Has NFC the Potential to Revolutionize Self-reported Electronic Data Capture? – An Empirical Comparison of Different Interaction Concepts

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Abstract
The objective of this paper is to analyze and assess different electronic data capture (EDC) interaction concepts regarding usability, hedonistic and pragmatic quality. We designed an application (app) for self-reported nutrition documentation and developed three different interaction concepts: an iPhone app, a computer based app and an app for a near field communication (NFC)-enabled phone with a smart poster. A plain paper protocol was used as a reference object. The prototype was evaluated in a laboratory setting with (n=206) participants. Our results show the potential of NFC for self-reported EDC. NFC outperformed the other solutions on pragmatic and hedonistic aspects, while the prototypes of iPhone and PC underperformed. The results provide initial findings for the design of such systems.

Author Keywords
Interaction Design; NFC; Electronic Data; Capture;

ACM Classification Keywords
H.5.2 [User Interfaces]: Input devices and strategies; Interaction styles; Prototyping;

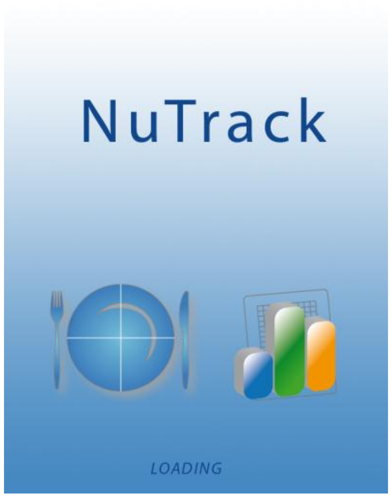


Figure 1. NuTrack Start Screen

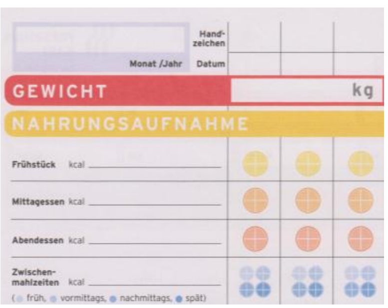


Figure 2. Sample of paperbased protocol

Introduction

Throughout the past decade, mobile devices have achieved a high level of public acceptance. The developing and testing of mobile applications is an emerging area of research in the field of Human-Computer Interaction [1]. Crucial for the design is the selection of adequate user interaction concepts. For illustration, we selected the case of nutrition management. The nutritional status of a person is the basis and the expression of certain illnesses. It is determined by nourishment and by personal consumption of energy and nutrients. Nutritional deficits take shape when the supply of energy and nutrients is insufficient over a longer period of time. The clinical consequences of progressive malnutrition are shown in numerous scientific studies [2]. These show that malnutrition is an independent risk factor for health, and causes enormous costs (e.g., costs for medical care, increased hospital stays and drug regulations). According to estimates, malnutrition costs the German public health system an approximately annual amount of about 17 billion Euros [2].

However, relevant contemporaneous information required to support therapeutic decision-making for patients being cared for at home is often not available. Different authors have pointed out the need for EDC in healthcare, and an extensive body of scientific literature elaborates on the various occurrences of EDC for the acquisition of quantitative and qualitative data in surveys [3, 4]. One of the advantages of EDC is that data are collected in digital form, ready for instant analysis, thus cutting costs on digitalization and improving data quality [5].

The application of NFC technology to support EDC for disease treatment and symptom management, specifically for the capture of self-reported patient data, is, however, comparatively novel and not widely implemented. Fikry [6] show how to employ NFC technology to collect medical data in hospitals by touching medical devices with NFC-enabled mobile phones. Data acquisition with a mobile device is performed by health-care personnel within medical facilities; hence, their suitability for chronically ill non-hospitalized patients is limited. Iglesias [7] describes an NFC-based health monitoring system for elderly patients as a self-management process which can be used by patients at home using mobile technology. The authors concentrate on the capture of vital signs and parameters such as weight or blood pressure and excluded self-reported, subjective patient data. Prinz [8] describes an NFC-based self-reporting questionnaire for patients with Fine Motor Diseases.

A variety of devices and technologies are used for EDC, such as personal computer and mobile devices (e.g., touch based phone or NFC). However, sometimes it is not easy to select a device or technology that fits to the special needs of the user, and there is a dearth of studies which compare different user interaction concepts for EDC in terms of quality, acceptance, usability and user experience.

Design Principles of NuTrack

As patients attribute an important role to the interactive application interface design, the overall process of our approach to user-centered design (UCD) is based on evaluating the usability of NuTrack in small iterative steps. The aim of UCD is to support the entire product development process with user-centered activities. It is important for creating applications which are easy to use and fulfill the needs of the focused user-group. The design goals have been identified in discussions and observations with students, physicians

Figure 2. PC version of NuTack

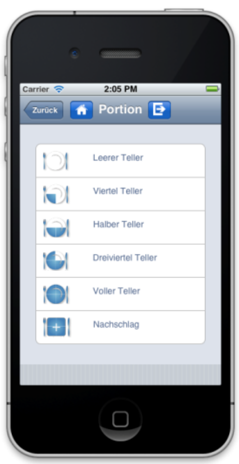


Figure 3. iPhone App of NuTrack

and patients, and form the basis for developing the solution idea for an EDC [9]. The findings and requirements form the starting point for developing the different interface concepts of NuTrack. Our concept of NuTrack is based on three main goals: 1) developing an easy-to-use service for patients, 2) heightening emotional user experience ("joy of use") and 3) improving the information logistics problem between physicians, home care nurses and patients by the active participation and integration of patients.

Implementation of NuTrack

A paper based protocol has been developed by different pharmaceutical industries [10], and is used in hospitals and nursing homes. The patient or the nurse marks on the protocol how much of the portion of nutrition was eaten. For this purpose, a plate with four parts is represented on the protocol. In addition, the daytime and duration are noted. We used this paper based protocol as a template for the NuTrack application and used this template as a reference object.

For evaluation, we designed and implemented three different user interface concepts: (1) An iPhone application incorporating touch on the display to interact with the mobile phone, (2) a PC Version which can be opened in a web browser and filled out with a mouse and (3) a mobile phone application that allows reading of NFC-tags on a smart poster with NFC-enabled mobile phones.

The nutritional intake for a normal portion of a meal (breakfast, lunch, dinner and in-between meals) can be calculated for each patient, and stored in the central unit of the NuTrack system.

The NuTrack applications for iPhone and PC are implemented as a web application which appears and functions much like a native application of iPhone, using the framework jQTouch. The application can also be used on other devices which support the WebKit4 engine for rendering web pages, such as Google Android powered phones. On NFC devices, the client is implemented as a Java J2ME midlet which controls the NFC-reader device of the Nokia 6212 phone through an API provided by Nokia. The smart poster has images printed in front and has NFC tags glued to the back.

Interaction Process

The basic interaction process of the prototypes consists of six steps: starting the application by touching (iPhone & NFC) or clicking (PC) on the NuTrack icon. For selecting daytime, meal size, drink size and duration of the meal, a touch (iPhone & NFC) or a click on the corresponding icon or text is sufficient. After each interaction the devices give audible, haptic (only iPhone & NFC) and visual feedback to the user. For audible feedback, the name of the chosen item is spoken; for haptic feedback, the vibration function of the phone is activated; and for visual feedback, the chosen item appears on the display. Finally, if the user selects the "Send" button, a confirmation of the selected items appears on the display, and the user can confirm it after verification. Again, the devices confirm the transmission of data with audible, haptic and visual feedback.

Research Method/Approach

To systematically evaluate and compare the hedonic and pragmatic quality of an interactive product, we used the Attrakdiff 2 questionnaire, a commonly employed scale [11]. The questionnaire consists of 28 items with bipolar adjective pairs (7-point semantic differential), such as ugly vs. attractive; inventive vs. conventional; stylish vs. tacky; simple vs. complicated.

Figure 5. NFC phone on smartposter

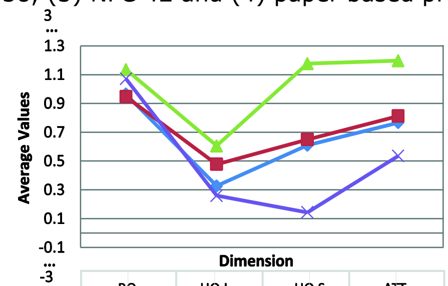
Seven items represent a dimension. The first "Pragmatic Quality" (PQ) describes traditional usability aspects (e.g., effectiveness and efficiency of use) of a product, and indicates how successful users are in achieving their goals using the product. The dimension "Hedonic Quality – Stimulation" (HQ-S) refers to the need of people for further development concerning themselves (e.g., new skills and knowledge). By supporting this aspect, products can offer novel, interesting and stimulating functions, contents and interaction, as well as presentation-styles. "Hedonic Quality – Identity" (HQ-I) allows measuring of the amount of identification a user has with a product. Pragmatic and hedonic dimensions are independent of each other, and share a balanced impact on the overall judgment. "Attractiveness" (ATT) describes a global value of the product based on the perceived quality.

Experiment

We conducted a laboratory test with 206 participants (97 Female), ranging in age from 24 to 46 years. All participants were students at a German university. We used a between-subjects design to exclude any possible carry-over effects, which means that each student group only tested one kind of application. The students received a ten minute introduction to the service, the scenario, the background and how to operate NuTrack. To reduce the effect of extraneous variables, the following controls were applied: The tasks had the same time constraints for all participants. The questionnaires were answered immediately after task completion. The groups for testing the different user interface prototypes were divided as follows: (1) iPhone 64, (2) PC 48, (3) NFC 46, and (4) paper based nutrition protocol 48.

Data Analysis and Discussion

After reliability checks, 172 from 206 questionnaire could be included in the evaluation; (1) iPhone 60, (2) PC 38, (3) NFC 42 and (4) paper based protocol 32.



	PQ		HQ-I		HQ-S		ATT	
	AVG	SD	AVG	SD	AVG	SD	AVG	SD
iPhone	.964	.81	.326	.624	.61	.669	.767	.849
PC	.947	1.338	.477	.622	.65	.872	.812	1.105
NFC	1.136	1.098	.605	1.228	1.177	.937	1.197	1.294
Paper based	1.071	1.004	.259	.937	.143	.856	.536	1.183

Figure 6. Average values of Attrakdiff2 dimension

The analysis of the AttrakDiff 2 scores revealed considerable differences between the four interfaces. Figure 6 shows that NFC scores highest on all four subscales PQ, HQ-I, HQ-S, and ATT. Further, PC prototype scores on subscale PQ better than iPhone, but worse than paper based. On subscale HQ-I, PC scores better again than iPhone, but worse than paper based. On subscale HQ-S PC scores better than iPhone and paper based. On subscale ATT PC outperforms iPhone and paper based.

The results of the experiment can be interpreted as follows: A possible explanation for the relatively poor scoring of the paper based protocol is that users obtain no feedback or interaction for their input. Especially the PQ value of NFC is surprising, as it has a positive mean difference (+0,065) to the paper based protocol. The high scoring of NFC can be explained by the ease of learning the touch metaphor of NFC interaction. However, it is surprising that the iPhone, as a lifestyle device, performed worse than the NFC solution did. A possible explanation could be the low level of awareness of NFC and the therewith connected wow-effect. Another reason for the poor score of iPhone could be the explication of Nielsen [12], who reports on usability as an entry barrier for the case of websites, highlighting that the users will not bother with anything that requires additional learning time because humans prefer to stick to what they know (even if it is hard to learn in the beginning), and users simply want to start getting something done instead of spending "unproductive" time learning ("paradox of the active user") [13]. Thus, to overcome the entry barriers stated by Nielsen [12], it may be assumed that further improvement in usability of iPhone is needed.

A major disadvantage of the NFC solution to the iPhone is that the application is only functional if the combination of device and Smart Poster is available. Thus, the user is limited in its spontaneity and freedom of movement. Since the application is to be used mainly in home care, this aspect is not yet substantial. The comparison of the reference paper based protocol with the applications shows that users' subjective comparison of ease of use of the novel interaction technique can have more hedonic and pragmatic quality than does a traditional paper based data capture system. Furthermore, we designed and developed prototypes that have high pragmatic quality. iPhone and PC do not reach the score of that of the paper based, but come close. However, the interactive prototypes scored much better in hedonic quality (HQ-I & HQ-S) and attractive quality than on the paper based protocol. Overall, it turned out that the NFC prototype is much more attractive and user friendly than iPhone, PC or paper based protocol.

Limitations

A limitation is that we did not test any other concepts for data capture, e.g., using tablet pc or pen based applications. Hence, there might be other concepts that could outperform our tested solutions. Also, in the laboratory setting, the participants did not need to ship the paper based protocol to a central office which analyzes the data and prints warnings to patients or physicians. At present, our results were verified in laboratory experiments only.

Conclusion and Future Work

This work-in-progress paper presents a first study evaluating three EDC prototypes with 206 participants on the example of nutrition tracking. The first contribution of this paper is a comparison of three different user interaction concepts with a paper based nutrition protocol as reference and identification of the application with most hedonic and pragmatic qualities for the user. Our results indicate that the NFC solution is the most hedonic and pragmatic concept. The second contribution of the paper are the underlying prototypes. Two mobile and one stationary application are currently at the state of a fully functional proof-of-concept prototype. We showed that an EDC system for self-reporting nutrition status can be successfully realized with mobile and stationary devices. The next steps of our work need to reassess and affirm our results. Therefore, we are performing a set of on-going usability tests to refine our results. Further, as recent technological advances allow for new interaction concepts, we are also checking and implementing further applications, such as tablet-based apps. Our work can provide insights to user interaction research and practice by providing new insights into usability and acceptance issues. As user generated content is crucial to a lot of applications and research about the right means to ease users entering data is still at its beginning, our results can be viable for developing new EDC solutions, leading the way for value-adding services based on this data. We further plan a compilation of user interface design guidelines for self-reported- EDC.

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