Chapter 2
Culturally-Aware HCI Systems

Rüdiger Heimgärtner

Abstract Culture influences human–computer interaction (HCI) heavily, since the end-user is always operating within a certain cultural context. First, cultural and informational factors jointly influence the look and feel of interactive systems, for example, widget position or information density. In addition, each individual develops a specific culture (eating style, walking style, etc.)—that is, their own characteristics, behavior, attitudes, and values. Consequently, individual adaptivity is sometimes a key factor in covering the disparate needs of culturally but uniquely imprinted end-users; this may involve such tasks as reducing the workload by recognizing the individual expectations of each end-user. This improves usability, shortens training units, and improves universal access. For Culturally-Aware HCI systems socio-cultural information is used and modeled in the design and application of the human–computer interface (HCI) of such systems. In this chapter, we describe a Culturally-Aware HCI system in the context of automotive navigation that culturally adapts its interaction with the end-user over time. We analyze the way in which culture influences reasoning and the way the users feel and behave in HCI in order to establish a model for automatically adapting HCI to users using a Culturally-Aware adaptive HCI system. Fundamental theoretical reflections are presented and exemplified, and design and functioning are thus described in both theory and practice.

Keywords Culturally influenced HCI model · Model · Culture
Architecture · Culturally-Aware HCI systems · System · HCI
Demonstrator · Cultural interaction indicator · Cultural dimension
HCI dimension · Structural equation model (SEM) · Culturally
adaptive HCI architecture (CAHCI) · Principle of culturally adaptive
HCI · Intercultural user interface design (IUID) · UID
Intercultural HCI design

R. Heimgärtner (✉)
Intercultural User Interface Consulting (IUIC), Lindenstraße 9, 93152 Undorf, Germany
e-mail: ruediger.heimgaertner@iuic.de
URL: http://www.iuic.de

C. Faucher (ed.), *Advances in Culturally-Aware Intelligent Systems and in Cross-Cultural Psychological Studies*, Intelligent Systems Reference Library 134, https://doi.org/10.1007/978-3-319-67024-9_2

2.1 Approach to Culturally-Aware HCI Systems

Culturally-Aware systems can be defined as systems where culture-related or, more generally, socio-cultural information is modeled and used to design HCI, or such information intervenes in the task carried out by this system, whether it is during reasoning, simulation, or any other task involving cultural knowledge. This information must be encapsulated in a cultural model in the Culturally-Aware HCI system in order to effect the right HCI adaptations to be made in a cultural context. In the following, a method for creating Culturally-Aware HCI systems is presented.

2.1.1 Intercultural HCI Design

One method for finding differences between cultures is analyzing critical interaction situations between humans [1]. Honold [2] introduced this approach to HCI analysis by considering the occurrence of critical interaction situations in problematic user interfaces and system functionality as well as considering systems as (artificial) agents with their own culturally imprinted behavior caused by the developer's culture. The user's internal model of the system is imprinted by their culture, by their expectations of the system's properties, and by their interaction experience with the system.

After deriving intercultural factors from cultural dimensions that describe the behavior of members of cultures [3], for example, [4] empirically showed the direct influence of cultural markers on the performance of users interacting with the system and showed the connection between culture and usability. In addition, [5] investigated the influence of culture on usability. In his conclusion, [5] stated that "Individualism/Collectivism is connected to and has an effect on usability" ([5], p. 17): Hofstede's individualism index [6] is significantly connected to the user's attitude toward satisfaction and their attitude toward product usability.

Röse [7] suggested a "method of culture-oriented design" (p. 103) (MCD) that integrates aspects from new concepts of culture-oriented HCI design and knowledge about cultural differences into existing concepts of HCI design. Relevant cultural variables for intercultural HCI design have to be determined and specified analytically through a literature review and requirements analysis. The values of the variables represent culture-dependent variations that can be found at all levels of HCI localization (surface, functionality, and interaction) [7] and can be exploited in intercultural user interface design (IUID) [8]. However, areas strongly influenced by culture do not come to the surface directly—only behavior is visible on the surface, which is imprinted by cultural aspects over time; only the user's behavior itself yields deep insights about the user's cultural imprint [7]. Therefore, one of the most promising methods for obtaining cultural differences in HCI is observing, analyzing, and evaluating user–system interaction. Qualitative and quantitative empirical analyses must show if the results of studying HCI correspond to cultural models. Finally, the values of the cultural variables need to be considered to develop guidelines for intercultural HCI design and intercultural usability engineering [8].

2.1.2 Determination of Cultural Interaction Indicators and Formation of HCI Dimensions

A first step toward a theory of culturally influenced HCI is to develop a set of cultural interaction indicators (CIIs), which establishes the basis of a model for describing cultural differences in the interaction behavior of the user by representing the relationship between (the values of) cultural dimensions and (the values of) the dimensions of user interaction behavior; that is, (the values of) "human computer interaction dimensions" (HCIDs) such as information speed, information density, interaction speed, and interaction frequency [9]. They represent the characteristics of HCI by describing the HCI style of the user, that is, the method of information processing and the interaction style exhibited by the user. Frequency, density, order, and structure are particularly affected during information processing; frequency and speed are affected by user–system interaction. The quality of information processing and interaction is nourished by effectiveness and efficiency. To be able to measure these parameters, the specifics of the HCI dimensions must be as concrete and exact as possible. They can be represented by quantitative variables to build a basic measuring apparatus, from which they can then be connected to cultural dimensions, thereby forming empirical hypotheses. Some of these quantitative variables are explained later in this chapter.

The most common approach to quantifying the influences of culture on HCI is to perform qualitative and personal studies. Although this process is relatively controllable, it is very expensive and time consuming. Conversely, asking many users online is a relatively quantitative and less controllable process. The advantages of both approaches can be combined to solve this dilemma: many users can be asked to respond to special use cases on their PCs and the resulting qualitative data can then be collected quantitatively. The "Intercultural Interaction Analysis" tool (IIA tool) was developed by [10], based on [11] and [12], to automatically obtain qualitative data regarding cultural differences in HCI and to find metrics which are adequate for measuring cross-cultural HCI.

2.1.3 Creating a Model for the Relationship Between Cultural Dimensions and HCI Dimensions

The collected quantitative data can be analyzed using statistical methods (such as ANOVA, the Kruskal–Wallis test, post hoc tests, etc.) to reveal the cultural differences in HCI (e.g., using potential CIIs). Structural equation modeling (SEM) serves to verify the postulated relationships between cultural dimensions' and HCIDs' values to confirm or to modify (or even to identify) relationships (e.g., in combination with factor analysis). From this, usability metrics [13] can be derived that are empirically valuable in terms of measuring quantitative variables in culturally influenced HCI. Thereby, HCIDs are connected to cultural models to construe a model that explains the relationship between HCI and culture, which, in turn, must also be empirically validated.

2.1.4 The Approach to Culturally-Aware HCI Systems in a Nutshell

The first task in obtaining a Culturally-Aware HCI system is to consider socio-cultural information in the design and application of such systems. Thereby, the influence of culture on the reasoning as well as the way the users feel and behave in HCI is analyzed (Sect. 2.2). Moreover, in order to adapt HCI in Culturally-Aware systems to the users, a cultural model has to be established that can be used to generate the adaptation rules for the required contexts of use (Sect. 2.3). This model uses cultural metrics to connect the adaptation rules in the system to the environment or obtain the environmental information for the system's model, leading to a generic framework and architecture for Culturally-Aware HCI systems (Sect. 2.4). The theoretical reflections are then empirically exemplified by a Culturally-Aware mobile driver navigation system (Sect. 2.5). Finally, the implications for Culturally-Aware HCI systems are summarized and recommendations given (Sect. 2.6).

2.2 Gathering Empirical Data

In order to adapt Culturally-Aware HCI systems to a user's cultural needs, first the differences in the cultural needs of the users—and hence the cultural differences in HCI at all levels of the HCI localization (surface, functionality, and interaction)—need to be investigated. Thus, areas such as the presentation of information (e.g., color, time and date format, icons, font size), language (e.g., font, direction of writing, naming), dialog design (e.g., menu structure and complexity, dialog form, layout, widget positions), and interaction design (e.g., navigation concept, system structure, interaction path, interaction speed) are considered [14]. Hall [15] found differences in communication speed between cultures, which also implies 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").

2.2.1 Empirical Evidence: Cultural Interaction Indicators

Using a literature review and analytical reasoning, 118 *potentially culturally sensitive parameters have been identified* [16], implemented in the IIA tool, and applied by measuring the interaction behavior of test persons in relation to their culture using the IIA tool. Two online studies were conducted, in 2006 and 2007, respectively, with almost 15,000 speakers of Chinese (C), German (G), and English (E) located around the world using the IIA tool. Almost 1000 complete and valid data sets are available for evaluation. The test persons had to do short test tasks (mainly concerning driver navigation), where their interaction behavior was recorded during their working. From the 118 potential variables, 18 showed significant differences and which therefore can be called CIIs. These indicators represent significant differences in user interaction due to the different cultural backgrounds of the users. F expresses the ratio of explained to unexplained variance: a high value of F indicates a high probability that the mean values of two samples are different. The level of statistical significance is referenced with asterisks (*$p < 0.05$, **$p < 0.01$).

- *Opentaskbeforetest* (F(2,94) = 3.234*) is a metric variable which represents the number of open tasks in the working environment (i.e., running applications and icons in the Windows™ task bar) before the test session with the IIA data collection tool began.
- *Messagedistance* (F(2,94) = 6.625**) denotes the temporal distance of sequentially showing the maneuver advice messages in the maneuver guidance test task.
- *Infopresentationduration* (F(2,94) = 4.595*) represents the time the maneuver advice message is visible on the screen.
- *Mg.speed* (F(2,94) = 8.665**) indicates the driving speed of the simulated car in the maneuver guidance test task.
- *Mg.mouseclicks* (F(2,94) = 3.627*) specifies the number of mouse clicks during the maneuver guidance test task.
- Similarly, *uv.mouseclicks* (F(2,94) = 4.274*) counts the mouse clicks in the test task “uncertainty avoidance.”
- *YesCounter* (F(2,94) = 4.012*) contains the number of acknowledged systems messages by the user during the whole test session.
- *Infohierarchy.number* (F(2,94) = 3.422*) indicates the number of entries in list boxes, group boxes, or combo boxes specified by the test persons.
- *Interactionexactness.duration* (F(2,94) = 3.892*) measures the duration of the abstract test task of “clicking dots away.”
- *MouseMove_norm* (F(2,94) = 4.473*) contains the number of mouse moves during the whole test session divided by the duration of the whole test session (indicated by the suffix “_norm”).
- *Break10s_norm* (F(2,94) = 5.150**) represents the number of interaction breaks with the mouse greater than 10 s divided by the duration of the whole test session.

- *Sem* (F(2,94) = 3.398**) measures the number of semantic events triggered by the user during the whole test session (e.g., the number of initiations of functions).
- *MoveAgent_norm* (F(2,94) = 44.204**) specifies the number of temporary moves of Microsoft's avatar "Merlin" into the middle of the screen every 30 s (which disappears again after 5 s) divided by the duration of the whole test session. If this indicator is low, the user switched off the agent quickly (as German- and English-speaking users did, in contrast to Chinese-speaking users).
- *Number of Chars* ($\chi^2(2) = 14.593$**) contains the number of characters entered by the user during the maneuver guidance and map display test tasks when answering open questions.
- *MouseLeftDown_norm* ($\chi^2(2) = 6.053$*) counts the number of clicks with the left mouse button divided by the duration of the whole test session.
- *MaxOpenTasks* ($\chi^2(2) = 10.061$**) is similar to *OpenTasksBeforeTest* explained above, but measures the maximal number of open tasks during the test session.
- *NoCounter* ($\chi^2(2) = 20.696$**) contains the number of refused system messages by the user during the test tasks which is similar to the variable *RefuseMessage* ($\chi^2 = 13.864$**), which measures the same but during the whole test session.
- *Break1 ms* ($\chi^2(2) = 23.430$**) represents the number of interaction breaks with the mouse greater than one millisecond, which effectively measures the speed of mouse movements made by the user.

The significant differences in the CIIs can also be seen when applying the IIA data analysis tool to plot "cultural HCI fingerprints" (in the style of [17]), which represent the cultural differences in HCI with respect to several variables for HCI design that depend on the cultural background of the potential target group of users (Fig. 2.1).

The data analysis showed that there are correlations between the interaction of Chinese and German users with a computer system (HCI) and their cultural background [9] concerning layout (more complex vs. simpler), information density (higher vs. lower), personalization (higher vs. lower), language (symbols vs. characters), interaction speed (higher vs. lower), and interaction frequency (higher vs. lower).

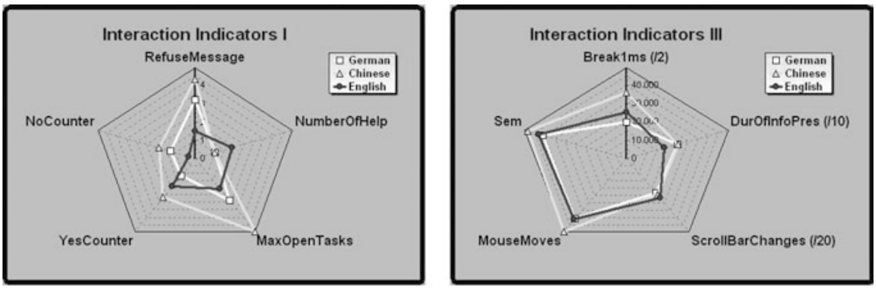

Fig. 2.1 Cultural HCI fingerprints (different values of the CIIs according to test languages) plot by the IIA data analysis tool

2.2.2 Possible Relationship Between Cultural Dimensions and HCI Dimensions

The cultural influence on HCI design can be represented by the relationship between the values of cultural dimensions and the values of the variables relevant for HCI design. Several basic assumptions were derived from the work of [18] regarding the connection between cultural dimensions and HCI dimensions [9]. The empirical hypotheses primarily concern quite basic user behavior, described with the following cultural dimensions: time orientation, density of information networks, communication speed, and action chains (sequential actions). Accordingly, it is reasonable to assume that HCI dimensions such as information speed (distribution speed and appearance frequency of information units), information density (number of and distance between information units), or information structure (order of information units) stand in relation to the culturally different basic behavior patterns of the users. If this is the case, the differences that [18] discovered also imply differences in information speed ("duration of the information presentation"), information density ("number of pieces of information presented in parallel"), and information frequency ("number of presentations of information units per time unit"). Interaction style should therefore also be affected. Table 2.1 shows some of these assumed connections.

For instance, based on the action chain dimension of [18], it can be assumed that German users' responses to questions are more linear (i.e., answered consecutively) in comparison to Chinese users. Furthermore, due to the high task orientation, the number of dialog steps taken until the completion of the task could be lower for German users. In addition, it can be assumed for German users that the number of interactions (such as the usage number for optional functions and help functions or adjusting colors, etc.) is higher because of their desire to work very exactly. However, the number of mouse movements or mouse clicks by German users should turn out to be lower than Chinese users due to the higher uncertainty avoidance and strong task orientation of German users [6, 19]). For these reasons, an interaction step (and thereby the complete test duration) might last longer for German than for Chinese users. Moreover, to save face [20], it is expected that Chinese users possibly do not click the help button as often as German users do. Finally, the speed of mouse movements should be lower for German users in accordance with higher uncertainty avoidance, lower communication speed, and low relationship orientation.

Table 2.1 Possible relationship between cultural dimensions and HCI dimensions

HCI dimension	Examples of specifics for HCI dimensions	CIIs	Cultural dimension
Information frequency (IF)	Number of words, sentences, propositions, or dialogs per minute)	Message distance, number of pieces of information per time unit	Relationship versus task orientation, individualistic versus collectivistic orientation, uncertainty avoidance, action chains, network density
Information density (ID)	Number of pieces of information presented simultaneously, distance of pieces of information to each other (e.g., images, words, sentences, dialogs)	Number of points of interest (POIs)	Relationship versus task orientation, individualistic versus collectivistic orientation, uncertainty avoidance, network density
Information /processing parallelism (IP)	Sequential or parallel presentation or reception of information units and information arrangement or order (e.g., widget positions, image–text distribution)	Maximal open tasks, refused system messages, time to disable virtual agents	Relationship versus task orientation, individualistic versus collectivistic orientation, all time-relevant cultural dimensions (such as uncertainty avoidance, action chains, time orientation)
Interaction speed (INS)	Clicking mouse buttons, length of mouse track per second, speed of entering chars	Mouse interaction breaks less than 1 ms	Relationship versus task orientation, individualistic versus collectivistic orientation, all time-relevant cultural dimensions
Interaction frequency (INF)	Overall mouse clicks, mouse moves, number of function, or help initiations per session	Number of left mouse button presses, number of mouse moving events	Relationship versus task orientation, individualistic versus collectivistic orientation, all time-relevant cultural dimensions

2.3 Toward a Model of Culturally Influenced HCI

The analysis of the collected data from Chinese-, German-, and English-speaking users showed that there are correlations between the users' interaction behavior with the system and the users' culture. There are CIIs in HCI which depend on the culture of the user (and which partly apply independent of the meaning of the application). The found CIIs can be applied by analyzing user interaction in order to describe the users' needs regarding HCI in terms of the users' culture; thereby, an explanatory model of culturally influenced HCI as well as a usability measurement system [13] for culturally influenced HCI has to be derived that is very valuable empirically.

2.3.1 Analytical Evidence: Structural Equation Model

In order to identify the correctness of the postulated relations between the cultural dimensions' and HCI dimensions' values, a structural equation model (SEM) can be employed to compare variances [21]. Confirmative factor analysis or regression analysis can support this process of modeling and explanation finding.

The primary objective is to reveal the connections between the interaction indicators and their cultural causes. The HCI dimensions can be represented on the right side of the structural equation models and the cultural variables on the left side connected with the suspected connections (parameter–variable combinations). A theory is then best explained if the left and right parts of the modeled structural equations correspond to the modeled variables; that is, the explanatory model is better if more variances in the empirical data can statistically be explained by the structural equation model. The structural equation is modeled by adding or removing variables or relations in order to improve the quality of the explanation. Figure 2.2 shows the sub-model of one side of the complete model, which arose from literature studies, posited hypotheses, and the empirical results of the described studies.

At the moment, the cultural shaping of the user is not connected with the HCI dimensions using cultural dimensions, but only using the variable "nationality." The effect of "nationality" on interaction fault (1.00) and information density (0.80) is not insignificant, even if the influence of the user age (−1.97) is even stronger. However, sex (0.18) and PC experience (2.08) obviously have far less effect on information density in HCI than nationality (89.05). Thus, using this structural equation model, it turns out that nationality has considerably more influence on information speed, information density, and interaction faults than age (36.13), PC

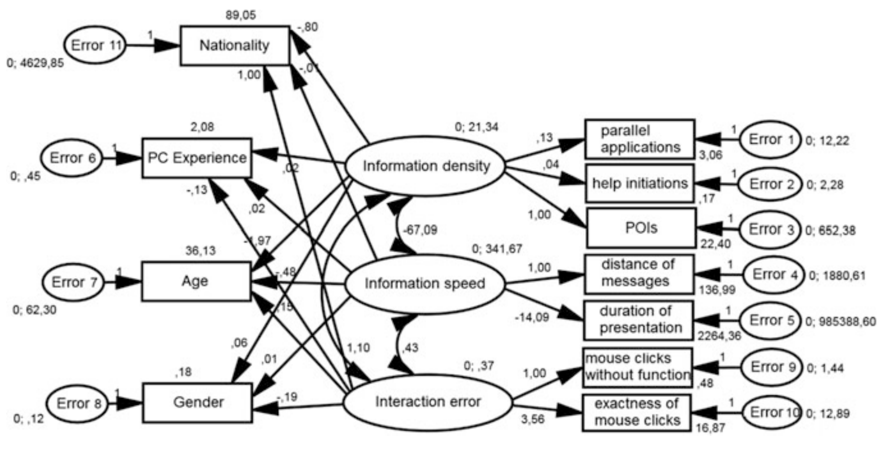

Fig. 2.2 Model for the explanation of the relations between HCI dimensions and CIIs on the *right* side and HCI dimensions and nationality or disturbance variables on the *left* side

experience, or sex—even if age represents a significant interference factor [though not on interaction faults (0.15)]. Furthermore, interaction faults, which are immediately connected with the interaction medium "mouse," are considerably less influenced by those disturbance variables than information density (−1.97) and information speed (0.48). The main emphasis of the evaluation of the data, therefore, was on log files generated by measuring the interaction with the mouse device.

Nevertheless, the model shows the relations between some specifics for HCI dimensions, for example, advertisement parameters as part of information density and information frequency or interaction precision as a part of interaction faults. Other combinations of CIIs can also be assigned to the HCI dimensions. Further modeling must show, however, which combinations provide the highest explanation quality. Furthermore, the other side of the structural equation model, where the cultural dimensions must be inserted and connected, also must be investigated in detail.

2.3.2 Discussion

Despite probable objections, it is not trivial to derive general guidelines for intercultural HCI design from the results of the studies. The results of the qualitative studies for interaction analysis also have a doubtful character, since very dynamic phenomena (such as interaction speed or information frequency) cannot be observed and recognized by people without the support of special tools like the IIA tool. Therefore, the qualitative studies that were carried out in parallel with the described quantitative studies offered no useful design recommendations for intercultural interaction design in the field of HCI.

In addition, an enormous amount of interpretation is necessary (even in quantitative studies) to achieve plausible, reliable, and valid results from which valid conclusions can be derived. Furthermore, it is not trivial to recognize differences in the interaction behavior that are not culturally dependent but that have, for example, demographic causes (e.g., different information reception or another interaction style due to age differences). Therefore, it is extremely problematic to bring cultural models completely into accordance with HCI design. Not all possible disturbing variables can be taken into account because of cultural complexity. The results obtained by the explanatory model containing CIIs necessarily differ from reality (because no model by definition completely covers all aspects of reality). Furthermore, the correctness of the explanatory model varies with the number of CIIs used for one HCID. In this sense, the explanation strength is still weak, because until now each HCID has only been substantiated by a few CIIs and only some of those CIIs display very high separation power.

Another consideration is that the amount of analysis and SEM, as well as the availability of relevant sets of data, being produced by intercultural studies in HCI is still relatively low. Likewise, the task of modeling the connections between cultural-, informational-, and interaction-related variables as a structural equation model using CIIs is not completely soluble at the moment due to too few or missing data, indicating the need for further urgent empirical data collections. As a result, only individual parts (sub-models) of the definite structural equation model are in the foreground for the moment. Hence, much work is still required to complete an adequate explanation model for cultural HCI.

Nevertheless, reciprocally confirming aspects attest the high reliability and criteria validity of the statistical results of the two studies: there is a high discrimination rate of over 80% using CIIs to classify users as Chinese (C) and German (G) as well as a high accordance of the HCIDs and the CIIs found by applying different statistical methods [9]. Therefore, the results found in the studies lead to the conviction that it is justified, reasonable, and encouraged to use CIIs in intercultural HCI research to develop an explanatory model of culturally influenced HCI, which is a necessary component in Culturally-Aware HCI systems.

In addition, it has been proven empirically that the interaction of the user with the system is influenced not only by cultural parameters, such as nationality, mother tongue, country of birth, etc., but also by other parameters such as experience or age [9]. Therefore, it is difficult to separate cultural influences from experience because experience is culturally imprinted too (depending on the definition of the terms). To escape these difficulties at least partly, corresponding measures were used (e.g., sensible rating of samples, clear up data sets, keep disturbing variables constant).

2.4 Framework for Culturally-Aware HCI Systems

In the following, the considerations so far will be integrated into a framework for Culturally-Aware HCI systems. First, the principle of culturally adaptive HCI systems derived from the findings of the model concerning the relationship between culture and HCI is presented. From this, a culture-adaptive interface agent architecture is developed, which in turn can be implemented in a demonstrator in order to prove that its functionality is empirically usable in Culturally-Aware HCI systems.

2.4.1 Principle of Culturally Adaptive HCI Systems (CAHCI)

The principle of CAHCI by [9] (Fig. 2.3) is in accordance with the ideas of [22], [23], and [24] and represents a feedback control system that allows the deduction of values of cultural dimensions by analyzing monitored user interaction behavior and retrieving associated cultural parameters stored in a database format (both during the design phase and runtime).

Suitable aspects for cross-cultural user interface design (parameters for cultural adaptation) can be derived herewith that allow the adaptation of both the “look” (appearance) and “feel” (behavior) of HCI according to the cultural needs of the

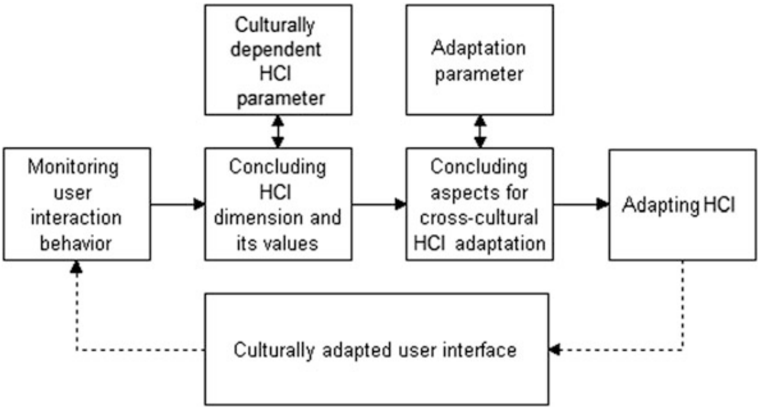

Fig. 2.3 Principle of culturally adaptive HCI systems

user. Adaptation parameters are directly visible cultural variables concerning "look" that are immediately visible (such as color, font, and menu position). The "feel" of HCI is affected by adaptation parameters (direct hidden cultural variables) that are perceivable over time, such as menu structure, usage of scroll bars, information presentation speed, or frequency of messages.

The system has to analyze the interaction behavior of the user to discover interaction patterns and to behave similarly to the user. This means gaining the acceptance of the dialog partner through unobtrusive imitation of the behavior of the dialog partner so that the cognitive models of the system and the user are on the same wavelength. Reconciling the cognitive models of the system and the user ensures a certain basic acceptance as well as a fundamental benevolence of the user with regard to the system (cf. the principle of charity according to [25]). This increases the possibility that the user will buy a device from the same company again, provided that its usability, functionality, and politeness are sufficient enough.

The system monitors and records the user's interaction behavior with the system. It then analyses this data using cultural interaction criteria to determine the cultural characteristics of the user. Finally, the system adapts the HCI according to the cultural preferences of the user, employing HCI design guidelines for intercultural interface design after asking the user or automatically if expectance conformity is not hurt or an emergency situation forces it to do so. The basic principle of each adaptivity consists in observing the behavior of the user with the system, generating a user model with the system, and automatically adapting the system to the user [26].

As a result, no cultural dimension will be used to relate the user–system interaction behavior to a certain culture. Only the interaction behavior itself will be classified according to the informational dimensions, whose specifics depend on the cultural background and imprint of the user. Hence, it is not necessary to classify the user as belonging to a certain culture, but to a certain interaction behavior from which the cultural settings the user presumably prefers are known. For instance, if the user interacts very frequently and quickly with the system, it can be assumed that either the user is very experienced or they belong to a cultural group which is highly relationship oriented, such as that of China. By understanding the default values of the variables of the informational dimensions determined for different cultures in the design phase, the system can compare those values with those actually initiated by the user currently interacting with the system. The best matching patterns allow the system to deduce the cultural adaptation parameters with which to adapt the HCI with the highest probability of coping with the user's cultural needs.

2.4.2 Culturally Adaptive HCI (CAHCI) Architecture

The principle of culturally adaptive HCI systems can be implemented in a culturally adaptive HCI architecture. A culturally different user employs the device. The system monitors and records the interaction patterns. The system classifies the interaction patterns into interaction classes using its knowledge about culturally dependent variables (CIIs). The principle works if the interaction classes are built up according to the culturally different users. After recognition of the culturally imprinted interaction pattern (CIP), the device should be able to adapt to the interaction preferences of the user and, if defined in the design phase by the determined guidelines for intercultural HCI design, to the preferences of the user regarding surface, functionality and interaction. According to the results of the reflected model and the architecture, additional adaptation can be made for the preferences of the user that emerge during runtime.

The culturally adaptive HCI architecture consists of several subagents, each of which fulfills a special sub-task (Fig. 2.4).

The HCI monitoring agent serves to record the interactive user behavior with the system to retrieve localized data, which is stored in a database communicating with the database agent. By specifying several profound use cases, the relationship between the use case and the cultural dimension has been extracted empirically (as shown in Sect. 2). From this, implications could be made concerning the intercultural parameters (cf. CIIs). The CIIs can be stored in a lookup table [23] and parts of them can be retrieved to adapt the graphical user interface (GUI) or the speech user interface (SUI). Thereby, existing possibilities for tracing and logging user interactions and in general determining and showing the user's behavior with the system can be used to recognize the cultural variables and their values within the localization process. However, the general preparation of the system for many localized configurations must also be considered to fulfill the concept of internationalization. The interaction agent deduces the interaction patterns of the user with the system. In combination with the learning agent, the patterns can be analyzed and recognized over time according to the identified user to facilitate acquisition of an adequate model of them, which also contains their cultural characteristics. The

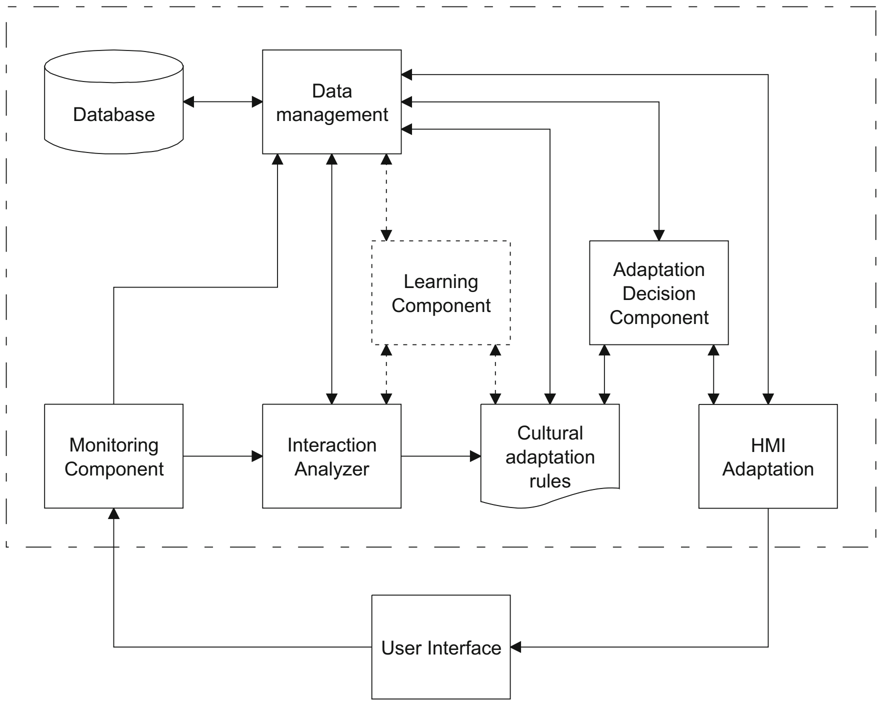

Fig. 2.4 Culturally adaptive HCI architecture

adaptation agent retrieves the recognized cultural characteristics from the database agent and adapts the HCI according to the connected HCI aspects for the desired cultural needs of the user.

2.4.3 Exemplification: Culturally-Aware HCI Systems in the Automotive Context

Today, in the automotive context adaptivity in driver information and assistance systems is necessary because the functional and informational complexity of infotainment systems (a mixture of information and entertaining systems) can no longer be handled solely by the driver without employing adaptivity [27]:

- It is hard for the driver to handle the functional and informational complexity of such systems in extreme driving situations: the mental workload which is caused by all possible senses (i.e., resulting from visible, audible and haptic information) simply exceeds the mental capacity of the driver.
- The mental workload should be maintained within acceptable limits in dangerous driving situations if the system adapts the information flow for the user

automatically. Due to this, adaptivity must also take external input sources into account (for instance from pre-crash sensors).
- The output modality has to be adapted automatically for at best the least workload (for example by using different displays).

It is also necessary to *culturally adapt* driver information and assistance systems because:

- The user preferences must be considered and covered, which depend on the cultural background of the user.
- The cultural background of the driver also determines behavior in certain (especially dangerous) driving situations.
- There are many different groups of drivers that exhibit their own “culture” (for example interaction behavior), whether this is regarding groups at an international level or at a national level (such as social, ethnic, or driver groups).
- The local market for cars has increasingly become a worldwide market. Future infotainment systems will have to handle the demands of various drivers and various cultures. This aspect can only be covered within a single system if this system is adaptable and configurable.

Hence, it is necessary to build Culturally-Aware HCI systems because of urgent application cases. Enhanced algorithms are needed to enable the system to automatically and correctly adapt itself to the culturally imprinted needs of the user to bring the mental model of the system in line with the user’s mental model.

2.5 Culturally-Aware HCI Demonstrator

The significant statistically discriminating cultural interaction indicators identified by the studies mentioned above motivated the author to demonstrate that they also work in a real environment. By means of a demonstrator, some important cultural variables, as well as the CAHCI principle (cf. Fig. 2.3), were exemplified to support the following argumentation: If the CAHCI demonstrator is capable of classifying the user according to their interaction with the system and correctly according to their cultural characteristics, then there is empirical proof that parts of the interrelationship between the HCI dimensions relevant for HCI design and the cultural dimensions are correct.

A demonstrator regarding culturally (adaptive) HCI requires the following properties to show the correctness of the theorized models and guidelines as well as the CAHCI principle :

- Parameterization with intercultural properties for different cultural groups;
- Recognition of the specifics of the cultural variables through user monitoring;
- Automatic adaptation of the HCI to the cultural needs of the user (i.e., CAHCI).

Fig. 2.5 The CAHCI demonstrator based on a mobile driver navigation system

CAHCI functionality has, therefore, been integrated in a portable navigation system called the "CAHCI demonstrator" (Fig. 2.5).

2.5.1 Setup, Runtime, and Using the CAHCI Demonstrator

Some of the variables for cultural adaptation that best categorize the HCI style of people from different cultures have been implemented in the CAHCI demonstrator in order to show that the CAHCI principle works in a real system—and not only statistically (cf. Sect. 2.2.1).

The following aspects can be covered and adapted within the CAHCI demonstrator:

- Color scheme of the map display;
- How often a voice output will be repeated automatically (NIT);
- Speed of the voice output (TPI);
- Number of displayed road names (~POI);
- Number of buttons and configuration possibilities in menus (~POI);
- Number of POIs (POI);
- Language.

The CAHCI demonstrator consists of three modules according to the three main parts of the principle of culturally adaptive HCI: the monitoring module, analysis module, and adaptation module. Table 2.2 gives an overview regarding some aspects of the possible adaptation levels and parameters within the CAHCI demonstrator for the adaptation of the HCI according to preliminary Chinese user expectations obtained through a qualitative survey with 20 Chinese students in Hangzhou.

Only five adaptation levels (none of which are fuzzy) have been implemented into the demonstrator due to cost restrictions and the system performance

Table 2.2 Adaptation levels provided by the CAHCI demonstrator depending on the C-value

Adaptation level	Number of POI (MD) [POI]	Highway color (MD)	Route color (MD)	Number of announcements (MG) [NIT]	Voice speed (MG) (Words per second) [DIP]	C-value (%)
1	40	Blue	Light blue	1	50	0–20
2	80	Light blue	Light violet	2	100	20–40
3	120	Turquoise	Violet	3	150	40–60
4	160	Light turquoise	Light red	4	200	60–80
5	200	Green	Red	5	250	80–100

limitations of the embedded technology. The C-value is the cultural index, which expresses the assumption strength that the user is a Chinese user (calculated by the system) as a percentage; that is, if the C-value is 100, the system has recognized a Chinese user; if the C-value is 0, the system has recognized a German user. MD indicates that the adapted aspect is mostly relevant for the use case of presenting information on a map display. MG indicates the "maneuver guidance use case."

Depending on the C-value, the look and feel of the demonstrator will change according to the adaptation levels presented in Table 2.2. (S) means "standard," that is, the default settings for German users are used, and (A) means that the HCI is adapted to Chinese users (for instance, a status bar with icons is displayed in the bottom right instead of in the top left of the screen). According to the results of the qualitative survey (cf. Sect. 2.2), Chinese users prefer the most important information to be in the top left (vs. the least important information in the bottom right). If the system recognizes that the user behaves like a Chinese user, it adapts the HCI to the Chinese settings according to the content of the C-value (Fig. 2.6). Figure 2.7 shows the differences in the appearance of the map display of the navigation system for German and Chinese settings.

Fig. 2.6 The initial screen of the CAHCI demonstrator (standard (*left*) for German users and adapted (*right*) to Chinese users)

Fig. 2.7 Differences in map display according to user interaction behavior [*left*: German setting (adaptation level is 2, C-value = 25); *right*: Chinese setting (adaptation level is 4, C-value = 62)]

Many more elements could be considered and adapted in intercultural HCI design regarding icon and symbol design, layout, language, text size, format, units, street names, etc. [28]. However, to localize and internationalize driver navigation systems in general remains a task for software developers and HCI designers in the industry.

2.5.2 Evaluating the CAHCI Principle

The functional test presented in this section served to prove the classification correctness and the proper functionality of the CAHCI principle, that is, that the basic principles of cultural adaptivity (monitoring, analyzing, adapting) work.

Twenty-five (13 Chinese and 12 German) users were asked to complete several test tasks as quickly as possible. Questions could be directed to the test leader, if necessary. For evaluation at the time, two groups from different cultures with similar conditions regarding use case, education, profession, age, and gender were built. Interaction data that emerged during the interaction of the users with the CAHCI demonstrator were recorded by the logging module of the demonstrator. The data sets were analyzed using the IIA data evaluation module using a neural network, as described in [10] . The results of the analysis led to the following statements:

- The number of total entries in the log file (representing the amount of user interaction), error clicks, and mouse moves classified very well.
- The more frequent the interaction breaks greater than 10 s, the less experienced or trained the user is at handling the application—a higher cognitive processing time of the user could also explain this—or the user is Chinese.
- The longer the test duration, the more exact or less experienced the test person is.
- The more interaction breaks <1 ms (equal to the number of scrolls <1 ms, i.e., moves with the finger on the touch screen, a.k.a. “mouse moves” (MM), or

"mouse movement speed" (MMS)), the less experienced the user is at dealing with use cases of driver navigation systems, or the user is very hasty or Chinese.

- Cross-validated interaction breaks (<1 ms and >10 s) classify up to 72% of the users correctly to their cultural background (Chinese or German). Including the third parameter ("test duration") within a linear discriminant analysis, the classification rate reached 74%.

Results showed that interaction differences exist between Chinese and German users. The averaged values of the culturally different groups tend to always be in one direction, which indicates a trend regarding CIPs. In addition, from the 25 data sets, nine were analyzable by linear discriminant analysis to calculate the statistical classification power of the CIIs used in the CAHCI demonstrator. Surely, this result reflects the small sample size and depends on several statistical settings (such as how many and which variables are in the set to which the linear discriminant analysis is applied or what including and excluding statistical limits are set). However, one-way ANOVA showed that the CIIs work very well: their discrimination power is high, and hence their weight within the adaptivity algorithm implemented in the CAHCI demonstrator using production rules is also high. Table 2.3 lists a ranking of the excellence of the CIIs used in the CAHCI demonstrator (green-marked).

Out of the implemented cultural indicators in the CAHCI demonstrator, two CIIs ("Mouse Up" and "Scrolls <1 ms") classified (cross-validated) 80% of the users correctly to their cultural background (Chinese or German). "Mouse Up" represents the measuring variable "mouse clicks" (MC). "Scrolls <1 ms" measures the number of interaction breaks less than 1 ms, representing the MM from which the MMS can be derived over time. Additionally, it can be proven that the CAHCI demonstrator classifies the nationality of the test user correctly to the interaction behavior of the test user. For example, the CIIs Nr_Of_Scrolls_Shorter_Than_1 ms, Breaks_Greater_Than_10 s, and Nr_Of_Scrolls_Over_1 ms, which represent interaction breaks, using a touch screen, and mouse up und counter entries, classify the respective nationality up to 80% correctly for the interaction of the test user.

There are classification quotes significantly over 50%, which proves that the results have not been found randomly, but support themselves mutually. Hence, these results prove that the CAHCI principle works not only statistically, but also within a real system exemplified by a mobile driver navigation system.

The obtained results using the CAHCI demonstrator justify the direction of research in this work, which supports further studies that will increase the exactness and the completeness of the results as well as the discriminatory power and separation effect of the CIIs.

Table 2.3 CIIs used in the CAHCI demonstrator

Cultural Interaction Indicator	*Weight in %*	*F-Value*	*Significance*	*Homogeneity of variances [h]*	*Weight [0;1]*	*Ranking*
Nr of IO Breaks Over 10s_NORM	100	9.06	0.006	0.539	1.000000000	1
Mouse Up_NORM	59	5.353	0.03	0.867	0.5908388521	2
Counter Entries_NORM	49	4.478	0.045	0.947	0.4942604857	3
Total Entries_NORM	48	4.382	0.048	0.82	0.483664459	4
Mouse Down_NORM	46	4.141	0.054	0.722	0.4570640177	5
Nr of IO Breaks Over 1s_NORM	41	3.69	0.067	0.571	0.407284768	6
Mouse Up_Error Click_NORM	40	3.629	0.069	0.111	0.4005518764	7
Mouse Down_Error Click_NORM	40	3.619	0.07	0.053	0.3994481236	8
Nr of Error Clicks_all_NORM	40	3.619	0.07	0.53	0.3994481236	9
Normal Entries_NORM	39	3.519	0.073	0.769	0.3884105960	10
Nr of IO Breaks Shorter than 1ms_NORM	34	3.091	0.092	0.053	0.341169977	11
Nr of Mouse Clicks_all_NORM	27	2.436	0.132	0.512	0.2688741722	12
Keyboard Button_NORM	22	2.007	0.17	0.674	0.2215231788	13
No Button_NORM	16	1.472	0.237	0.969	0.1624724062	14
Nr of Mouse Clicks_Since Start Driving_NORM	11	0.976	0.333	0.643	0.1077262693	15
Whole Scrolling Time_NORM	7	0.617	0.44	0.098	0.0681015453	16
Average Scrolling Time_NORM	6	0.54	0.47	0.113	0.0596026490	17
Duration of Test in Min	3	0.263	0.613	0.047	0.029028697	18
Nr of Scrolls_NORM	2	0.189	0.668	0.49	0.0208609272	19
Nr of IO Breaks Shorter than 1s_NORM	2	0.158	0.694	0.332	0.017439293	20

Legend:

Best variable with best significance and very high F-value	100	9.06	p=0.006	h=0.047	Ref.: 1.00 = 100% of F_{max} (9.06)	1
Very good variable with significance p < 0.05 and very high F-value	48–59 (100)	4.382–9.06	p < 0.05			
Good variable with significance p < 0.1 and high F-value	34-46	3.091-4.141	p < 0.1			
Bad variable without significance and very low F-value	2–27	0.158–2.436	p > 0.2			
Worst variable with worst significance and very low F-value	2	0.158	p=0.694	h=0.969	0.017439293	20

2.5.3 Enhancing the CAHCI Demonstrator

Cultural adaptivity does not only concern the look and feel of the user interface, but also the interaction devices as well as the number and the type of system functions [14] that can be changed dynamically according to user preferences and the usage context [29]. Thus, designing an appropriate system according to the user in the design phase helps to avoid the problems arising from adaptivity. For instance, it is problematic that automatic adaptation (adaptivity) 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: the behavior of the system has to be in accordance with the beliefs of the user to prevent unexpected situations for the user. In addition, legal restrictions have to be taken into account, as only the effects of user actions are allowed to be permanently stored, but not the log files of the personalized sessions themselves.

Additionally, there are many open questions that have to be addressed very carefully: How many dynamic changes are optimal for and will be accepted by the user? When does a "hidden" adaptation occur? How can this be prevented? How much does the user trust the adaptive system? Adaptivity may not surprise the user but must be in accordance with the mental model of the user [30]. Additionally, there are culturally dependent questions which have to be answered. For example, what cultural aspects must be adapted? Which of them can be adapted automatically? Additional technical problems include when to stop behavior analysis and start adapting ("the bootstrapping problem") (one example for a possible solution to the bootstrapping problem can be found in [31]).

As long as no solution is available that can achieve meaningful adaptations 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, for example, 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 set simultaneously as standard parameters for the desired country. Furthermore, the adaptive system obtains the 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).

The near-term objective is to enhance the tool for "cross-cultural HCI analysis" by applying enhanced techniques using statistical and data mining methods and semantic processing to extract cultural variables and their values as well as guidelines for cross-cultural HCI 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 adaptivity based on neural networks as well as structural equation models to prove basic theoretical cultural interaction models. In the long-term view, the best discriminating algorithms for adaptivity will be transformed and implemented in Culturally-Aware HCI systems to be evaluated qualitatively using intercultural usability tests with users of different cultures and users under mental stress.

2.6 Implications for Culturally-Aware HCI Systems

The findings so far indicate some recommendations for designing Culturally-Aware HCI systems. CIIs from the culturally influenced HCI model serve as basis for the quantitatively derivation of adaptation rules concerning HCI according to the culturally imprinted interaction patterns of the user with the system at runtime to ensure cultural adaptivity of HCI (CAHCI) in Culturally-Aware HCI systems.

2.6.1 Quantitative Apparatus of Recognition

The specifics (values) of intercultural variables can be determined purely quantitatively through analysis of the interaction of the user with the system (considering only the interaction tracing log file of the system). Hence, it is possible to determine the culturally imprinted characteristics of the user by analyzing the interaction of the user with the system. Furthermore, the greater the cultural distance, the greater the difference in the kind of interactions of humans with a system (computer, machine, navigation system, etc.). It has been statistically proven that there are significant cultural differences in the interaction behavior of the user with the system using the IIA tool. The combination of cultural differences represented by CIIs form CIPs according to the cultural imprint of the user. There are different patterns of interaction in HCI (composed of combinations of CIIs) that are culturally significant depending on the cultural imprint of the user; that is, it has been statistically and empirically proven that the interaction of the user with the system depends on the user's cultural background. Furthermore, the cultural interaction differences of the users with the system have been identified quantitatively and not qualitatively (by using interaction times or the number of interactions): they can be statistically identified and measured by a computer system (using the IIA tool and the CAHCI demonstrator). Cultural interaction differences in HCI can be recognized and measured quantitatively by a computer system (although only by monitoring and analyzing the interaction of the user with the system quantitatively, resulting in the adequate culturally dependent specifics for the intercultural variables). For this purpose, it is suggested to deploy the principle of culturally adaptive HCI systems (cf. Sect. 2.4.1) as well as the culturally adaptive HCI architecture (cf. Sect. 2.4.2) in Culturally-Aware HCI systems.

2.6.2 Deploying the Culturally Influenced HCI Model

The interaction of the user with the system in HCI is influenced by static aspects (preferences), which are present due to the cultural shaping of the user and their experience with the system, and due to dynamic aspects depending on the situation. Therefore, the type of user–computer interaction within HCI must be adaptable in such a way that the system can do justice to the interaction requirements of the user (i.e., the specifics of the HCI dimensions).

The empirical results obtained through the described study partly confirm the relationships theorized in the literature by showing that there are metrics composed of CIIs, which are adequate for measuring culturally influenced HCI as a basic property of Culturally-Aware HCI systems. The values of the CIIs revealed interesting tendencies in user interaction behavior (i.e., HCI style or HCI characteristics) related to the cultural imprint of the user. Therefore, it should be possible to complete and optimize the explanatory model of culturally dependent variables for HCI design using the methods of factor analysis and SEMs by revising the relationship between user interaction and user culture.

The design of Culturally-Aware HCI systems can continue to profit as long as the presented culturally influenced HCI model is developed and validated. The ideas presented in this chapter represent a reasonable step toward an explanatory model of culturally influenced HCI. As this process continues, the connections between HCI and culture will become clearer and comprehensive in the end, even if much work still remains (for instance, improving the separation power of the CIIs or the explanation strength of the model of culturally influenced HCI).

2.6.3 Design Recommendations

With regards to additional parameters for adjusting HCI according to the cultural needs of the user to provide for and tend to adequate slots for the CIIs presented in this work, the following aspects should at least be considered very carefully when designing new architectures of *Culturally-Aware* HCI systems or extending existing systems in addition to explicit formation principles when designing adaptive HCI systems for vehicles in the Automotive context, cf. [28, 30, 32–36]:

- The number of information units presented simultaneously (e.g., POIs in the map display should be about a half in number for German than for Chinese users. Number, duration, and frequency of information units presented sequentially (e.g., (system) messages or maneuver advice in maneuver guidance should be lower in number for German than for Chinese users).
- When designing information systems, consider that the frequency and usage speed of interaction devices (e.g., a touchscreen, hard keys, or a mouse) are almost twice as high and fast but less exact for Chinese than for German users

Furthermore, some results of this work can be 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 simply by counting certain interaction events without the necessity of knowing the semantic relations to the application. Such indicators include the number of MM, breaks in the MM ($\neg IN_{MM}$), MMS, MC, interaction breaks in general (¬IN), and the number of acknowledging system messages (AM) or refusing system messages (RM). Surely, all these indicators can also be connected semantically to the use cases of applications running on the system. However, simply counting such events related to the session duration from users of one culture and comparing them to those of users of another culture is obviously sufficient to indicate differences in the interaction behavior of culturally different users. Furthermore, the values of the CIIs change in a similar way even if different use cases and test tasks are applied. Hence, those CIIs can be called "general cultural interaction indicators" (GCIIs) and that can be applied in Culturally-Aware HCI systems in general.

Using methods of artificial intelligence may help to fulfill the steps to achieving cultural adaptivity, which in turn will broaden universal access in the application of the following culturally adaptive HCI principles (cf. Sect. 2.4):

- Learning the differences in the interaction of the users of different cultures.
- Classifying interaction patterns according to culture.
- Determining the user preferences according to culture.
- Adapting HCI according to user preferences.
- Learning user preferences by observing HCI over time.
- Integrating knowledge from observation into the system's user model.

Finally, to improve system intercultural usability, it is necessary to internationalize and to localize intercultural variables; that is, to consider such variables within the process of product design [5].

2.7 Conclusions and Outlook

Culturally-Aware HCI systems need a cultural model that allows them to automatically derive adaptation rules to adapt the system's HCI to the culturally imprinted user's needs (cf. Sect. 2.1). Statistically valid and significant results from two empirical studies confirmed (cf. Sect. 2.2) that *special combinations of cultural interaction indicators (CIIs)*, are *statistically discriminating enough* to enable computer systems to detect different culturally influenced interaction patterns (CIPs) automatically and to relate users to a certain culture behavior according to the theorized principle of culturally adaptive HCI.

Reflections have been made to generate a structural equation model (SEM) of the relationship between HCI dimensions and cultural dimensions (cf. Sect. 2.3). For example, the higher the relationship orientation (e.g., toward collectivism), the higher information density, information speed, information frequency, interaction frequency, and interaction speed are and vice versa. However, further research showed that no cultural dimension has to be used in the first place to relate the interaction behavior of the user with the system to a certain culture. Only the interaction behavior itself will be classified according to the HCI dimensions, whose specifics depend on the cultural background and imprint of the user. Therefore, it is not necessary to classify the user to a certain culture, but to a certain interaction behavior from which the cultural settings the user presumably prefers are known.

According to the CAHCI Architecture (cf. Sect. 2.4), by knowing the default values of the variables of the HCI dimensions determined for different cultures in the design phase, the system can compare those values with those actually initiated by the user currently interacting with the system. The best matching patterns allow the system to deduce the cultural adaptation parameters and adapt the HCI with the highest probability of coping with the user's cultural needs.

Even though the results of the quantitative studies conducted up to now have primarily concerned and demonstrated the cultural differences in HCI related to use cases in driver navigation systems for the Automotive context exemplified by the CAHCI demonstrator (cf. Sect. 2.5), they serve to offer some confirmed facts and a basis for providing at least some general recommendations (even if no guidelines are available) for the design of intercultural user interfaces in Culturally-Aware HCI systems (cf. Sect. 2.6).

It is up to future studies to derive scientifically sound and practically relevant design guidelines from explanatory models for culturally influenced HCI. Furthermore, they must reveal, for instance, the degree of *acceptance of cultural adaptivity* of the user as well as the degree to which the user's mental workload is affected using cultural adaptivity in Culturally-Aware HCI systems.

Acknowledgements I would like to thank everyone who supported the cultural adaptivity project, which was the basis for the reflections on Culturally-Aware HCI systems presented in this chapter.

References

1. Thomas, A.: Psychologie interkulturellen Handelns. Hogrefe, Göttingen, Seattle (1996)
2. Honold, P.: Interkulturelles usability engineering: Eine Untersuchung zu kulturellen Einflüssen auf die Gestaltung und Nutzung technischer Produkte. Als Ms. gedr. ed. Vol. 647. VDI Verl, Düsseldorf. 343 (2000)
3. Hofstede, G.H., Hofstede, G.J., Minkov, M.: Cultures and Organizations: Software of the Mind, 3rd edn. McGraw-Hill, Maidenhead (2010)
4. Badre, A, Barber, W.: Culturabilty: the merging of culture and usability. In: Proceedings of the 4th Conference on Human Factors and the Web. AT and T Labs, Basking Ridge, NJ, USA (1998)
5. Vöhringer-Kuhnt, T.: The Influence of Culture on Usability. Freie Universität Berlin (2002)
6. Hofstede, G, Hofstede, J.G.: Cultures and Organizations: Software of the Mind, 2nd edn. McGraw-Hill, New York, USA (2005)

7. Röse, K.: Methodik zur Gestaltung interkultureller Mensch-Maschine-Systeme in der Produktionstechnik, vol. 5. Univ. 244, Kaiserslautern (2002)
8. Heimgärtner, R.: Intercultural user interface design. In: Blashki, K, Isaias, P. (eds.) Emerging Research and Trends in Interactivity and the Human-Computer Interface, pp. 1–33. Information Science Reference (an imprint of IGI Global), Hershey (2014)
9. Heimgärtner, R.: Cultural differences in human computer interaction: results from two online surveys. In: Oßwald, A. (ed.) Open Innovation, pp. 145–158. UVK, Konstanz (2007)
10. Heimgärtner, R.: A Tool for getting cultural differences in HCI. In: Asai, K. (ed.) Human Computer Interaction: New Developments, pp. 343–368. InTech, Rijeka (2008)
11. Shneiderman, B.: User Interface Design. MIT Press, Munich (2002)
12. Dix, A., et al.: Human-Computer Interaction. Prentice Hall, London (1993)
13. Nielsen, J., *Usability metrics.* nngroup, 2001
14. Röse, K., Zühlke, D.: Culture-oriented design: developers' knowledge gaps in this area. In: 8th IFAC/IFIPS/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, Preprints, Kassel, Germany, 18–20 Sept 2001 (2001)
15. Hall, E.T.: Beyond Culture. Anchor Books, New York (1976)
16. Heimgärtner, R.: Research in progress: towards cross-cultural adaptive human-machine-interaction in automotive navigation systems. In: Day, D., del Galdo, E.M. (ed.) Proceedings of the Seventh International Workshop on Internationalisation of Products and Systems (IWIPS 2005), pp. 97–111. Grafisch Centrum Amsterdam, The Netherlands, Amsterdam (2005b)
17. Smith, A., Chang, Y.: Quantifying Hofstede and developing cultural fingerprints for website acceptability. In: V.R.K.H.P.C.J.D.D. Evers (ed.) Proceedings of the Fifth International Workshop on Internationalisation of Products and Systems, IWIPS 2003, Germany, Berlin, pp. 89–102. University of Kaiserslautern, Kaiserslautern, 17–19 July 2003
18. Hall, E.T.: The Silent Language. Doubleday, New York (1959)
19. Halpin, A.W, Winer, B.J.: A factorial study of the leader behavior descriptions. In: Stogdill, R.M., Coons, A.E. (eds.) Leader Behavior: Its Description and Measurement, pp. 39–51. Bureau of Business Research, Ohio State University, Columbus, OH (1957)
20. Victor, D.A.: International Business Communication, 7th edn. Harper Collins, New York, NY, 280 (1998)
21. Bortz, J., Döring, N.: Forschungsmethoden und Evaluation: Für Human- und Sozialwissenschaftler, 4., überarb. Aufl. ed. Springer, Berlin. 897 (2006)
22. Stephanidis, C., Savidis, A.: Universal access in the information society: methods, tools, and interaction technologies. Univ. Access Inf. Soc. **1**(1), 40–55 (2001)
23. Baumgartner, V.-J.: A Practical Set of Cultural Dimensions for Global User-Interface Analysis and Design. Fachhochschule Joanneum, Graz, Austria (2003)
24. Leuchter, S., Urbas, L.: Useware engineering mit kognitiven Architekturen. Automatisierungstechnische Praxis **46**(9), 68–72 (2004)
25. Davidson, D.: Inquiries into Truth and Interpretation. Clarendon Press, Oxford [u.a.]. 292 (1984)
26. Mandl, T., Schudnagis, M., Womser-Hacker, C.: A framework for dynamic adaptation in information systems. In: Stephandis, C. (ed.) Human Computer Interaction: Theory and Practice. Proceedings of 10th International Conference on Human-Computer Interaction, pp. 425–429. Springer, Heidelberg, 22–27 June 2003 (2003)
27. Heimgärtner, R., et al.: Towards cultural adaptability to broaden universal access in future interfaces of driver information systems. In: Universal Access in Human-Computer Interaction. Ambient Interaction, 4th International Conference on Universal Access in Human-Computer Interaction, UAHCI 2007 Held as Part of HCI International 2007 Beijing, China, 22–27 July 2007 Proceedings, Part II, Stephanidis, C. (ed.). Springer, Heidelberg. pp. 383–392 (2007)
28. Röse, K., Heimgärtner, R.: *Kulturell adaptive Informationsvermittlung im Kraftfahrzeug: 12 Uhr in München – Stadtverkehr, 18 Uhr in Shanghai – Stadtverkehr.* i-com, 7 (3 Usability und Ästhetik), pp. 9–13 (2008)

29. Heimgärtner, R., Holzinger, A.: Towards cross-cultural adaptive driver navigation systems. In: Holzinger, A., Weidmann, K.-H. (eds.) Empowering Software Quality: How can Usability Engineering Reach these Goals? 1st Usability Symposium, pp. 53–68, HCI&UE Workgroup, Vienna, Austria, 8 Nov 2005. Austrian Computer Society, Vienna (2005)
30. Kobsa, A.: User modeling in dialog systems: potentials and hazards. AI & Soc. **4**(3), 214–231 (1990)
31. Heimgärtner, R.: Cultural Differences in Human-Computer Interaction. Paperback B: Einband - flex. (Paperback) ed. Vol. 1. 2012: Oldenbourg Verlag. XVIII, 325 S. - 24,0 x 17,0 cm
32. Kolrep, H., et al.: Mobile Anwendungen im Kraftfahrzeug - Mensch-Maschine-Interaktion und Akzeptanz, in Informatik 2003 - Innovative Informatikanwendungen, Band 2, Beiträge der 33. Jahrestagung der Gesellschaft für Informatik e.V. (GI), 29. September - 2. Oktober 2003 in Frankfurt am Main, D.K. R., et al. (eds.), pp. 386–391. GI, Bonn (2003)
33. Malinowski, U., Obermaier, A.: Adaptivität und Benutzermodellierung - Was ist ein adäquates Modell? In: Kobsa, A.e.a. (eds.) Tagungsband KI-93-Workshop “Adaptivität und Benutzermodellierung interaktiven Softwaresystemen”, pp. 61–68. Univ.-Verl. Konstanz, Konstanz (1993)
34. Kobsa, A., Wahlster, W., Carberry, S.: User models in dialog systems: [based on UM86, the first International Workshop on User Modeling, held in Maria Laach, Germany]. Springer, Berlin (471) (1989)
35. Dieterich, H., et al.: State of the art in adaptive user interfaces. In: Schneider-Hufschmidt, M., Kuehme, T., Malinowski, U. (eds.) Adaptive User Interfaces Principles and Practice, pp. 13–48. Elsevier Science Publisher B.V., North-Holland (1993)
36. Shneiderman, B., Plaisant, C.: Designing the User Interface: Strategies for Effective Human-Computer Interaction, 4th edn. Pearson, Boston, Mass (652) (2005)

Author Biography

Dr. Heimgärtner earned undergraduate degrees in Psychology and Computer Science. He did graduate work in Information science, Linguistics, Philosophy, and Religion Studies and obtained his Ph.D. in Information Science from the University of Regensburg. Dr. Rüdiger Heimgärtner is a specialist of cultural differences in HCI and has worked in software and HCI projects at Siemens AG and Continental AG. He is the founder and managing director of the company Intercultural User Interface Consulting (IUIC) and has provided training and consultation for Intercultural User Interface Design (IUID). The areas of interest of Dr. Heimgärtner include machine learning, automated reasoning, psychology of judgment, and mathematical psychology. One of his main contributions to information science, usability engineering, and HCI design is detailing IUID in articles, proceedings, and books, e.g. as author of the first German speaking book on IUID. Dr. Rüdiger Heimgärtner is iNTACS certified ASPICE assessor with more than 10 years of experience in quality and process management in international software and HCI projects. He is member of the International Usability and User Experience Qualification Board (UXQB) as well as of the working team of ambient assisted living (AAL) at the German Institute for Standardization (DIN).

http://www.springer.com/978-3-319-67022-5

Advances in Culturally-Aware Intelligent Systems and in
Cross-Cultural Psychological Studies
Faucher, C. (Ed.)
2018, XXVIII, 459 p. 68 illus., 49 illus. in color.,
Hardcover
ISBN: 978-3-319-67022-5