From Cloud Computing to Mobile Internet, From User Focus to Culture and Hedonism
The Crucible of Mobile Health Care and Wellness Applications

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Abstract

With the rise of mobile Internet and cloud computing new ubiquitous medical services will emerge coinciding with changes in demographics and social structures. Mobile e-health and wellness applications can help relieving the burden of accelerating health care costs due to aging societies. In order to leverage these new innovations a holistic approach must be considered. Facilitating user centered design, acceptance models for user diversity and cultural as well as hedonic aspects can lead to development of services that improve therapy compliance and can even change the youth's lifestyle. An overview of such applications is presented and put into a cultural context.

Keywords: Health Care, Mobile, Wellness Applications, ICT, Hedonic Aspects, Acceptance.

1. Introduction

Future "killer applications" of tomorrow's mobile information and communication technology (ICT) will not be hardware or software but social practices and compatible infrastructure services provided by clouds. Far reaching changes in technology will emerge from relationships, enterprises and communities. Within a decade the major population centers of the world will be saturated with microchips built into different forms of computers that will be able to communicate with each other. Some will be in mobile phones, some in designated health care devices, some in laptops, and others in stationary computers linked over the Internet into a super cluster of interconnected devices – the cloud.

Cloud computing is a remote, Internet-based computing, which provides shared resources, software, and information to computers and other devices on demand. When using a cloud for a scientific computation for example, a researcher can remotely connect to a cloud on the internet, perform complex calculations and obtain the results on a web browser. All technical details are abstracted from the user, eliminating the need for expertise in, or control over, the technology infrastructure "in the cloud" that supports them. It denotes a paradigm shift away from current desktop-based computing to using software as a service accessible by stationary computers and mobile devices alike. Especially smartphones with Internet connections will provide pervasive access to cloud services, blurring the boundaries between the physical and digital, allowing personalized and ubiquitous healthcare services.

Over 1.2 billion mobile phones were sold in 2009 with a 20% share of smartphone sales Germany already has 128.5% mobile phone subscriptions in regard to its population in 2008 [1]. As mobile phones become as computationally powerful as traditional computers, they will be able to see, read, hear and understand human language. They will know where you are, where you have been, what you have consumed and, of course, who you know and how often you communicate. Never has more data been recorded and aggregated than today. And a reversal in that trend seems very unlikely.

Interconnection of basal services provided by different vendors, hardware and ways of distribution will weave a net of personalized and ubiquitous support, which will guide and enhance overall decision making processes. Some of them will be for entertainment, some for ease of living and others will help protect your health or regain social connectedness and mobility through virtualization of yourself.

Let's take electronic/personal health records (EHR/PHR) in the US as an example: with 74% of all US adults being online [2] and all the promising advantages of switching to digitally managed EHR/PHR in cloud based services – such as cost reductions, data security, redundancy, privacy and availability – it is not surprising that there is a multitude of investment and companies jumping into this fast growing market. With a public expenditure of roughly 20 billion USD to promote the adoption of EHR/PHR systems, there are currently over 300 different EHR/PHR systems available in the US [3]. Even with

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this multitude of available systems, EHR/PHR systems still struggle with problematically low adoption rates, reaching only about 1% of the online US population in 2008 [4]. Cost factors and poor usability have been cited as the biggest obstacles. One research institute comments the low adoption simply with: “Most PHRs are Garbage” [4], emphasizing also the missing user centrism in the design of those systems.

But not only does penetration of ICT rise in our society, the biggest inevitable change will be the change of age distribution in all modern cultures.

1.1. The need for user centered design

A permanently increasing life expectancy, a generally improving health care for citizens combined with a severe decrease in birth rates has lead to a state, where all first world societies have more and more old and frail people who will need medical care in the near future, while at the same time the amount of people being able to take care of medical tasks and nursing has relatively dropped. This has created a considerable medical bottleneck, which will narrow independently of an improbable change in causes [5, 6]. Usage of electronic devices assisting medical staff and patients alike promises a relief for health care expenditure and affected people.

Usage of electronic devices is also becoming decreasingly voluntary because of either work or everyday life requirements (e.g., [7, 8]). This impact will be even stronger concerning medical appliances of mobile devices. Since the increase of age related illnesses like diabetes or chronic heart disease accompanies both demographic change and sedentary lifestyle, medical care and age appropriate independent domestic care can only be economically realized through technical solutions (e.g., [6]). Innovations in information and communication technology in combination with future developments in medical engineering, offer novel or improved chances for medical diagnosis, treatment and rehabilitation [10, 11].

Designing such solutions in a self-explanatory and usable way for heterogeneous user groups has not been realized to date [9, 12, 13]. Acceptance barriers are still prevalent, as device development is predominantly technically-oriented and criteria of usability and learnability are mostly applied subordinately, if at all [14]. This is directly related to the development of these devices through computer scientists and engineers, and lack of harmonization with psychological and ergonomic knowledge of necessities, capabilities and cognitive structures of the end users. Full facilitation of e-health applications requires consideration of acceptance and usability issues, especially for older users’ specific needs and requirements. [15, 16, 17].

Aging populations are not the only challenge for our health systems. Another important issue is the poor general state of health of young people. Based on a recent OECD study (see [18]) additional costs for the Austrian health care system will be at 3.9 billion Euros in 2050 [19]. This trend will not only lead to increased costs in health care, but it will also result in a lack of available manpower in the job market. One possibility is to reallocate this money to preventive measures. One such measure can be to promote a permanent change in lifestyle and health-awareness by providing motivating incitements and enabling self-observation through the use of wellness management [20]. This approach also complies with the description of the health continuum [21], which emphasizes the advantage of proactive management of health and illness instead of reactive action and also encourages the provision of knowledge and tools for self-management.

While “mainframe healthcare” will surpass the threshold of scalability and feasibility within the near future, personal wellness technologies can scale with the needs of an aging population. They can also drive a demanding specification for the requirements of ubiquitous, proactive computing in everyday life [22].

2. Cultural Requirements

Cultural differences in handling technology or communicating ease of use can lead to problems during development if they are not considered pre-emptively. In order to gain insight into the impact of cultural differences in usability research for mobile health care devices a survey in three countries (Germany, Poland and Turkey) has been performed. A selection of some preliminary results is presented here.

2.1. Method

In the aforementioned survey several factors were assessed using a 4-point Likert-Scale as well as detailed demographic facts about the participants. The participant’s perceived ease of use (PEU) for everyday technology (each four questions) and perceived ease of use of functions of mobile phones (nine questions) were assessed. Questions like “Do you find using the calendar on your phone easy?” were used and the answer keys ranged from “strongly agree” (=1) to “strongly disagree” (=4). Furthermore, reasons for and against possible usage of medical technology in general were surveyed (nine questions each like “I would use medical technology because it would make me feel safer.”). Lastly determining factors for a mobile assisted living device, regarding concrete design options – integrated or as a separate device – aspects were assessed (nine categories with 6 questions each).

2.2. Participants

The study was performed with 219 participants from Germany (N=42), Poland (N=110) and Turkey (N= 66). The participants ranged from 19 to 83 years (M=50.57, SD=14.804) and were 89 males and 130 females. An effort was done to keep the age distributions similar over all countries, although polish participants were significantly younger ($M_{Germany}$ = 43.42, $SD_{Germany}$ = 15.561, M_{Poland} = 44.8, SD_{Poland} = 14.1, M_{Turkey} = 58.32, SD_{Turkey} = 11.71).

Correlational analysis of age and technical experience showed a highly significant negative relation ($p<0.01$) between perceived ease of use and participants' age in regard to computers ($r=-0.51$) and mobile phones ($r=-0.44$) and confirms earlier research.

2.3. Results

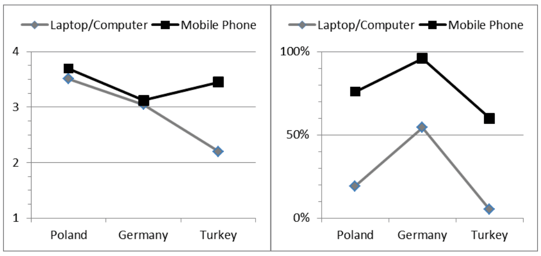

Figure 1. Means for perceived ease of use (PEU) for PCs and mobile phones (left); market penetration of PCs and mobile phones for 2005 (right)

Generally participants from Poland and Turkey differed to a bigger extend between each other than between themselves and participants from Germany. Strong differences were found between perceived ease of use of computers and mobile phones (see Figure 1). These differences in means are highly significant ($p<0.01$) and were analyzed by ANOVA and Bonferroni testing and MANOVA controlling for age ($p<0.01$). Possible explanations lie in market penetration of these devices, which greatly differ between the countries (compare Figure 1)[1].

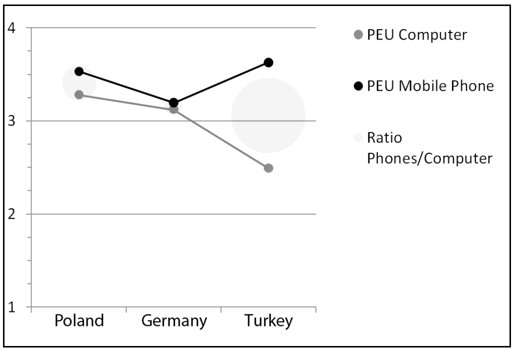

Figure 2. Estimated marginal means for perceived ease of use (PEU) for laptops/computer and mobile phones and ratio of mobile phone: computer penetration (bigger circle reflects higher ratio and thus more phones per computer)

When looking at the ratio of penetration of mobile phones to penetration of computers, an insightful picture emerges (see Figure 2). Performing a spearman rank analysis with the differences between perceived ease of uses of mobile phones and computers, a highly significant and very strong correlation is found ($r=1$, $p<0.01$) even when controlling for age in MANOVA analyses (see Figure 2).

Furthermore differences were found when looking into the reasons for or against usage of medical technology. When looking at arguments against usage of medical technology participants of all countries were mostly in agreement (see Figure 3). The only exception is the reason "The usage is too complicated" ($p<0.01$) which Turkish citizens in particular were more worried about.

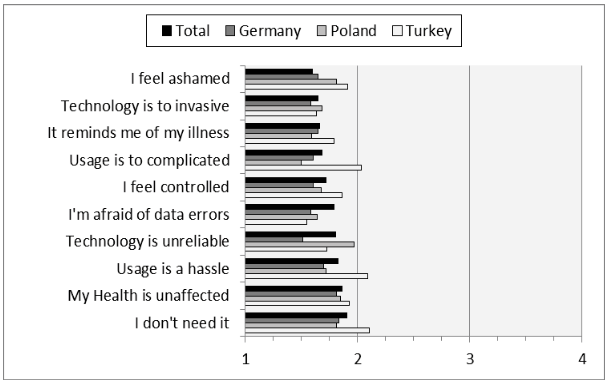

Figure 3. Reasons against general usage of medical technology (1=strongly disagree, 4=strongly agree).

When considering arguments for the usage of medical technology, reasons greatly differed between all countries ($p<0.01$). The only reasons that showed no difference in means are "Better Mobility", "Feeling safer" and "Having to go to the doctor less often" ($p<0.01$) (see Figure 4).

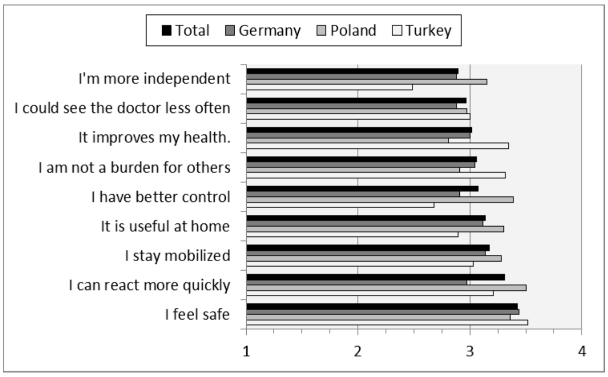

Figure 4. Reasons for general usage of medical technology (1=strongly disagree, 4=strongly agree).

Most surveyed participants where strongly against the implementation of an integrated device (medical device within a cell phone) and preferred a dedicated device for medical aspect. Biggest determining factor for this effect is expertise with mobile phones. The more a user is comfortable using a mobile phone, the more she/he is likely to accept an integrated device ($r=0.285$, $p<0.01$). A similar factor associated to this is the participant's age. The older the user is the less likely will she/he like an integrated device ($r=0.18$, $p<0.01$).

3. Mobile Living Assistants

Mobile devices that support their owners in their everyday lives – or so called mobile living assistants – can and independence of immediate medical care personal. By that, mobile living assistants can relieve substantial costs of the strained health care budgets.

These mobile devices are designed to be in line with users' specificity and diversity. Nonetheless designing an intelligent interface for a mobile device, which complies with demands and suits the ability of especially older users with chronic illnesses, remains an extremely sophisticated task, since aging is a highly complex and individual help elderly or illness-affected users to live independently at home. They are often used to accompany persons in keeping track of their health, reminding of medication, and collect information for therapy customization. All this is aimed at greater comfort, increased therapy compliance process in itself. Humans age considerably different in regard to onset of age-related degradation and to the extent of these consequences. Design approaches should take the user-perspective seriously [23, 24, 25, 26]. This includes research of behavior of adults with current technology and of user abilities, which affect interaction with mobile ICT.

Miniaturization of mobile devices contributes to occurring usability shortcomings. In addition to handling and visibility issues, restricted screen real estate allows only few information chunks to be synchronously displayed at any time. This increases short term memory load in the brain, a scarce resource. Beyond that, orientation in small-screen-menus is complicated because users are unable to elicit "spatial" structure and arrangement of menus and facilitate this information for navigation [9, 12, 27, 28, 29, 30, 31]. Disorientation can occur when hierarchically structured menus resemble complex and large trees in respect to both depth and breadth [27, 32, 33].

Changes in sensory, physical, psychomotor and cognitive functioning over the life span are profound and well known [34]. These changes may explain some of the older users' decrease in performance with technical devices as well as different technical penetration during their upbringing and thus a resulting lower exposure to modern technology. This circumstance leads to lower technical understanding and less computer experience and usage in older users, and naturally this paves the way to only limited computer knowledge [35, 36, 37]. However, it was found that age-related decreases could be compensated by expertise (e.g., [38, 39]). Thus, performance of older adults can be just as good as that of younger adults when they can rely on elaborated domain-specific knowledge.

Mobile living assistants that are developed for portable runtime environments blend in into the ecosystem of different hardware access-points to cloud based health care services, because they provide a unique, portable and customizable interface that can be integrated into already existing technology such as mobile phones, PDAs, Tablet PCs and stationary PCs. Each of these systems can provide a context-adaptive and user dependent view on health care data.

Mobile phone adaptations are suited especially well; because users have a willingness to spend money on mobile phones that is dramatically higher than their willingness to spend money on a health care device, like a standalone diabetes small-screen-device for instance.

3.1. Diabetes Living Assistant

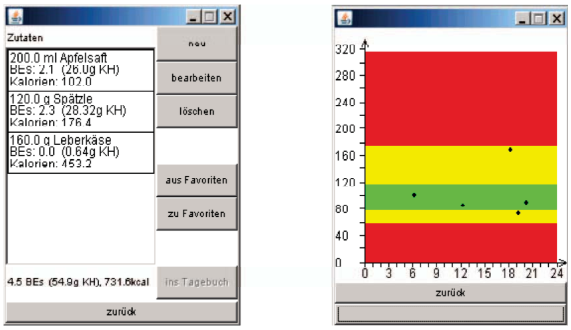

Figure 5: Bread unit calc. (left), the plotter showing overview of the blood sugar concentration (right)

For a successful diabetes therapy, a strict monitoring of blood glucose level is critical in order to regulate it by applying insulin or other medication. 61% of diabetes patients in Germany are using a diary to record their values; 91% of these are keeping their diaries on paper. Furthermore is it important to teach the patients a basic knowledge of the nutrient contents of groceries. Especially patients who inject insulin need to calculate their drug dosage on the basis of the food they consume. Most people weigh the ingredients and then look up the bread units (BU) per gram in a nutrition table to calculate the total bread units for their diabetes diary.

The DiabetesLivingAssistant [39] is a diabetes management program for mobile devices. It includes a diabetes diary, health parameter tracking, a BU-calculator and a calendar based reminder tool for medicine intake (see Figure 5). Tracked key health values can then be graphically visualized for analysis purposes. The diabetes diary goes beyond simple tracking and logging of glucose readings and food intake. It is able to suggest adjusted insulin dosages in regard to current glucose measurement, activity level and planned eating, thus simplifying the patients tedious calculations for everyday insulin administration. BU-calculations are to a great extent performed automatically by allowing users to store and retrieve favorite dishes for use in their personal diary. In order to ease switching from paper-based tracking to a mobile device, user interface layouts are based on commonly used paper-based diabetes diaries (see Figure 6).

Figure 6. The paper version of the diary (left) and the diary function of our application (right)

Acceptance testing of a prototype of the DiabetesLivingAssistant yielded good acceptance rates not only on a mobile device [39] but also in a simulated AAL-Environment [40] from young and elderly participants that were either diabetes-affected or healthy.

3.2. Future Care Lab and Heart Mate

Figure 7. Simulated home environment of the future care lab

The Future Care Lab is an experimental space for studying users' "life" at home and examining how they interact and communicate with invisible technology [41]. Developed in a multidisciplinary and user centered design process, the lab enables the exploration of future homecare environments to define crucial technical and medical requirements needed to satisfy fundamental user needs regarding data protection, dignity, and intimacy.

The lab consists of a simulated home environment (see Figure 7) and provides an intelligent healthcare infrastructure, consisting of different integrated and mobile devices to support elderly people in technology-enhanced home environments [42]. Devices should be perceived as personally helpful, supportive, safe, and secure and should evoke feelings of trust and reliability, while at the same time respect patients' desire for intimacy, independence, and dignity. In addition, the way devices are communicating with their owners must be easily understandable at any time. Devices are conceptualized as context-adaptive, smart and immersive. Thus, they are not only communicating with patients, but also with the environment (furniture, floor, mobile devices), family members, doctors or emergency personnel (see Figure 8).

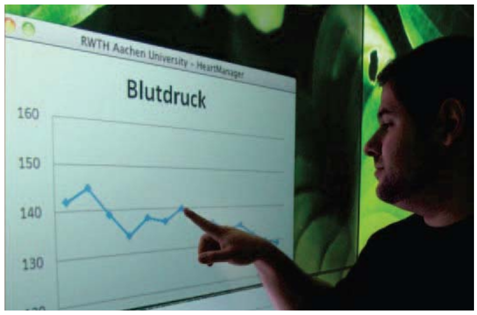

Figure 8. Interaction between the display wall and a patient while browsing blood pressure measurements.

An integrated set of smart sensor technologies provides unobtrusive monitoring of a patient's vital health functions, such as:

- a smart floor, providing location tracking of multiple persons, fall detection and weight measurement,
- an infrared camera, for noninvasive temperature measurement, and
- measurement equipment which is naturally integrated into the furniture, such as blood pressure or coagulation measurement devices.

Centerpiece of all human computer interaction inside the future care lab is the 4,8m x 2,4m big multitouch-capable display wall. As the central element of the room, its unusual size promises new and natural interaction possibilities, rendering traditional interaction concepts obsolete. Remote interaction mechanisms, for example for supporting immobilized patients, could include a sensible mix of voice control, visual gesture recognition and/or mobile devices (see Figure 9).

To study age-sensitive concepts for assistive medical technologies inside a living environment, the support of elderly patients with chronic heart disease is being observed, due to the high clinical demand, recurrent hospital stays, high morbidity, and mortality of this illness. The main issues addressed within the project are the systematic evaluation and consecutive optimization of the interrelation of medical, environmental, technical, architectural, communicative, psychological and social factors and their consequences for the design, use and acceptance of personal healthcare systems [41].

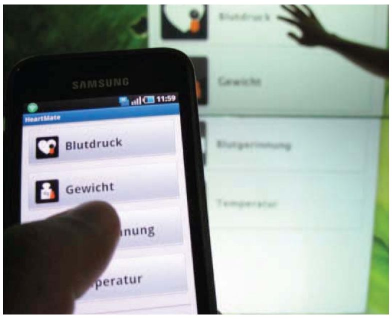

Figure 9. Concurrent wall display and remote smartphone interaction.

4. Wellness Applications and Hedonism

4.1. Wellness Applications

Research in the field of health informatics has been very prominent during recent years. While patients are generally seen as a source of data and the healthcare systems as end users of applications in this area, we can now see a new area of informatics that tries to reverse this flow [43]. Personal Health Applications allow their users to store a wide variety of personal health information and data ranging from medical conditions and test results to medications and allergies. Among the most prominent of these applications are Google Health, Microsoft HealthVault and LifeSensor.

The increasing availability of smartphones and the accompanying popularity of online software stores including Apple's App Store or Google's Android Market have made mobile devices a popular platform for personal wellness applications. Diary applications like Wellness Diary [44], UbiFit Garden [45] or Absolute Fitness support the management of health related, dietary, and exercise data as well as the setting and tracking of personal goals. Some applications utilize sensory data like pedometers or GPS receivers to track outdoor sports activities. Gesture-based technologies and the integration Web 2.0 like social networking or social gaming still offer very interesting possibilities for the further development of wellness applications [46].

4.2. Hedonistic Aspects

In addition to these mentioned technological aspects, the usage and success of such applications strongly depends on the consideration of human properties, namely cognitive, affective, and motivational aspects. The demands and cognitive abilities of a broad and diverse user group should be met and supported by intuitively usable interfaces. As the main goal of wellness applications, promoting a healthy lifestyle, depends on continuous and long-term usage, wellness applications should be developed in a way that users want to use it and should include emotional or affective designs. Thus good interface design should not only focus on mere functional aspects, but should also include hedonic aspects aiming at the user's well-being, pleasure and fun [20, 46].

A set of design strategies for technologies that aim to support behavior change was proposed by [47]. Starting with four design goals that were suggested by [48] in their breakaway project, they added four additional design goals based on behavioral theories and social psychological theories. These design strategies also take into account hedonic aspects of wellness applications. The following list describes these goals and examples on how they could be obtained:

Abstract & Reflective: Raw data should be displayed in an abstract way, allowing users to reflect on their behavior. Instead of just showing plain numbers, collected information could have visual effects on a virtual avatar, changing its shape and showing additional icons.

Unobtrusive: Instead of forcing itself upon the user, the data should just be easily available when needed. Modern web applications offering rich graphical user interfaces can be accessed from a variety of mobile devices without requiring a download or installation procedure.

Public: Unwanted disclosure of personal data to others must be avoided. Web applications cannot be seen as icon and therefore avoid curiosity. Personal logins are also a common way of preventing others from accessing data the user doesn't want to share.

Aesthetic: Personal aesthetic preferences should be taken into account. The high usability potential of rich inter application (RIA) technologies, together with the easily customizable look & feel offered by Cascading Style Sheets (CSS) can combine comfort with adaptability to personal aesthetic preferences.

Positive: Encourage users with positive reinforcement and avoid negative reinforcement. Personal goals and rewards for reaching them have already been employed in several wellness applications.

Controllable: The user should be able to modify the managed data and control access to it. Even applications making use of a lot of sensory data should allow their users to edit this collected data.

Trending / Historical: Access to historical data and goals should be available to see trends and changes. Easily understandable visualization of longitudinal data can be employed to show historical trends [49].

Comprehensive: Data collection should account for the multitude of different types of data; user might want to manage and should not be limited into too strong limits. Applications should not rely solely on sensory data, but also allow users to manually enter and edit data.

5. Conclusions and Discussion

Cloud based health care and wellness applications will have to prove themselves in the future. Individual solutions that have successfully integrated important requirements have already been developed, but hardly any of those manage to integrate all facets of interdisciplinary research into their approach.

Putting the focus of development onto the user of the application has to go along with a widening of the focus as well. As the border of computation and interface blurs, further aspects need to be integrated into the development approach. A pervasive look onto the user must no only reveal aspects of usability and cognitive compatibility but also socially acceptable practices within the cultural environment of the user.

Crucial aspects of electronic health care applications will not only be their ubiquitous availability but also their ability to be integrated into social dynamics with respect to cultural differences and individual preferences. They will have to be usable by a diverse user group, populated by users stretching over an age span of almost a century. These users all share a common yearning for beautiful, aesthetic and usable interfaces. Designing against hedonic requirements can change the users' perception from obligation to desire.

Not only does therapy compliance depend on measurable and predictable acceptance but also whole cultural developments. Wellness applications that teach younger users a healthier and more mobile lifestyle will inevitably change how a society sees itself and what it values, not by coercion but by attraction. A holistic approach to development of e-health and wellness applications is required to create sustainable solutions for the global challenges of the upcoming century.

5.1. Limitations of this study

Cultural aspects of mobile ICT acceptance need to be looked into to ensure predictable roll out of international cloud based health care services. In this regard the presented results only offer insight into three selected countries and very few aspects. Especially the correlational relationship of market penetration and perceived ease of use needs further validation and more data points. Further research should offer insights if correlations like this prove themselves to be valid in other countries as well as in regard to other aspects in order to be able to plan ahead in e-health application distribution and development of a holistic approach.

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