

Impact of cultural diversity on the menu structure design of Driver Information Systems: a cross-cultural study

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Abstract—A detailed study of cultural differences can facilitate the process of introducing a product into a particular market. Such an analysis can be used to decide to what extent a global design of a product needs to be considered and which subsequent measures related to localization or adaptation to a specific target culture need to be taken. In the particular case of a Driver Information System (DIS), cultural preferences in the interaction with the user interface could lead to a decrease of the ease of navigation through an insufficiently localized human machine interface depending on the culture. In this study we examine cultural differences on the interaction with the menu of a DIS through a cross cultural survey. The web based comparative multilingual questionnaire was analyzed to determine the impact of the user’s culture on preferences in the design of the menu structure of a system to be used in a vehicular environment. Results confirm the existence of cultural differences among users from Germany, USA and Japan. In particular we show heterogeneity that affects the menu structure design of the DIS’ user interface. The implications for the design and adaptation of entertainment related functions in the DIS’ menu structure are outlined.

I. INTRODUCTION

The globalization of markets increasingly requires the adaptation of products to different countries and cultures. This process, localization, is particularly important in the case of software and software controlled applications if demands and preferences vary between cultures. Considering cross cultural differences in the development phase of a product can affect its success or failure in a new market. The probability that a person buys a product is four times higher when the product description is written in his mother tongue than when the product is described in a foreign language [1]. Moreover, the ease of use can vary between cultures and cultural differences in navigation can affect the product development phase and the system architecture for different markets. Driver Information Systems (DISs) are systems developed to be operated in a vehicular environment and include different subsystems for entertainment and information in vehicles. Since the available in-vehicle screen space to display all possible courses of action to the user is reduced [2], DISs’ user interfaces are commonly implemented in form of hierarchical menus. Like other software applications its user experience

can depend on cultural diversity and require cross cultural awareness when designing the dialog [3].

In addition, in-vehicle information displays can represent a source of distraction due to the fact that the driver has to move his eyes from the road to access the information: a poorly designed interface would in addition increase this risk, having negative effects on the driving performance [4]. Since most DIS interfaces use screens as an information source a proper organization of the menu options in the display could facilitate the drivers’ interaction with the device assuring a smooth operation and reducing potential distractions. The infrastructure of a country, work organization, cultural level of the user, experience with the product etc. can be summarized under the term “culture” according to the definition in [5]. This definition complements the definition in [6], according to which culture can be defined as an orientation system typical for a society, an organization or a group and does not include, in contrast to the previous definition, infrastructural conditions or data. According to this definition the individual aspects in the use of DISs can be classified as culturally justified, if they can be attributed to an orientation system that includes language, preferences and different settings. In this paper, we investigate if cultural differences according to the definition in [5] related to the interaction with the DIS dialog exist and to which extent these differences would affect a local adaptation of the DIS’ menu structure. Moreover we want to find out if possible cultural differences depend on infrastructural and technological conditions or on other cultural factors such as language or ethnicity. We present the statistical analysis of a comparative survey of members of different cultures about preferences in the menu structure and outline implications for an internationalization of the menu. The remainder of this paper is organized as follows. In the next section we revise related work in the areas of software cultural adaptation. Section III presents a detailed description of the followed methodology to acquire and filter the data, Section IV reports on the results of the data evaluation. Finally, Section V concludes the paper.

II. RELATED WORK

In the course of the worldwide expansion of markets, studies have increasingly shown the role of cultural diversity regarding the use of products and other economically relevant questions [7], [8]. Cross cultural surveys within an international employer focusing on organizational and work structures have been conducted to acquire relevant data in different work environments [9], [10], [11]. In this context a fundamental definition of culture focusing on the

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product acceptance aspect and highlighting the different factors that affect the use of a product (i.e. infrastructure of country, different labor organizations, cultural level of the user, experience with the product, etc.) was introduced in [5]. In addition other sociological descriptions of culture also include technical peculiarities of a country as a part of the national culture [6].

Cultural differences that should be considered in a localization process are related in most of the cases to language and region but can also reflect ethnicity and social status [10]. A part of them are also values and beliefs and affect the expectations regarding the use of technical systems [12]. Therefore a crucial step in the localization process of a software application is the identification and description of the target culture [13].

To which degree cultural differences can affect the ease of use and design of a software application has been subject of several studies: for example the role of different cultures on the usage behavior of information technology applications was topic of research in [14]. In addition, research on the need for a localization of user interfaces in a multicultural society as Botswana was conducted in [15]. Product usage depending on cultural diversity was also investigated by the examples of cellular phones and washing machines in [16], [13].

A local adaptation of a software application for a target market requires not only the localization of the text that is displayed but also the documentation language, instructions manual, menus, help functions, error messages, etc. This implies a correct representation of user interfaces, windows, symbols, colors, field lengths, dates and time format, currency and reading directions [17], [18], [19], [20].

After an exhaustive review of literature related to driver distraction the authors in [21] concluded that the most efficient way to reduce technology-based distraction in a vehicular context is to design the Human Machine Interface (HMI) ergonomically. It has been shown that not only the input modality but also multiple glances between in-vehicle devices and the road can affect the driver's attention reducing his ability to maintain vehicle control and delaying or interrupting cognitive processing of traffic awareness [22], [23], [24], [4].

Poorly designed user interfaces can affect visual attention from the road and might cause crashes. Since cultural adaptation is one of the factors to be considered in an ergonomic design, it is crucial to find out cultural differences in the needs of the DISs' users. In this context an analysis tool to measure the metrics of cross-cultural usability was developed in [3], [25]. The tool was tested by use cases of navigation systems and the parameters investigated (i.e. time of information's display, number of mouse moves or clicks, etc.) confirmed previous research concerning the Hofstede's indexes for cultural behavior [9]. However, in the study menu structures related cultural preferences and sociological descriptions of culture that include technical peculiarities of a country were not considered.

A lot of research has also been dedicated to multimodality in vehicular information systems. Cognitively demand-

ing interaction indicates a reduction in the traffic situation awareness. This even applies to voice communications, since they appear to increase driver brake- reaction times [26]. An additional interesting remark is that the voice tasks' performance decreases under challenging traffic situations and a higher workload is reflected in an increased rate of misspellings and hesitation phenomena in the interaction between driver and machine [27], [28]. A further study related to the operation with Driver Information Systems showed that Japanese, contrary to Americans and Germans, prefer a Touch screen as input modality. USA and Germany did not show big differences in the input modality preference: in both countries a rotating control was preferred, whereby the acceptance of touch screens was smaller in the USA [29]. Since this diversity of Asian and Western people is apparent, it has been the subject of various research works. This diversity concerns for example the general way of thinking and the connection to the family [30] but it is also related to the interaction with technology: users from Japan enjoy the contact with new technologies and regard it as a challenge rather than a difficulty even if a particular HMI was not especially conceived for them [16], [29].

A large amount of research has been conducted related to the role of cultural diversity in the design of user interfaces. However there is little research concerning the potential need of a cultural adaptability of menu structures in Driver Information Systems. We analyze cultural preferences in the navigation through menus from a complete Infotainment System and determine if such preferences can affect the product development phase and the system architecture for different markets.

III. DATA ACQUISITION AND FILTERING

We developed a web based comparative multilingual survey to determine the impact of the user's culture in the process of communicating with a system conceived for use in a mobile environment. Data should allow us to reach conclusions about the existence of cultural differences when using a Driver Information system, particularly regarding the menu structure. The survey was implemented as an online questionnaire that was distributed over the Intranet of the BMW Group. This data collection approach relies on other methodologies consisting of a comprehensive survey among employees of the same company (for example, IBM). This research approach assumes that all groups by the same employer are comparable to a considerable degree, and that those groups differ only from each other by the country of origin [9].

In addition a survey within the same company enabled us to address persons with the required previous knowledge of DISs. The questionnaire was developed using pre-formulated answers that guaranteed a proper proportion of alternative answers obtaining answers with no remarkable deviations. This was done to prevent inconsistent or incomplete answers [31], [32] which were further reduced by control questions.

A. Online questionnaire structure

The survey covered the main aspects of a DIS dialog: After selecting the language the questionnaire was displayed according to the selection in German, English, French, Spanish or Japanese. Data entered in the fields “native language” and “country” allowed a subsequent filtering and grouping of records with the same cultural background. In addition questions covered issues related to the use of vehicles and to the user’s experience with DIS applications. In this way we excluded differences between probands that might possibly be due to discrepancies in their personal background and not in their different country of origin. In addition, the participants in the survey were asked to evaluate 47 functions of a Driver Information System referring to the importance, the preference of seeing the function in a visible location or rather in submenus and the frequency of use of the function in question. For abbreviation purposes we define below the questions with the three parameters: “importance”, “visibility” and “frequency of use”. The pre defined answers and rating scale were “very important”, “important” and “not important” for the “importance” parameter; “find at a glance” and “in submenus” for the “visibility” parameter and “very often”, “rarely” and “never” for the “frequency of use” parameter. Figure 1 shows a section of the online questionnaire in English and Japanese. The functions were classified and named relying on the menu structure of the BMW iDrive system into 6 modules partitions: “Entertainment”, “Navigation”, “Information”, “Climate”, “Communication” and “Settings”. Following 16 functions were classified under the menu “Entertainment”: “Radio”, “FM”, “AM”, “Satellite radio”, “Manual search”, “Auto store”, “Pre-set radio stations”, “Traffic information”, “Storage of radio stations”, “Volume of radio”, “MP3”, “CD”, “MD”, “TV”, “DVD”, “Games”. “Navigation” included the 3 functions: “Navigation”, “Arrow diagram”, “Map diagram”. “Information” included the 3 following functions: “Parking garage ticket”, “Logbook” (gasoline consumption, driven miles or km.), “Parking information”. “Climate” had the following 8 functions: “Climate controls”, “Air distribution”, “Seat heating distribution”, “Auxiliary heating/ventilation”, “Climate controls for the driver”, “Climate controls for the passenger”, “Temperature setting (warm/cold)”, “Fan speed control”. “Communication” included the following 14 functions: “Telephone”, “Direct dialing (using phone/keypad)”, “Last dialed numbers”, “Missed calls”, “Received calls”, “Address book”, “Redialing”, “Mailbox”, “Call waiting”, “E-mail”, “Send messages”, “Receive messages”, “Internet”, “Calendar / appointment book”. “Settings” included the 3 functions: “Activate/deactivate” the Driver Information System, “Settings of the system” (background color, font type, font size, etc.) and “Seat or steering wheel settings”. Within all the modules of a Driver Information System, especially “Entertainment” is one of the favorites and plays a decisive role in the activation frequency. Therefore we use this module in this paper as an example to show cultural differences.

a)

Questionnaire about preferences in Driver Information Systems

DEUTSCH ENGLISH 日本語 FRANÇAIS ESPAÑOL

Region/Country

North America	Europe	Japan	South and Central America
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Gender

M	F
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Please check the corresponding box to define	9a) the importance of the following functions			9b) which functions you would like to find at a glance		9c) how often you use the function in the car			
Activate/deactivate the driver information system	very important	important	not important	find at a glance	in submenus	very often	rarely	never	
Radio	very important	important	not important	find at a glance	in submenus	very often	rarely	never	
FM	very important	important	not important	find at a glance	in submenus	very often	rarely	never	
AM	very important	important	not important	find at a glance	in submenus	very often	rarely	never	
Satellite radio	very important	important	not important	find at a glance	in submenus	very often	rarely	never	

b)

ドライバーインフォメーションシステムの嗜好に関するアンケート
Questionnaire about preferences in Driver Information System

DEUTSCH ENGLISH 日本語 FRANÇAIS ESPAÑOL

国 / 地域

北米	ヨーロッパ	日本	中南米
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性別

男	女
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9) 以下に挙げる各項目について、	9a) 重要度	9b) どこより表示させたいか	9c) 車での使用頻度や表示時にメニューをすぐ見たいか
ドライバー情報システムの起動 / 停止	非常に重要 重要 重要でない	メインメニューに示す サブメニューに示す	頻繁に使用 時々使用 使用しない
ラジオ	非常に重要 重要 重要でない	メインメニューに示す サブメニューに示す	頻繁に使用 時々使用 使用しない
FM	非常に重要 重要 重要でない	メインメニューに示す サブメニューに示す	頻繁に使用 時々使用 使用しない
AM	非常に重要 重要 重要でない	メインメニューに示す サブメニューに示す	頻繁に使用 時々使用 使用しない
衛星ラジオ	非常に重要 重要 重要でない	メインメニューに示す サブメニューに示す	頻繁に使用 時々使用 使用しない
メモリアル機能	非常に重要 重要 重要でない	メインメニューに示す サブメニューに示す	頻繁に使用 時々使用 使用しない
オート調音	非常に重要 重要 重要でない	メインメニューに示す サブメニューに示す	頻繁に使用 時々使用 使用しない

Fig. 1. Section of the online questionnaire in a) English and b) Japanese.

B. Questionnaire distribution and participation rate

Emails were distributed asking for participation in the survey with a link to the online questionnaire and a short explanation text. Confidentiality was guaranteed. This invitation was sent to 250 persons in each of the following countries Germany, United Kingdom, France, Spain, USA and Japan. In addition the questionnaire was also sent to 135 persons in Mexico and 36 in Argentina. The highest survey participation rate came from Germany with 28%, USA with 21% and Japan with 22%. Since this proportion was comparable, we focused on a main data evaluation of these data. The resulting sample consisted of 170 persons ranged in age from 20 to 59 years and an average age of 39.09 (80% men, 20% woman).

C. Data description and evaluation

Filters were applied to the data to sort out comparable groups. We extracted data accomplishing certain patterns like data correspondent to the same mother tongue and region,

excluding in this way all answers from native speakers of a certain language living abroad that could be considered influenced through the immersion of the new culture. Applying the χ^2 independent test by Pearson [33] for data with nominal measurement level we examined the null hypothesis of being both characteristics, namely belonging to a specific culture and corresponding to the group that classifies a certain function in a specific way, evenly distributed. Significant differences among the samples are determined by p values. If the p value is smaller than the predefined significance level α ($\alpha = 0,05$), the null hypothesis that says that no effect takes place is rejected. Consequently the differences between samples are accepted as significant. The expected frequencies from the analyzed data were high enough. Thus, a Yates' correction for continuity was not required.

In addition to the significance analysis a correlation analysis was performed that consisted of measuring the relationship between two data rows calculating the correlation coefficient. The use of the function for calculating the correlation coefficient makes it possible to examine if two data collections develop in the same way. The correlation analysis was implemented as a control tool to find out answer similarities between two countries. In addition it also allowed determining the correlation between each asked parameter. For example, we expected an answer correlation for the following parameters: "importance", "visibility" and "frequency" of a function. Conclusions on culture-based preferences related to the menu hierarchy could be drawn comparing these parameters in every function between the individual countries.

IV. DATA EVALUATION RESULTS

The importance degree of a certain Driver Information System's function as well as its immediate visibility on the menu and frequency of the activation in the vehicle determine the location of a function in the menu options. These parameters allow us to make decisions about whether a function should be located in the main menu or rather in submenus. In addition cultural preferences allow identifying differences between countries related to the function's location.

A. Evaluation of the cultural differences between Germany, USA and Japan

In the "Entertainment" module altogether 36 significant differences were found in the "importance", "visibility" and "frequency" parameters. From them 23 differences (47.91% of all performed analysis) were highly significant and were distributed in the parameters as follows: 6 significant differences were found in "importance", 8 in "visibility" and 9 in "frequency". Results show that the number of differences in the answers was higher between Japan and US and Japan and Germany with 12.5% and 11.11% respectively, in contrast to the low percentage of differences between Germany and the US, with 7.63%. Table I shows results concerning the effect of culture on the importance, visibility and frequency of activation of the "Entertainment" module.

The proportion in the population of participants in the survey from Germany that found the function "AM" important

(7.35%) was significantly lower than the proportion from the US (77.08%) and the proportion from Japan (60.78%). However, satellite radio was classified as important by significantly fewer users in Germany and Japan (18.33% and 12% respectively) than in the US (50%). The same occurred with the "manual search" function in Germany and Japan with 55.88% and 36% compared to 89.58% in the US. The percentage of participants that found the "traffic radio" function important in the US was also significantly lower (60.42%) than the percentage of users in Japan (96.15%). This value correlates with the high percentage of participants from the US, which do not have traffic radio (74.47%). In addition further significant differences could be found in the proportion of participants that considered the "TV" (50% Japan, 7% US and 21% Germany) and the "MD" functions important (Japan 80%, USA 14%, Germany 27%). This last one as a result of the more extended use of the mini disc (MD) in Japan than in Germany or in the USA.

Function	Importance (Nparm/DF=2)		Visibility (Nparm/DF=2)		Frequency (Nparm/DF=4)	
	L-R ChiSq	Prob >ChiSq	L-R ChiSq	Prob >ChiSq	L-R ChiSq	Prob >ChiSq
AM	72.02038	<.0001*	53.61326	<.0001*	94.10927	<.0001*
Auto store	4.336335	0.1144	17.71882	0.0001*	2.282148	0.6840
CD	0.309407	0.8567	4.478907	0.1065	10.93811	0.0273*
DVD	4.816095	0.0900	1.454551	0.4832	8.351304	0.0795
FM	8.330127	0.0155*	19.16266	<.0001*	33.02197	<.0001*
Games	3.292676	0.1928	8.19805	0.0166*	6.617027	0.1576
Manual search	36.06706	<.0001*	51.88876	<.0001*	58.64483	<.0001*
MD	52.59847	<.0001*	22.55656	<.0001*	45.94213	<.0001*
MP3	3.251354	0.1968	9.066303	0.0107*	6.977594	0.1371
Preset radio stations	16.8773	0.0002*	48.23246	<.0001*	39.51632	<.0001*
Radio	12.19383	0.0022*	24.76847	<.0001*	19.66115	0.0006*
Satellite radio	19.20581	<.0001*	31.15784	<.0001*	41.3899	<.0001*
Storage radio stations	5.488178	0.0643	8.344884	0.0154*	33.06922	<.0001*
Traffic information	26.47664	<.0001*	17.04669	0.0002*	22.338	0.0002*
TV	25.8379	<.0001*	8.722344	0.0128*	26.34411	<.0001*
Volume radio	10.34234	0.0057*	31.03971	<.0001*	31.7706	<.0001*

TABLE I
EFFECT OF CULTURE ON THE ESTIMATED IMPORTANCE, VISIBILITY IN THE MENU AND FREQUENCY OF ACTIVATION OF DIS FUNCTIONS FOR ENTERTAINMENT.

In order to evaluate, for which functions a localization of the menu structure could be relevant the correlation analysis between the importance, visibility and frequency parameters was calculated for the functions of the Entertainment module in Germany, USA and Japan. If a function is considered important, it should be, as a result, activated more frequently and as a consequence should be visible immediately. The analysis showed a relatively high correlation with coefficients between 0.86 and 1. The importance of a function was estimated higher than or equals to the other parameters but nearly always a correlation was given regarding minima and maxima within a country: a specific function that was considered important was also frequently used and a quick access to it was preferred. Thus, the data collected was confirmed to

be congruent. A contradictory result from the evaluated data showed that, even if a function was evaluated as important or immediately visible, a smaller percentage of the participants selected the highest category when responding to the frequency of use. Figure 2 shows the classification of the Entertainment functions after the parameters “importance”, “visibility” and “frequency of activation”.

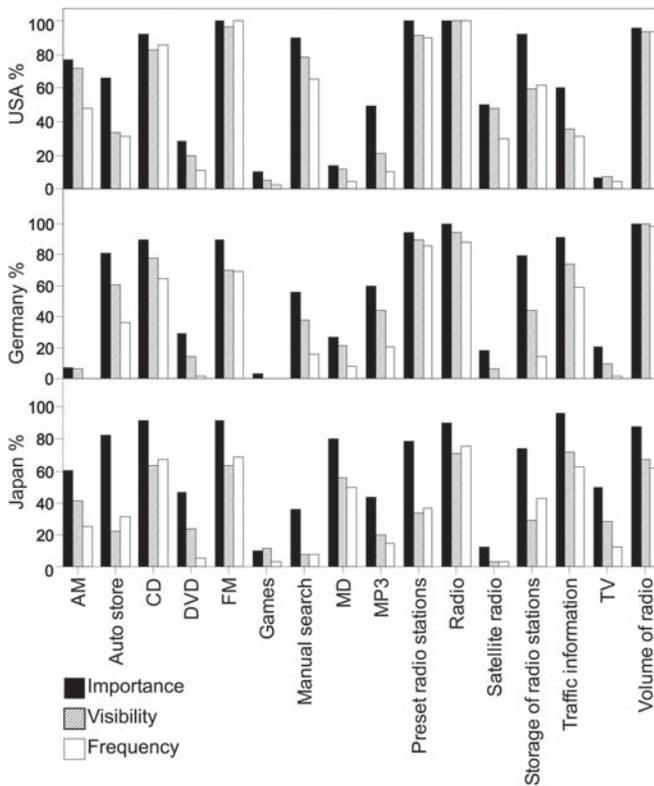


Fig. 2. “Importance”, “Visibility” and “Frequency of activation” of DIS functions for the “Entertainment” module in Japan, Germany and USA.

B. Evaluation of the differences regarding technical or cultural conditions in the respective countries

34 (72%) of the functions that were evaluated had a cultural component. Belonging to this group are those functions, which each person uses differently, independently of the country, in which the user resides, as for example “manual search” or “auto store” and “storage of radio stations” within the radio as well as the functions of the modules “Communication” and “Settings”. Altogether 13 (28%) functions can be regarded as dependent on the structure and the specific conditions of a country. These are functions, which are differently offered in each country, as for example the radio frequencies of FM, AM, satellite radio and traffic information as well as a majority of functions, which are summarized in the modules “Climate” and “Information”. The “automatic park ticket voucher” function belongs to the “Information” module which is not offered everywhere and therefore might have a different degree of acknowledgement in the individual countries. The number of significant differences was similarly distributed over all functions. In the case of the functions classified as affected by culture the percentage of these

differences was 35% in the “importance”, “frequency” and “visibility” parameters in at least one country (41% in one to two of those parameters). In the group of not culturally affected functions the percentage was 23% for all three parameters and 46% for one to two. In those functions, in which, due to well-known peculiarities in the different countries, differences in the answers were expected, significant differences between the participants could be determined in each case. These were the availability of AM as radio frequency, the traffic information, availability of a TV in the car (in Japan more frequently) and destination input in the navigations system over a telephone number (only possible in Japan). Traffic information in the USA is sent under AM, in Japan over its own frequency on the radio. In Germany traffic radio can be switched on usually as a function of the radio and is controlled through an audio signal. This way traffic information can also be heard if the radio is not turned on.

V. CONCLUSION AND FUTURE WORK

The goal of this international survey was to determine whether cultural differences related to the interaction with the menu of Driver Information Systems existed that affect localization of the menu structure and in which extent. Results show that the evaluation of functions between individual countries can be very heterogeneous and confirmed that a localization of the menu structure in DISs should be accomplished. Altogether approx. 20% of all the evaluated functions was classified by a sufficiently high number of participants from different cultural background as significantly different. The largest cultural heterogeneity found among the participants from Germany, USA and Japan was confirmed by previous research work related to international differences in work-related values [9]. It could be stated that due to different culturally shaped favorite choices, differences in the preferential order of operation of DISs’ functions exist. The cultural differences affecting DISs are mainly due to different technological factors and infrastructure in the analyzed countries. Therefore, a variable menu structure should be considered in the design phase through an implementation approach that facilitates the local adaptation of the menu options [28]. The data collected through the online survey was shown to be congruent through the conducted correlation analysis. Thus, the online questionnaire developed to acquire the data was proved to be a suitable tool to meet statements about the quantification of DISs’ functions that should be locally adapted. However, rules of action for the development of a variable menu structure adapted to these cultural specific needs are not defined yet. Thus, in order to determine the exact position of a function in a menu, further studies on cultural adapted menu structures must be performed through usability tests with users from the relevant target markets. To perform these usability tests a previous knowledge to build the hypotheses to be tested is required. Therefore, the results presented in this paper confirming the existence of cross cultural differences in the preference of navigation through a DIS’ menu, establish the base for our further research in the field.

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