design the system architecture according to the preferences (personalization) and enable the system to detect the driver behavior to adapt the HMI accordingly and automatically (adaptability).

4 The First Step to Cultural Adaptability: Determining Cultural Differences in HCI

The first step has been started doing two online studies to get the preferences of users according to their cultural background. The "Intercultural Interaction Analysis" tool (IIA tool) was developed to obtain automatically quantitative data regarding cultural differences in HMI by simulating use cases of navigation systems.[3] Using literature research and analytical reasoning, 118 potentially culturally sensitive parameters in HCI have been identified, implemented into the IIA tool and applied by measuring the interaction behavior of the test persons in relation to the culture. Some of the most impressing results will be presented and discussed here to demonstrate the difficulties, but also the importance to accomplish the first step for personalization and adaptability.

Employees of SiemensVDO all over the world were invited to do interaction tests by downloading the IIA tool from a central server. The differences in HCI in these studies have been analyzed according to the selected test languages by the participants (Chinese (C), German (G), and English (E)).

Some of the considered variables have shown significant differences that therefore can be called *cultural interaction indicators*. They represent significant differences in user interaction due to the different cultural background of the users. E.g., *Message distance* denotes the temporal distance of showing the maneuver advice messages in the maneuver guidance test task. (C) desired about 30% more pre-advices (“in x m turn right”) than other users before turning right. This can be an indication for higher information speed and higher information density in China compared to Germany, for example. *POI* counts the number of points of interest shown in the navigation map display. Information density increases with the number of POI and is two times higher for (C) than for (G) or (E). *MaxOpenTasks* represents the maximum number of open

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[2] Cf. “Towards Cultural Adaptability to Broaden Universal Access in Future Interfaces of Driver Information Systems” in this conference proceeding.

[3] For a detailed description of the test settings and the results please refer to [3], [4] or to “A Tool for Cross-Cultural Human Computer Interaction Analysis” in this conference proceeding.

tasks in the working environment (i.e. running applications and icons in the Windows ™ task bar) during the test session. (C) tend to work on more tasks simultaneously than (G) or (E) (ratio (C,G,E) = 1.7:1:1) which can be possibly explained by the way of work planning (polychrome vs. monochrome timing, cf. [2]) or the kind of thinking (mono-causal (sequential) vs. multi-causal (parallel) logic, cf. [13]). *Infopresentation-duration* means the time the maneuver advice message is visible on the screen. (C) and (G) wanted the advices to be about 40% longer than (E) do. *Number of Chars* contains the number of characters entered by the user during the maneuver guidance and map display test tasks in answering open questions ((C) less than (E) or (G)). This is explained by the fact that the Chinese language needs considerably less characters to represent words than English or German.

Age had influence on the cultural interaction indicators, which should not correlate with the test language (Table 1).

Table 1. Similarity matrix between test language and control variables

Study	1	2
	Test language	Test language
Test language	1,000	1,000
Age	0,370**[4]	0,161**
Gender	-0,038	-0,017
Computer experience	0,174	-0,048

This high correlation came from the fact that the age of the test persons of the different countries was not distributed equally: there were no Chinese test persons above the age of 40 in the first study (n=102). This influence was lower using only test persons whose age is distributed equally in the user groups (separated by the test language) or by calculating partial correlations or univariate tests. This conclusion has been confirmed by the collected data of the second study: Pearson correlation and Kruskal-Wallis-test showed a lower correlation coefficient for the variable *Age* than in the first study because of n=916. In both cases, the statistical methods used justified the results of the studies as correct and representative for employees of SiemensVDO. None of the control variables influenced the cultural interaction indicators in a way that they cannot be called *cultural interaction indicators*. Nevertheless, the influence of the user age has to be observed and considered very carefully when looking for adequate samples and test groups in future data collections.

Even if computer experience is the most significant variable directly connected to interaction behavior (e.g. interaction speed and frequency) it did not interfere with the measuring process of the different cultural interaction behavior (of the users) employing the cultural interaction indicators. This results can be explained by the fact that computer experience was almost equally distributed in the test users at the worldwide locations of SiemensVDO because the link to the IIA tool has been sent per e-mail only to users who have Internet access and hence, who have some basic computer experience.

[4] The level of significance is referenced with asterisks in this paper (* p<.05, ** p<.01).

There are many combinations of cultural interaction indicators that contribute positively to a high discrimination rate in assigning users to their test language without knowing their nationality. Only the interaction patterns within use cases or applications are known. The resulting discriminating rate for classifying all test users to their selected test languages simultaneously and correctly is 60%.[5] Applying the same method classifying the cases into two groups (instead of three at the same time), the discriminating rate increases tremendously: between German and English test language the discriminating rate goes up over 70% and between Chinese and German test language the discriminating rate is even higher than 80%. This outcome in conjunction with the weak influence of disturbing variables supports the high reliability and criteria validity of the statistical results received in these two studies and the reliability of the IIA tool. This is also supported by the discriminating rates according to different group variables including or excluding the control variables in the set of input variables of the step-by-step discriminance analysis (Table 2).

Table 2. Classification rates according to different group variables excluding or including the remaining control variables

	Classification rate		
Group variable	Excluded	Included	Most discriminating cultural interaction indicators
Test language (df = 2)	60 %	65 %	Information speed value, uncertainty avoidance value, speed (MG), interaction exactness value, number of maneuver, ~ POI, ~ restaurants, ~ streets, ~ chars, ~ maximal open tasks
Age (df = 46)	10 %	10 %	Number of help, ~ error clicks, ~ exceptions, ~ mouse clicks, ~ chars, interaction exactness value
Gender (df = 1)	82 %	82 %	Speed (MG), message distance, number of help, ~ mouse clicks, ~ chars, ~ street names, ~ maximal open tasks
Computer exp. (df = 3)	53 %	54 %	Interaction speed, uncertainty avoidance value, number of mouse clicks, ~ open tasks before test
Nationality (df = 10)	42 %	69 %	Information speed value, interaction exactness value, total dialog time, speed (MG), number of help, ~ exceptions, ~ maneuver, ~ error clicks, ~ POI, ~ streets, ~ maximal open tasks

It seems that the combination of the most discriminating cultural interaction indicators points to the characteristics of the group variables. The users grouped by test language or nationality exhibit almost the same HCI characteristics mirrored by almost the same high discriminating cultural interaction indicators. In contrast, the users grouped by age, gender or computer experience are characterized by different cultural interaction indicators. For example, number of help and number of error clicks as well as interaction exactness value classify users of different age. Experienced users can be recognized by interaction speed, uncertainty avoidance value, the number of mouse clicks and the number of open tasks before doing the test. The classification of the user to his cultural background needs the combination of many more cultural interaction indicators than to classify the user in respect of age, gender or computer experience because those variables influence the culture of the user.

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[5] For detailed statistical explanations and results, please refer to [4] or to "A Tool for Cross-Cultural Human Computer Interaction Analysis" in this conference proceeding.

There have been also implemented potential cultural interaction indicators that are statistically not discriminative. In the first study *ScrollBarChanges_norm* ($F(2) = 0.954$, $p=.389$) e.g. shows that the number of the scrolling events triggered when moving a scroll bar slider by the user is not significantly different between the groups. In the second study *TotalDialogTime* ($F(2, 916) = 1.370$, $p=.255$) e.g. shows that the time needed by the users to pass the dialogs of the test tasks is not significantly different between the groups. In both studies, *NumberOfHelp* counts the number of initiations of online help by the test persons. Usually this variable was zero, which shows that help was not needed. This fact can be exploited, e.g. to indicate that the test tasks were self-explaining and comprehensible for the users. Nevertheless there are differences between the groups in using the help function ($\chi^2(2, 916) = 1.619$, $p=.445$, ratio (C:G:E) = 5.6:1:1.4). This can possibly explained by the fact that the IIA test was developed by a German designer. Hence, the German imprinted design and explanation of the test shall be optimized for the Chinese users even more profoundly in future regarding the aspects for intercultural usability engineering [8].

Even if the cultural characterization of the users asked by the VSM94 questionnaire based on Hofstede [6] is very similar for all users [4], the *HCI between the Chinese, German and English speaking participants differs significantly.* A possible implication of that is grounded in subconscious cultural differences imprinted by primary culture and learning the mother tongue, which leads to different HCI independently of the conscious cultural propositional attitudes. However, this explanation has to be verified in future studies.

Nevertheless, *some results are expected to be valid for HCI design in general* because there are culturally sensitive variables that can be used to measure cultural differences in HCI only by counting certain interaction events without the necessity of knowing the semantic relations to the application. Such indicators are e.g. mouse moves, breaks in the mouse movements, speed of mouse movements, mouse clicks, interaction breaks and possibly the number of acknowledging or refusing system messages. Surely, all those indicators can also be connected semantically to the use cases or applications. Nevertheless, simply counting such events related to the session duration from users of one culture and comparing them to users of another culture is obviously sufficient to indicate differences in interaction behavior of culturally different users.

This preparatory work contributes to the first step to establish cultural adaptability, which is the basis to be able to tackle the next steps: personalization and adaptability.

5 Discussion: Problems, Benefit and Implications of Cultural Adaptability

It is problematic that an automatic adaptation (adaptability) depends on maximum data when observing new users: the system needs more data in order to be able to release information about the user as well as to be able to infer the characteristics of the user regarding information presentation, interaction and dialogs. Furthermore, the knowledge gathered about the user can be *misleading or* simply *false*. Hence, the reliability of assumptions can be a problem [10]. The user model has to match the system model to prevent unexpected situations for the user, which may confuse him.

Another problem is that legal restrictions also have to be taken into account. Because of legal restrictions, only the effects of driver actions in a driver model are allowed to be permanently stored, but not the log file of the personalized driving sessions themselves [1]. As long as no solution is available, which can achieve meaningful adoptions from minimum data automatically, it remains necessary to investigate standard parameters and their values very early in the design-phase, and long before runtime, in order to integrate them into the system. Therefore, it is necessary that the system already has corresponding user-knowledge (standard parameters) before the user's first contact with the system occurs. Before using the system for the first time, it must be adjusted e.g. to the nationality of the user (which indicates the main affiliation of the user to a cultural group) and the corresponding cultural parameters can be placed simultaneously as standard parameters for the desired country. Thus the adaptive system also obtains adequate characteristics of the user more quickly at runtime, because there is "more time" to collect the culture-specific data for the user, since a basic adaptation to the most important user preferences has already been performed before runtime (by putting the standard parameters into the system). Hence, designing an appropriate system according to the user in the design phase helps to avoid the problems rising from adaptability.

The benefit of cultural adaptability hopefully lies in the reduction of driver workload by recognizing and knowing the cultural expectances of the user by the system, which improves the usability of the system ([7], [9]) by adapted user and system models, shorter training times by fast adaptation to the driver as well as in less distraction from traffic and mental workload by automatically optimizing and adapting the HMI according to the current driving situation to increase driving safety ([5], [12]). Finally, the resulting effect of improved usability by cultural adaptability is that many more drivers are able to use the same systems in the car more easily and with contentment that contributes to universal access. [6]

However, many questions remain open and have to be addressed very carefully in future studies. How many dynamic changes are optimal for the driver? When does a "hidden" adaptation occur? How can this be prevented? How much does the driver trust the adaptive system? Adaptability must not surprise the driver but has to be in accordance with his mental model [4]. Additionally there are culture dependent questions [3], which have to be answered because cultural adaptability underlies more than the problems of adaptability. E.g., what cultural aspects *must* be adapted? Which of them can be adapted automatically? How is the acceptance of cultural adaptability?

Additionally, studies that are more detailed must show whether or not changing the metrics of potential cultural interaction indicators (or using them in other situations, use cases or circumstances) will improve their discriminating effect and yield appropriate values accordingly to show the *general validity* of some cultural interaction indicators. Moreover, cultural parameters regarding different user groups (elderly vs. younger drivers, experienced vs. beginning drivers, female vs. male drivers, drivers of different vehicles etc.) have to be found.

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[6] Cf. "Towards Cultural Adaptability to Broaden Universal Access in Future Interfaces of Driver Information Systems" in this conference proceeding.

6 Conclusion

Cultural adaptability in driver information and assistance systems is necessary. The functional and informational complexity of infotainment systems today cannot longer be handled only by the driver alone without employing adaptability. Drivers do have individual preferences that are culturally influenced: the cultural background of the driver determines the behavior in certain (especially dangerous) driving situations. There are many different groups of drivers, which exhibit their own "culture" whether regarding groups at international level (e.g. countries) or within the national level (e.g. social, ethnic, or driver groups). A study with a tool for cross-cultural human computer interaction analysis revealed different interaction patterns according to the cultural background of the users regarding e.g. design (ample vs. simple), information density (high vs. low), menu structure (high breath vs. high depth), personalization (high vs. low), language (symbols vs. characters) and interaction devices [4]. These results are partly confirm by qualitative studies e.g. [14]. The cultural differences in HCI found using *special combinations of cultural interaction indicators* are *statistically discriminating enough* to enable computer systems to detect different cultural interaction patterns automatically and to relate users to a certain culture behavior, which in turn makes *cultural adaptability possible* in the first place. Many kinds of interaction patterns are only recognizable over time. Hence, enhanced algorithms are needed to enable the system to automatically and correctly adapt itself to the cultural imprinted needs of the user to bring the "mental model" of the system in accordance with the users' mental model. The reduction of the mental workload by recognizing and knowing the cultural expectances of the driver by the system supports system usability and driving security. To design cultural adaptive systems formation principles in the vehicle context have to be taken into account to hold the mental workload of the driver as low as possible and using methods of artificial intelligence can help to get cultural adaptability and to broaden universal access.[7] Further studies have to be done to yield more precise values and relevant cultural parameters regarding different user groups as well as the degree of acceptance of and the power to reduce the mental workload by cultural adaptability in driver information and assistance systems.

7 Outlook

The near-term objective is to apply enhanced techniques using statistical and data mining methods and semantic processing to extract the cultural variables and its values as well as guidelines for cross-cultural HMI design in a more automatic way. The mid-term objective is to analyze and evaluate the test data in more detail to generate several algorithms for adaptability based on neural networks as well as structured equal models to prove basic theoretical cultural interaction models. The best discriminating algorithms for adaptability will be transformed and implemented into driver information systems to be evaluated qualitatively using intercultural usability tests with users of different culture and under mental stress.

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[7] Cf. "Towards Cultural Adaptability to Broaden Universal Access in Future Interfaces of Driver Information Systems" in this conference proceeding.

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