TOUCH'N'DOCUMENT

A nutrition management system on an NFC-tagged TFT-display

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Keywords: Telemedicine, Near Field Communication, Electronic Data Capture, Nutrition Management

Abstract: Self-reporting of patient data is a valuable tool for data capture in clinical trial studies and to support ailment treatment. However, traditional paper-based self-reporting is cost- and time-consuming and consequently suffers from low patient compliance. NFC-based electronic data capture methods allow a quick and easy self-reporting for patients and the real-time presentation of patient data enables direct medical intervention by physicians. Malnutrition, for example can be attenuated by continuous medical supervision of nutrition data. Consequently, we introduce an NFC-based prototype system called Touch'n'Document (TnD) that supports automatic aggregation and measurement of self-reported nutrition status. The hardware of TnD consists of a TFT-display that was outfitted with an array of NFC-tags on the backside. These allow an NFC-enabled mobile phone to be used as an input device to any software system, running on the TFT-display. The patients simply have to touch the display with their mobile device to log into the system and report and analyze their current nutrition. This ensures an adequate usability of the nutrition management system, especially for non tech-savvy or physically impaired patients, consequently increasing patient compliance. The technical feasibility, benefits, limitations and future research prospects of the prototype system are discussed in this manuscript.

1 INTRODUCTION

Patients suffering from chronic diseases, e.g., dementia, Parkinson´s disease, motor neuron diseases, such as amyotrophic lateral sclerosis (ALS) and Multiple Sclerosis or spinal and bulbar muscular atrophy (SBMA), often have to cope with limitations and a reduced quality of life. In particular, patients diagnosed with a motor neuron disease suffer from progressive paralysis. Therefore patients are seriously affected by an insufficient dietary intake which in the long run leads to an (unnoticed) reduction of weight due to malnutrition or cachexia (Cleveland and Rothstein, 2001). The loss of weight is affiliated with high morbidity and mortality, and negatively affects the quality of life (Desport, Preux, Truong, J. M. Vallat, Sautereau et al., 1999) of patients and family members. Due to medical complications and social consequences, malnutrition and cachexia are of significant socio-economic importance (Ludolph, 2006). In many cases, supplementary nutrition by increased calories or the use of percutaneous endoscopic gastrostomy (PEG) tubes for enteral nutrition becomes inevitable in the course of most motor neuron diseases. This intervention not only causes a dramatic decrease in patients' quality of life (Löser, Lübbers, Mahlke and Lankisch, 2007) but significantly affects personal, logistical and financial expenditures for service providers, as well as insurance and funding agencies. The total financial impact on the German public health and welfare system caused by malnutrition is estimated to 17 billion Euros while the annual costs for enteral nutrition amount to a total of approximately 15,000 Euros (Löser et al., 2007) per patient and year. This estimation excludes additional costs of complex care expenses which result to total expenditures of 50,000 Euros per patient and year (Schauder, 2006).

In order to guarantee highly qualitative treatment procedures, attending physicians need to be adequately supplied with information regarding their patients' actual state and well-being. The differing logistic challenges of capturing, archiving, analyzing and interpreting health status information in routine clinical practice are well recognized (Wolfe and Pincus, 1995). For patients with impaired motor control, resulting from chronic or motor neuron diseases, this implies an even greater challenge, as patients are usually living at home and relevant contemporaneous information supporting the therapeutic decision-making is not available in real time.

Therefore, the objective of our work is to provide a simple, effective and efficient electronic data capture (EDC) system, which can be used by patients with impaired fine motor skills by using a mobile phone implementing Near Field Communication (NFC) technology. NFC is an extension of the ISO/IEC 14443 (ISO/IEC, 2000) proximity-card standard (such as contactless card, RFID, etc.) that allows data exchange between devices that are about four inches apart.

The motivation for the underlying prototype derives from the unobtrusive integration of applications following ambient assistant living (AAL) concepts into everyday life environments- enabled by radio frequency identification (RFID) - for the purpose of real time and accurate data collection. RFID technology features seamless and non-intrusive integration of novel applications and services into everyday life environments (Köbler, Koene, Goswami, Leimeister and Krcmar, 2010, Köbler, Koene, Krcmar, Altmann and Leimeister, 2010, Leimeister, Knebel and Krcmar, 2007, Resatsch, Sandner, Leimeister and Krcmar, 2008, Uhrich, Sandner, Resatsch, Leimeister and Krcmar, 2008) and thus supporting AAL environments. In addition, mobile networks allow a flexible, location-independent monitoring of the patients in real time. An intelligent EDC system thus can improve productivity of medical processes not only by being more cost efficient, but also by accounting for improved standards of medical care as well as quality of life.

In the subsequent chapters we will first give an overview of related research on NFC technology and EDC methods, used in clinical trials, patient care and AAL scenarios. We then elaborate on the Touch'n'Document (TnD) prototype system, its functionalities, application environment and technical implementation, along with a potential use case scenario. The benefits of the proposed system for patient self-reporting and EDC in ailment treatment are presented. We close with a discussion of the contributions from this research, its implications and the derived recommendations for future research on contactless electronic capture of self-reported patient data for different use cases (e.g., fitness and dietary programs).

2 RELATED WORK ON EDC IN HEALTH CARE

A vast number of literature elaborates on various occurrences of EDC for the acquisition of quantitative and qualitative data in surveys (Bischoff-Ferrari, Vondechend, Bellamy and Theiler, 2005, Blake H., 2008, Dale and Hagen, 2007, Palmblad and Tiplady, 2004, Richter, Nixdorf, Koch, Schneider, Becker et al., 2006). A number of studies (El Emam, Jonker, Sampson, Krleza-Jerić and Neisa, 2009, Hyde, 1998) document the basic advantages of EDC in panel surveys and trial studies, which are the decrease in costs and increase in data quality due to the digital form of data collection.

Another set of advantages of EDC are brought to bear within the domain of clinical and population sciences, including medicine, health-care, health services, epidemiology and demography. These areas of research often "depend on self-reported states, characteristics and behaviours" (Stone, Shiffman, Atienz and Nebeling, 2007) of patients in order to understand, e.g., disease progression, treatment outcomes or gerontological requirements. Self-reporting is described as "the only window on the inner states" (Schwarz, 2007) of patients. In comparison to traditional, paper-based questionnaires, the application of EDC for the self-reporting of patient data is shown to increase the patient´s compliance, since it "has the potential to dramatically reduce the time taken to acquire (…) data" (Nyholm, Kowalski and Aquilonius, 2004). Electronically captured, self-reported patient data can furthermore be compiled in real-time and thus provide cues for possible medical interventions (Velikova, Wright, Smith, Cull, Gould et al., 1999).

Clinical trial studies, an area of widespread EDC application, currently see a noticeable trend going from remote, web-based data entry by the patients or care-personnel to a direct capture of the data using barcode scanning, or most recently, NFC or RFID tags. This allows further improvement of generated data quality and enables cost-reduction (Hyde, 1998, Morak, Hayn, Kastner, Drobics and Schreier, 2009, Smith and Offodile, 2002) . The application of RFID technology for data capture in retail business processes, solving complex tracking and tracing problems of objects within the supply chain, is well documented (Fleisch and Thiesse, 2007, Knebel, Leimeister and Krcmar, 2007, Loebbecke and Palmer, 2006, Murphy-Hoye, Lee and Rice, 2005). More recent publications also describe the employment of RFID-based EDC for marketing purposes, either from a consumer and retail perspective (Resatsch, Karpischek, Sandner and

Hamacher, 2007) or focusing on the generation of media usage data, vital to for publishers and advertisers (Koene, Köbler, Burgner, Resatsch, Sandner et al., 2010).

Employing NFC technology for the capture of self-reported patient data in disease and ailment treatment is an emerging practice without widespread application. Fikry (2006) and Morak (2009) employ NFC technology for the collection of medical data in hospitals. Their systems envision hospital personnel touching medical devices with NFC-enabled mobile phones for the purpose of data capture. The prototype system, described by Lahtela (2008) is an NFC-based solution for the control and distribution of medication in hospitals. The data acquisition with the mobile device is conducted in these systems exclusively by health-care personnel and only within medical facilities, limiting their suitability for long term disease and ailment treatment that commonly involves patients, residing at home. However, Iglesias (2009) describe a NFC-based health monitoring system for elderly patients, that can be conducted as a self-management process, using mobile communication technology at home. The authors concentrate however, on the capture of vital signs and parameters like weight or blood pressure with their proposed system solution and exclude self-reported, subjective patient data. A similar concept with similar limitations is developed by Morak (2007) for the monitoring of heart failure patients.

Few research projects focus on the support of ailment treatment through electronic capture of self-reported patient data on disease progression (Nyholm et al., 2004), quality of life (Velikova et al., 1999) or nutrition management (Denning, Andrew, Chaudhri, Hartung, Lester et al., 2009, Jarvinen, Jarvinen, Lahteenmaki and Sodergard, 2008, Siek, Connelly, Rogers, Rohwer, Lambert et al., 2006). Nyholm et al. (2004) and Siek et al. (2006) implement EDC systems by employing mobile communication technology, highlighting the increased patient compliance, when compared to paper-based self-reporting, and the convenient, real time access to patient data for medical personnel. However, none of those research projects tap into beneficial effects of NFC technology on the usability of mobile applications.

Therefore this research paper presents the Touch'n'Document (TnD) nutrition tracking prototype application for patient self-reporting via NFC technology. The TnD prototype is designed to enable easy and highly usable electronic self-reporting of patients´ nutritional data with the goal of providing cues to physicians for possible medical interventions in between practice appointments.

3 THE TOUCH'N'DOCUMENT PROTOTYPE SYSTEM

Before we outline the technical solution of the nutrition management prototype system, we will describe the application environment, use case, basic features and functionality of the prototype.

The application environment for the conceptual prototype builds on GSM cellular phones equipped with NFC antennas, mobile internet broadband connectivity enabled through EDGE or UMTS technologies and sufficient display measurements. These mobile telephones interact with NFC-tags (e.g., Mifare Ultralight, Standard 1k and DESfire) attached to the backside of the screen of a standard TFT-display in combination with a personal computer equipped with Internet connection. The personal computer is connected to a web server, running the nutrition management system.

3.1 Use Case Scenario

In the following a use case scenario for a possible employment of the presented TnD prototype or similar applications is outlined:

Several months ago, John was diagnosed with spinal and bulbar muscular atrophy (SBMA), which started with a hypotension and atrophy of his musculature in his upper legs and hip area. In addition to the diagnosis, John has shown a tendency to be overweight since his adolescence. His attending physician, Dave, advises him to reduce his weight by a long-term adjustment of nourishment to cholesterol-low whole food. Dave knows that in some cases of SBMA, patients tend to resort to extreme measures to control their body weight, e.g., starvation diets and fasting cures, which can be potentially dangerous for the patient and should be avoided. In a therapy session, Dave reports to John about a new nutritional management system (TnD), featuring the simple and uncomplicated possibility of recording and analyzing daily nourishment. The physician devises a nutrition plan, setting and documenting daily lower and upper limits of calorie and cholesterol intake within the TnD system. Although John has never been interested in technical equipment in his life, he is fascinated by the non-intrusive integration of this new system: all functionalities are operated from his mobile phone by touching an NFC-tag equipped TFT displaying food icons. Touching the screen twice is sufficient to send nutrition data to the system, which is then processed for the attending physician and patient. Dave has set a minimum and maximum limit for calories within the system. This enables the system *to warn the physician, patient and care giver of a possible malnutrition or supernutrition of the patient. Through the constant supervision and guidance from his physician, enabled by the TnD self-reporting, John was able to continuously reduce his weight over the last months.*

A potential prototype system and its implemented functionalities that support the described health care environment are described in the following chapters.

3.2 Prototype Functionality

The current prototype system provides a simple set of features:

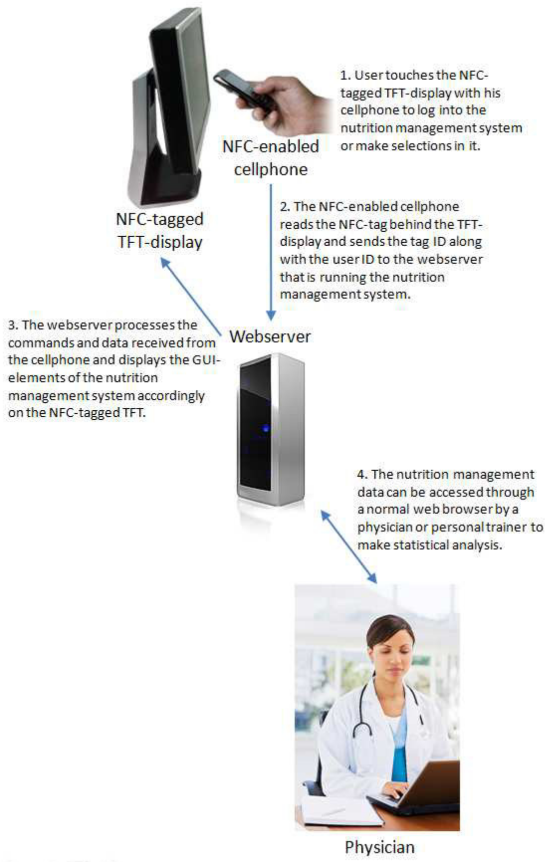

Figure 1. Interaction Process of the TnD prototype system

1. The user can log into the nutrition management system and can operate it through a simple touch-based interface. She uses his cell phone to touch the specific area on the TFT-display and her cell phone gives a short haptic and visual feedback that the control-input was successful.
2. The nutrition management interface allows her to select different kinds of food and amounts in order to specify and log her food intake. For the sake of an intuitive user interface and a quick interaction, the selection of food will be example-based. A comparative study will be necessary to confirm, whether the results of an example-based input of nutrition data coincides with the real nutrition intake within an acceptable margin of error. In this step, the system could also provide the user with specific information on food characteristics (e.g., calories and ingredient information) of his example-based input of nutritional data.
3. Both user and physician/nutrition manager can access the nutrition data in the form of reports and statistics on a web-browser.

From a technical point of view, the data input component of the prototype is implemented as a J2ME midlet and Grails web server (see technical description for details).

3.3 Technical Description

The hardware prototype we constructed for the nutrition management system consists of a regular 17-inch TFT display that was equipped with NFC-tags. The display was dismantled and the tags were attached directly to the back of the Perspex sheet that distributes the backlighting for the display. The Perspex layer and the liquid crystal layer of the display are together approximately half an inch thick and high quality NFC-tags can be read through them. The electronics of the TFT-display had to be moved about one inch away from the back of the screen to allow operation of the NFC-tags.

The interaction process description in Figure 1 outlines the communication routine of the hard- and software components of the conceptual nutrition management system prototype.

The mobile component of the prototype system is implemented as a J2ME midlet that can facilitate the communication with the NFC reader of the mobile device on the one hand and on the other hand gain access to functions and data of the web server component through a RESTful API (representational state transfer application programming interface). The web server component is implemented as a Grails web server with a Flash graphical user interface (GUI) (see Figure 2 and Figure 3). The basic communication routine of the prototype consists of four steps (see also Figure 1). The NFC-tagged display is connected to a personal computer with a browser opened and connected to the nutrition management web server:

1. The user touches the login button or another GUI element of the nutrition management system displayed on the TFT-screen with her NFC-enabled mobile device.
2. The NFC-enabled mobile device reads the corresponding NFC-tag on the backside of the display and the J2ME midlet component of the nutrition management software is started (if not running already). The midlet sends the ID of the tag and the ID of the user (stored on the mobile device) to the nutrition management web server through a mobile internet connection, using the RESTful API.
3. The web server component looks up the tag ID and the user ID in its database to determine what button was pressed and by whom. The GUI (or login) command is then processed and the GUI is updated for that specific instance of the nutrition management system interface.
4. Physicians, nutrition consultants or users with an affinity to technology can also access the nutrition management system through a web interface that is not meant for easy data entry, but for data analysis.

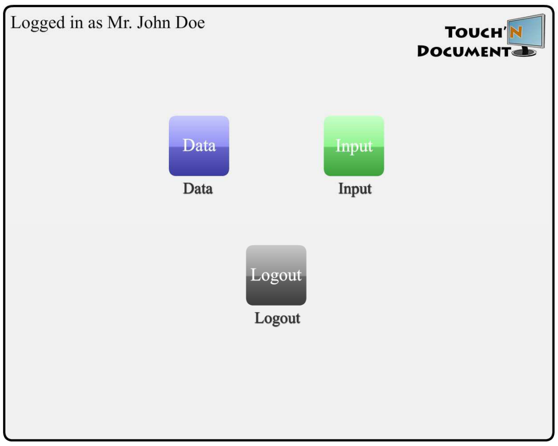

Figure 2. Login-Screen of TnD

In a next step, we elaborate and discuss the benefits of the proposed concept in the domain of telemedicine.

4 BENEFITS OF THE PROPOSED CONCEPT FOR TELEMEDICINE

The following gives an overview over the major benefits of the integration of NFC technology, mobile devices and a client-server-architecture for telemedicine applications:

- The TnD prototype system could be easily expanded to capture patient data, different from nutrition data, e.g., weight, heart rate, blood pressure, quality of life measures, etc.
- The utilization of NFC and mobile devices, as well as the implementation of a client-server-architecture lowers technological barriers of and costs for integration in established hospital information systems (HIS).
- The presented prototype solution offers the possibility for the easy integration of NFC equipped medical devices such as blood pressure instruments, for direct capture of medical data.
- Novel mobile devices (e.g., smartphones) and mobile computing devices similar to the Apple iPad could be enhanced with NFC technology in the near future and provide users (patients and medical personnel) with an adequate user interface.
- The utilization of mobile devices, in particular of mobile phones, guarantees an absolute mobile and ubiquitous data transmission but and additionally enables a voice channel for real time support for patients or medical personnel.

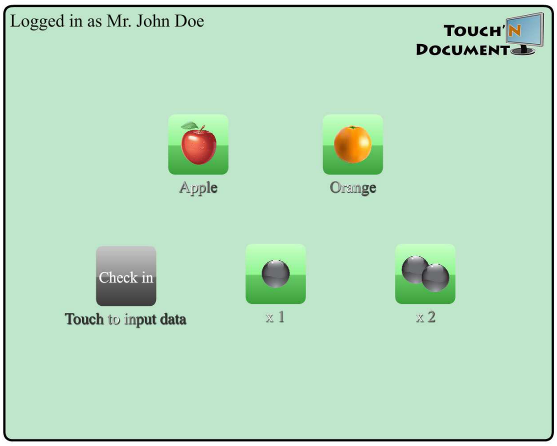

Figure 3. Main Menu of TnD

- The TnD prototype provides an intuitive and secure solution for the user to (1) simple data capture by touching, to (2) initiate data capturing and transmitting processes and to (3) secure login and authentication without entering login and password information. The usability and consequently the acceptance of the proposed system need to be evaluated in further research, however.
- In terms of usability, the utilization of mobile devices and NFC for the capturing of data results in a: (1) high usability, (2) minimal interaction with the display and keypad of the mobile device and (3) avoidance of erroneous data entries.

4 NEXT STEPS AND FUTURE RESEARCH IDEAS

From a technical point of view, both soft- and hardware of the data input component of the nutrition management prototype system demonstrate the concept of using NFC-tagged TFT-displays in conjunction with NFC-enabled mobile phones for simple, efficient and usable data entry. The system is currently in a refinement phase of the GUI design. In a next step we plan to setup focus groups with patients suffering from motor neuron diseases to collect improvements for the usability and data capture process. In this step, we additionally plan to evaluate the degree of functionality that could be implemented on the mobile device itself, in order to make the system less dependent on a stationary desktop personal computer and a fixed or mobile Internet connection. A field test with a larger number of participants is continuatively planned to be conducted in a German hospital specializing on motor neuron diseases. The evaluation will focus on technology acceptance and usability of the proposed prototype system.

Future versions of the hardware device could serve different purposes, besides a nutrition management system, for example to capture patient data different from nutrition data, e.g., weight, heart rate, blood pressure, quality of life measures.

The prototype system could also be applied in environments uncoupled form medical use case scenarios, e.g., supporting and expanding campus management systems in universities.

We see the proposed prototype system as a first step and proof of concept, to develop autonomous and dynamic smart posters by utilizing NFC technology and electronic ink foil (E-Ink) or organic light emitting diode displays (OLED) (Payne and Macdonald, 2004). In our vision, novel dynamic smart posters are autonomous in the sense that electronic ink foil in front of the NFC-tags of the smart poster is charged by using power of the mobile device through an adapter or induction and that the data displayed on this electronic ink foil is requested through the internet link of a mobile device from a server. This technical setup allows a dynamic mode of operation, in the sense that the poster can be used for multiple and different sessions (in contrast to paper based smart posters) by displaying different information in front of NFC-Tags, thus changing the data-input command that is activated by touching them with an NFC-enabled mobile device.

5 LIMITATIONS AND CONCLUSION

The TnD prototype system can enhance the productivity of telemedicine processes by improving the information logistics between the involved stakeholders in nutrition management, thus fulfilling the seamless healthcare paradigm, postulated by Schweiger (2007). With TnD, an active participation and integration of patients into ailment treatment processes, a better documentation of disease progression and therefore an improved communication basis for treatment and nursing can be achieved. Furthermore, we predict, that the proactive participation of malnutrition patients, while recording their nutrition status, can foster their ability to cooperate in the treatment and consultation processes by enabling a deeper understanding of the disease and condition itself. Our results at present and the prognosticated benefits of the TnD system are, however, not yet verified in a real world setting. Beyond this stage, studies are necessary to evaluate the acceptance of the proposed system by patients, family members, care personnel, physicians and funding agencies. In addition, the effects of the proposed system on patient compliance with nutrition plans and in a second step the consequences of an improved nutrition situation for the progression of, e.g., motor neuron diseases need to be assessed. For further iterations of the prototype system, issues like data security and privacy, robustness, stability and scalability will be subject to close scrutiny.

ACKNOWLEDGEMENTS

The Touch'n'Document prototype was developed in the context of the research project Mobile HybriCare. Mobile HybriCare is funded by the German Federal Ministry of Education and Research (BMBF - FKZ: 01FG08001). It is a joint project of the Technische Universität München and various partners. For further information, see www.mobilehybricare.de.

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