From Cultural to Individual Adaptive End-User Interfaces: Helping People with Special Needs

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Abstract. Culture heavily influences human–computer interaction (HCI) since the end-user is always within a cultural context. Cultural and informational factors correlate to jointly influence the look and feel of interactive systems, e.g. widget position or information density. Every single individual also develops a specific culture (eating style, walking style etc.), i.e. characteristics and behavior as well as attitudes and values. Consequently, individual adaptability can be essential to cover individual needs of the culturally but uniquely imprinted end-users with special needs e.g. reducing the workload by recognizing and knowing the individual expectances of the end-user. This improves usability and leads to shorter training and improves universal access.

Keywords: Intercultural Human–Computer Interaction, Cultural Adaptive Information Systems, Special Needs, Individual Adaptability.

1 Culturally Influenced Individual Differences in HCI

Culture influences interactions between end-user and computer systems, since the end-user acts within a cultural milieu [26]. Culture is a concept that captures the values and behavior of a group of people in different contexts. It is a "silent language" people use to "talk" to each other without words in an unexplored universe of behavior that nevertheless is taken for granted [11]. The group can be a nation, a region, a team etc. Cultural dimensions are *models* to describe the behavior of the members of different cultures and support quantitative analyses of characteristics of different groups [18]. For HCI, those cultural dimensions are most interesting that directly connect to communication, information, interaction and dialog design i.e. that concern the culturally differentiated concepts of space, time and communication [11]. Space

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and time are influential variables in the communicative behavior of human beings, which, in turn, form the social processes, culture and behavior of a group. Basic types of such behaviors are time handling, density of networks of information, communication speed and the time behavior of action chains. If so, it may be suggested that *variables connected to information science* such as information speed (distribution speed and frequency of information), information density (number and distance of information units) or information order (appearing sequence and arrangement of information) *correlate with culturally basic patterns of behavior expressed by differences in the interaction styles of the individual.* The differences that Hall [11] found in communication speed between cultures add empirical support to the above predictions about human interaction behavior with information systems.

2 Cultural Adaptive Systems

To design interfaces for the global market that adapt to the cultural needs of the end-user requires evidence about different cultural needs and cultural differences at all levels of HCI (surface, functionality, interaction) [12]. Topics such as presentation (e.g. colors, time and date format, icons, font size) and language (e.g. font, writing direction, naming) or dialog design (e.g. menu structure and complexity, dialog form, layout, widget positions) and interaction design (e.g. navigation concept, system structure, interaction path, interaction speed) can all be varied. When a system knows the cultural preferences of the end-user, it adapts to them *to reduce mental workload,* prevent mental distress and increase expected conformity [29]. The objective of cultural adaptive system is the situation-referential adaptation of cultural aspects e.g. of the graphical and the speech interface. For cultural adaptive systems, end-user models can be averaged within a cultural group (e.g. information dimming or multi-modal dialogs) [16]. One method is to observe and analyze the interaction behavior of different end-users and systems by automated analysis tools to determine interaction patterns that reflect individual cultural backgrounds. *Cross-cultural usability metrics* can be derived as a basis of *cultural adaptability* [14]. Two online studies have measured users' cultural preferences: the Intercultural Interaction Analysis tool (IIA tool) obtains automatically quantitative data about cultural differences by simulating several use cases (e.g. of navigation systems).[1] End-users all over the world were invited to interaction tests by downloading the IIA tool from a server. The data from these studies are analyzed by selected test language (Chinese (C), German (G), and English (E)). The results of these online studies revealed differences in interaction behavior that depend on the cultural background of the end-users (e.g. attitude, preference, skills etc.). Some of these significant differences are denoted *cultural interaction indicators*. They represent important differences in culturally grounded end-user interactions [13]. Control variables like age, gender or computer experience did not interact significantly with the cultural interaction indicators, a result consistent with their designation as *cultural interaction indicators*. Computer experience complicates the measurement of cultural interaction indicators regarding interaction speed and frequency. There are many combinations of cultural interaction indicators that can assign end-users to their test language without knowing their nationality (about 80%).

[1] For a detailed description of the test settings and the results please refer to [15] and [14].

This outcome in conjunction with the weak influence of disturbing variables supports the high reliability and criteria validity of the statistical results received in these two studies and the reliability of the IIA tool.

3 Individual Adaptability

Individual adaptability aims to cover the specific, individual needs of the culturally but uniquely imprinted end-user. Every single individual exhibits a specific "culture" (e.g. eating style, walking style etc.), i.e. specific characteristics and behavior as well as specific attitudes and values. Hence, there are many design aspects that can be adapted to the needs of single end-users derived from cultural surrounding. The combination of the most discriminating cultural interaction indicators point to the characteristics of the related group variables: the end-users – grouped by age, gender, or computer experience – as characterized by different cultural interaction indicators. Thus, number of help, number of error clicks and interaction exactness value classify end-users of different age. Experienced end-users can be recognized by interaction speed, uncertainty avoidance value, the number of mouse clicks and the number of open tasks before doing the test. The classification of end-users to their cultural backgrounds requires many more variables than simply age, gender or computer experience. Individual design aspects strongly influence end-user interaction behavior: some end-user groups have their own characteristic preferences for information systems (e.g. beginners vs. experienced, old vs. young people, female vs. male, healthy vs. handicapped end-users requiring special needs) that are influenced by their primary culture. If so, the meaning of the usual conception of *culture* as ethnical determined is extensible to the *individual culture* of the end-user (e.g. individualistic but culturally influenced style of using a device, interacting, typing, driving, etc.). The individual end-user behavior, including aspects such as fast, stressed, hectic, or unsteady use, depends on the cultural influences on the end-user by group membership (beginners, intermediates, professionals, experts), or gender and experience (interaction times, interaction frequencies, etc.) [17]. The data collected contain important information about end-user preferences such as: preferred navigation paths, average speed, using help, short or long sessions, having different interaction breaks. Interaction styles vary significantly (e.g. reasonable, rational, arbitrary, sequentially fast, well-considered, haptic, visual, auditory, linguistic, etc.). End-users with special needs require adequate access (e.g. gearing by hand). By the use of individual models, it becomes possible to individually adapt the interactions and functionality of such systems. Hence, it is time to expand cultural adaptability to individual adaptability by analyzing the individual end-user instead of end-user groups, using the same measuring methodology. Thereby, the principle of cultural adaptive human-machine interaction (HMI) as presented in detail in [12] can be extended to the principle of individual adaptive HMI.

4 Related Work and Proof of Concept

Applying the synergy between individual and cultural factors to interactive system design is, of course, relatively new. However, it is possible to evaluate the validity of this concept through a systematic consideration of a sample of research studies that consider cultural and individual factors in design or which represent relevant prototypes. That is the purpose of this section of this paper, in order to provide proof of concept. There is a substantial movement of research and development in modeling the individual requirements of users, including people with special needs and personality and cultural factors [1]. For this analysis, ten papers were selected from the ACM Digital Library on the basis of "culture" and "system design" as search terms:

1. Oulasvirta, Kurvinen and Kankainen [24] report the "bodystorming" method, i.e. it supports design sessions in the real context rather than the lab. First, easily readable design questions are generated. Design questions capture the events, experiences, and/or practices of users. This method goes to a representative environment, e.g. if studying public transport, designers go to a train station. Participants attempt to solve one question at a time in the actual cultural context.
2. Asokan and Cagan [3]: "Demands for novel and fancy experiences with technology are being replaced by the need to return back to the roots of [..] culture". These researchers employed a tool that supports design to create a balance between cultural factors and technological factors to support meaningful innovations embedded in the roots of cultures, based on long lasting identities of cultures within organizations and countries.
3. Gaver, Dunne and Pacenti [9] present cultural probes as a well established approach to cultural factors. Their cultural probes are made up of packs of different objects and materials and are designed to promote informative responses from people in diverse cultures.
4. Iqbal, Gatward and James [21] investigated cultural requirements for the design of new ubiquitous collaborating systems. They extended ethnographic methods to develop the "Ethno-Model approach" to provide rich, concrete portrayals of the context of use of a system that requires collaboration and communication. This approach combines an ethnographic approach with different types of UML modelling.
5. Duncker [6] provides an evaluation of cultural influences that imply that some system design metaphors are appropriate for some cultures and not for others. This author studied the library metaphor of digital libraries in the cultural context of the Maori of New Zealand, finding out that the library metaphor fails Maori and other indigenous users. Cultural factors influence the development of metaphors.
6. Gasson [8] proposes that system design is a socio-technical process, proposing a social process model for design activity based on a dual cycle of opening up the design problem and narrowing down design solutions. She reported an interpretive, participant observation method for information system design.
7. Evers, Maldonado, Brodecki and Hinds [7] investigated human robotics interaction (HRI) as a growth area where cultural factors are important. We need to understand better how people from diverse cultures respond to such systems. They explored the problems of robot design that assume that Western cultural values are always optimal, varying nationality (US vs. Chinese), in-group strength (weak vs. strong) and human vs. robot assistant as dimensions. Their findings showed that people from different national cultures respond differently to robots, and that predictions from human-human interaction do not always apply.

8. Gaver and Dunne [10] explored the design of public electronic displays to produce meaningful conceptual designs in a local culture for older adults, using cultural probes and experimental studies (see item 3 above).
9. Convertino, Asti, Zhang, Rosson and Mohammed [4] studied cross-cultural collaboration through board-based collaborative systems, with American-Chinese and American-American pairs working face-to-face or remotely. Survey data, video recording, and design products were collected to examine the impact of culture (American-American vs. American-Chinese) and medium (face-to-face vs. remote) on the process and outcomes of collaboration. Results from the survey showed significant effects of these variables on several reliable measures.
10. Suchman [27] points out that ethnography is best seen as an encounter between actors "differently embedded within particular social/cultural milieus". When observers describe a culture, it is not culturally neutral but proposed from a specific cultural perspective. Such descriptions reflect both their own culture and the culture in question. This is not just a problem to be solved but an intrinsic feature of this approach to be respected when taking culture into account.

The above sample of papers shows very clearly, that important new design methods are emerging that can deal with the complexities and challenges of cultural factors in the design of interactive systems. However, it is also clear that no studies have yet to exploit the synergy between cultural and individual factors to the extent proposed in this paper. If the concept is valid, we should be able to identify system prototypes that successfully incorporate cultural issues. Current work has evaluated a quasi-random sample of ten prototypes that purport to reflect important cultural factors. They address a surprisingly varied range of types of prototype and issues. Even allowing for positive result bias, it can be noted that all ten papers report successful prototypes that deal with cultural factors. Moreover, to show the working principle of cultural adaptive HMI, Heimgärtner [17] implemented a demonstrator into an existing driving navigation system: the program is able to adapt the HMI according to the culturally imprinted individual interaction behaviour of the end-user.

5 Problems and Benefit of Individual Adaptability

First, there are general problems for adaptability. Problematically, automatic adaptation (adaptivity) depends on maximal data when observing new end-users: the system needs more data to provide end-user information and to infer the end-user characteristics for information presentation, interaction and dialogs. Since, end-user data can be *misleading or false,* the reliability of assumptions can be a problem [23]. The end-user model must match the system model to prevent unexpected and confusing situations for the end-user. Legal restrictions also have to be taken into account, for example only the effects of end-user actions in an end-user model can be permanently stored, but not the log file of the personalized end-user sessions themselves [5]. Second, without automatic and meaningful adaptivity from minimum data automatically; it remains necessary to investigate standard parameters and their values very early in design-phase, and long before runtime, to integrate them into the system. The system already has corresponding end-user-knowledge (standard parameters) before the end-user's first contact with the system occurs. Before using the system for the first time, it must be adjusted e.g. to the default end-user group (which indicates the main affiliation of the end-user to his preferences (e.g. experienced, beginner, old, young, blind, deaf, etc.) and the corresponding parameters can be placed simultaneously as standard parameters for the desired preferences. Thereby the adaptive system also obtains adequate characteristics of the end-user more quickly at runtime, because there is "more time" to collect the specific data for the end-user, since a basic adaptation to the most important end-user preferences has already been performed before runtime (by putting the standard parameters into the system). Hence, designing an appropriate system according to the end-user in the design phase helps to avoid the problems rising from adaptability.

6 Conclusion

The benefit of individual adaptability lies in the reduction of end-user workload by recognizing their individual expectances of the system, to improve the usability of the system [22] by adapted end-user and system models, shorter training times by fast adaptation by the end-user. Furthermore, the resulting effect of improved usability [19] by individual adaptability is that many more end-users can to use the same systems more easily and with improved satisfaction that, itself, contributes immensely to universal access [17]. End-users do have individual preferences that are culturally influenced: the cultural background of the end-user determines the interaction of end-user and system. There are many different groups of end-users, which exhibit their own "culture", including international level (e.g. countries), within the national level (e.g. social, ethnic groups) or even at the individual level of "one's own culture". A study with a tool for cross-cultural human computer interaction analysis revealed different interaction patterns according to the cultural background of the end-users regarding design (ample vs. simple), information density (high vs. low), menu structure (high breath vs. high depth), personalization (high vs. low), language (symbols vs. characters) and interaction devices [14]. These results are confirmed by qualitative studies e.g. [28]. The cultural differences in HCI were found by using *special combinations of cultural interaction indicators* that are *statistically discriminating enough* to enable computer systems to detect different culturally imprinted interaction patterns automatically and to relate end-users to a certain culturally imprinted behavior. This *cultural adaptability is made possible*. Moreover, this principle of cultural adaptability can be extended to the principle of *individual adaptability* as every individual exhibits cultural influences. Enhanced algorithms using methods of artificial intelligence are needed to enable the system to automatically and correctly adapt itself to the individual imprinted needs of the end-user to bring the "mental model" of the system in accordance with the end-users' mental model because interaction patterns are only recognizable over time. *The adaptation of the system to the individual expectances by observing and analyzing the interaction behavior of the end-user with the system leads to a better match of system with end-user model which necessarily supports system usability and hence, helps people with special needs.* To design individual adaptive systems, formation principles have to be taken into account to hold the mental workload of the end-user as low as possible [25], [29] and to broaden *universal access* [17]. The near-term objective is to apply more enhanced techniques using statistical and data mining methods as well as semantic processing to extract the *individual variables* and its values from the interaction pattern data. The mid-term objective is to analyze and evaluate the data in more detail to generate several algorithms for adaptability based on neural networks as well as structured equal models. The long-term objective is to develop a demonstrator and to evaluate the acceptance of *individual adaptability* qualitatively using intercultural usability tests [20] with many different end-users with special needs. Additional studies that are much more detailed must show whether or not changing the metrics of potential individual interaction indicators (or using them in other situations, use cases or circumstances) will improve their discriminating effect and yield appropriate values accordingly to show the *general validity* of some individual interaction indicators.

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