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Michael Burkard
Universität Bayreuth

Jannik Lockl
Universität Bayreuth

Tristian Zürl
Universität Bayreuth

Nicolas Ruhland
Universität Bayreuth

Managing My Bladder Dictates My Daily Routines – A Model for Design and Adoption of mHealth in Lower Urinary Tract Symptoms Management

Michael Burkard, Jannik Lockl, Tristan Zürl, and Nicolas Ruhland

University of Bayreuth, Wittelsbacherring 10, 95444 Bayreuth, Germany
{michael.burkard,lockl.jannik,tristan.zuerl,
nicolas.wolfgang.ruhland}@uni-bayreuth.de

Abstract. Lower urinary tract symptoms (LUTS) are prevalent urological health issues affecting billions of people worldwide. While conventional aids have unhygienic and cumbersome attributes, mobile health (mHealth) solutions have the potential to significantly improve the quality of life. However, knowledge of how LUTS patients adopt mHealth and how these solutions should be designed is scarce. In this study, we present an adoption model to explain and support the adoption of mHealth solutions by patients suffering from LUTS, and derived design principles to guide future developments of such mHealth. We, therefore, conducted a systematic literature review of 67 papers and followed an action design research approach with 32 expert interviews and a confirmative survey to build, refine, and evaluate the *ex-ante* model. The *ex-post* model consists of five categories and 28 sub-categories of mHealth adoption.

Keywords: Action Design Research, inContAlert, Literature Review, mHealth, Technology Acceptance

1 Introduction

Lower urinary tract symptoms (LUTS) are prevalent urological health issues estimated to currently affect 2.3 billion people worldwide [1–3]. Conventional aids to counteract these symptoms predominantly contain unhygienic and cumbersome attributes [4, 5]. Mobile health (mHealth) solutions have the potential to significantly improve both the quality of life and care of those suffering from LUTS [6–8]. The number of mHealth solutions and the amount of respective research are quickly growing [6, 7, 9]. However, mHealth regularly lacks in user acceptance and fails when entering the market [9, 10]. Designing mHealth with the objective to ensure later user adoption needs further guidance and structure [12, 13].

In this study, we present a model for the adoption of mHealth solutions by patients suffering from LUTS and derived principles for designing such mHealth. We developed and evaluated the model along *inContAlert*, an mHealth device to support patients suffering from LUTS in their daily routines and prevent harmful incidents.

At the outset, we conducted a systematic literature review [14, 15] to build an *ex-ante* adoption model of factors that positively affect the intention of patients suffering from LUTS to adopt the intended mHealth solution. Subsequently, we applied an action design research (ADR) approach [16] to revise the adoption model and develop an mHealth solution, which noninvasively determines the filling level of the urinary bladder and displays the filling level to a digital end-device. Equally split in the *α*- and *β*-cycle, we conducted 20 semi-structured interviews [17–19] with patients suffering from LUTS and twelve with selected experts in various LUTS-related fields. To evaluate our constructs in a larger setting, we conducted a confirmative survey [20] as the last part of the *β*-cycle. We concluded with the *ex-post* adoption model that we call the *Chronic Disease mHealth Adoption Model* (CDmHAM) and derived principles for designing such mHealth.

2 Background

LUTS occur as a consequence of diseases affecting the urinary bladder and the urethra [21]. Many patients suffer from perturbing symptoms influencing their health-related quality of life and life expectancy [21, 22]. LUTS come along with high stigmatization and psychological problems for those affected [1, 23]. Conventional aids to manage LUTS include absorbent and draining aids, medicaments, surgeries, and strengthening training for pelvic floor muscles. They have in common that they contain unhygienic or cumbersome attributes [4, 5]. Due to their widespread appearance and insufficient means to counteract their symptoms, LUTS have a huge socio-economic impact [23, 25]. Meanwhile, experts predict that digital technologies, such as mHealth applications, have the potential to reduce the overall healthcare costs, further extend life expectancy, and improve the quality of life of those affected [7, 8].

As multiple LUTS result from missing knowledge on the filling level of the urinary bladder [21], an mHealth solution to digitally output that information would be of significant value. Unwanted spontaneous micturition and backflow of urine to the kidneys can be avoided. Yet, under which conditions patients would adopt such an mHealth solution and how it should be designed remain unclear. For this reason, though still grounding on seminal technology acceptance models (i.e., TAM [26], TAM2 [27], and UTAUT [28]), we investigate the adoption and design of such a sensor system.

3 Methodology

3.1 A Literature Review to Build the *Ex-ante* Model

To build the *ex-ante* adoption model, we conducted a systematic literature review following recommendations from vom Brocke et al. [15] and Webster and Watson [14]. We applied title, abstract, and keyword search in the seven online databases PubMed, IEEE Xplore, AISeL, Epistemonikos, Web of Science, ScienceDirect, and EBSCOhost with the search terms *mHealth, mobile health, noninvasive, chronic disease, chronic* *illness*, and *health care*. We limited our search to peer-reviewed research papers and reviews written in English and published between January 2006 and January 2020 [15, 29]. A total of 302 papers was suitable for analysis.

To sort the sample of papers, one co-author reviewed the abstracts in-depth to obtain a detailed overview and assessed the papers with a four-point Likert scale. Articles of score 4 were dropped before a second co-author reviewed the papers with score 3 to drop or give them the score 2. A third co-author read all those with score 2 to finally ex- or include them for the in-depth analysis, concluding in 60 papers with a score 1 [15, 30]. Finally, we found another seven papers relevant for our purpose after a backward/forward search [14]. The so-identified 67 papers were the base for our in-depth analysis, during which we analyzed the papers with open, axial, and selective coding. Identifying basic constructs, we grouped them in superordinate categories and simultaneously built sub-categories between the constructs and categories to implement an additional abstraction level [29, 31, 32].

3.2 Action Design Research to Build the *Ex-post* Model

The *α*-cycle

Within the *α*-cycle of our ADR approach, we developed large parts of the *ex-post* model and the sensor system. To gain an in-depth understanding of the intention of potential users to adopt our mHealth solution, we conducted semi-structured interviews [17–19] with users and practitioners. In the *α*-cycle, we iteratively interviewed ten patients suffering from LUTS. To include a representative group of interviewees [33, 34], we decided to involve patients suffering from diseases associated with LUTS, such as multiple sclerosis, paraplegia, Parkinson's disease, spina bifida, or stroke. Further, we interviewed six practitioners from urology, neuro-urology, paraplegiology, physiotherapy, or medical technology. We stopped the interview process of the *α*-cycle after these overall 16 interviews since we realized that new knowledge emerged only marginally and conceptional saturation had been achieved [35]. We conducted all interviews via telephone taking from 25 to 50 minutes each. The overall structure of the explorative interviews reached from open to more specific questions about the adoption model and the *α*-version of the sensor system. We analyzed the interviews qualitatively using coding techniques from grounded theory [29, 32, 36], hence revised the *ex-ante* adoption model, and developed the *β*-version of the sensor system.

The *β*-cycle

During the *β*-cycle, we evaluated, incrementally enhanced, and confirmed the results of the *α*-cycle to conclude with the CDmHAM and derive design principles from the so-built sensor system. To ensure the generalizability of our findings, we interviewed ten new patients suffering from LUTS in the *β*-cycle [17–19]. This time, the sample consisted of individuals suffering from congenital LUTS, multiple sclerosis, paraplegia, prostate cancer, or stroke. Furthermore, we interviewed six practitioners from urology, paraplegiology, physiotherapy, daycare of demented patients, or medical technology. We again stopped the interview process in the *β*-cycle since we realized conceptional saturation [35]. In the *β*-cycle, the interviews were of confirmatory nature to appropriately evaluate the initial findings, although, all interviewees were invited to complement with new insights. Building upon these findings, we concluded with the CDmHAM, developed the final sensor system, and derived a catalog of principles for designing mHealth solutions.

Finally, we conducted an online survey to validate our previous findings in a larger setting [20]. We applied this quantitative approach, as we sought to weight our sub-categories regarding their relevance to allow for a better focus of later research and practice [18, 37]. In the survey, we asked participants to rate our sub-categories concerning their relevance on a scale from 1 to 7 where 1 means the sub-category is not important at all and 7 means the sub-category is very important. Patients suffering from LUTS as well as care assistants supporting respective patients were allowed to take part in the survey. In the end, a total of 387 individuals participated. We analyzed the survey examining mean scores, standard deviations, and variances of the ratings.

4 Results

As a result of the literature review, we identified factors affecting the intention of potential users to adopt mHealth solutions in general. Our *ex-ante* adoption model consisted of five superordinate categories (i.e., *User Factors*, *Perceived Benefits*, *Hard- and Software*, *Data Factors*, *Environment*) and 21 sub-categories. Building upon the generic *ex-ante* model, we developed the α-version of the sensor system. Within the α- and β-cycle of our ADR approach, we specified our perspective on LUTS patients and practitioners. We confirmed the five categories and enhanced them to conclude in 28 sub-categories. The *ex-post* adoption model (i.e., the CDmHAM) in Figure 1 depicts the interrelations between the categories, the adoption intention, and the design of mHealth devices.

In the following, we provide an overview of the identified sub-categories and list them adding their mean scores obtained from the survey to illustrate the relevance of each. First, the category *User Factors* is characterized by *Accessibility* (5.96), *Customization* (6.12), *Initial User Briefing* (6.20), and *Constant User Consulting* (5.78). Second, *Perceived Benefits* are split into *Usefulness* (6.14), *Autonomy* (6.38), *Convenience* (6.37), *Comfort* (6.30), *Mobility* (6.54), and *Unobtrusiveness* (6.23). Third, *Hardware and Software* build upon *Safety* (6.39), *Reliability* (6.52), *Performance* (6.32), *Durability* (6.28), *Hardware Fixation* (5.60), *Design* (4.78), *Interoperability* (5.23), and *Connectivity* (5.26). Fourth, in terms of *Data Factors*, *Generation and Integration* (5.14), *Storage and Access* (5.13), *Analysis* (5.27), *Feedback on Usage* (5.66), *Transfer* (5.19), and *Privacy* (5.73) are relevant. *Environment*, fifth, is determined by *Ongoing Maintenance* (6.01), *Costs* (5.89), *Health Insurance Involvement* (6.19), and *Provider Involvement* (6.12). *Perceived Benefits* is the most important superordinate category, and its sub-categories all belong to the top ten of the most relevant ones. Noticeably, the category *Data Factors* obtains the lowest relevance by far. On the sub-category level, *Design* shows the lowest mean of all sub-categories.

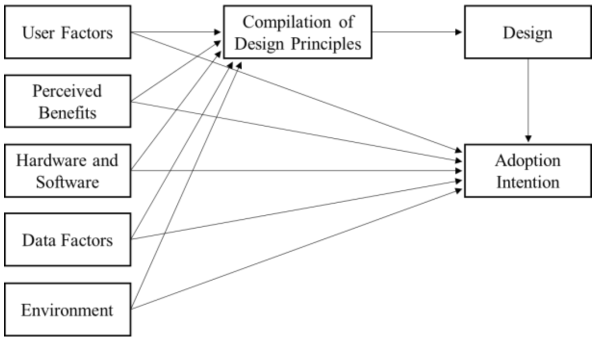

Figure 1. The Chronic Disease mHealth Adoption Model

Resulting from the β-cycle, the final version of the sensor system comprises an mHealth sensor device, a monitoring app, and an additional drinking protocol app. Furthermore, we derived a catalog of 26 design principles guiding future developments of mHealth for LUTS and other chronic health issues. Design principles addressing the hardware comprise *Miniaturization*, *Flexibility*, *Soft Materials*, *Lightweight Construction*, *Smooth Surface*, *Wireless Device*, *Transparency*, *Washability*, *Biocompatibility*, and *Durable Components*. Addressing both the hard- and software, *Plug-and-Play*, *Reduction of Manual Input*, *Clearness*, *Voice Assistant*, *Multiple Interfaces*, *Energy Efficiency*, *Internal Data Storage*, and *Cost-Effectiveness* are relevant. In terms of the software, *Readability*, *Intuitive Operating Steps*, *Appropriate Language*, *Graphic Visualization*, *Mobile-Friendly Software*, *Cloud Computing*, *Alert Mechanism*, and *Learning Algorithm* are pivotal determinants to be considered.

5 Discussion

As research provides little knowledge on mHealth adoption with urological health issues, we followed a multi-method approach to build both the CDmHAM and catalog of design principles. Integrating patient and expert interviews, we ensured the applicability of our generic model for the specific case of LUTS. Our study thereby contributes with a comprehensive model of mHealth adoption [cf., 26–28].

Our study faces limitations as we investigated neither dependencies between factors nor the influence of moderating variables [38]. Hence, we invite future studies to investigate whether the factors depend on each other, to identify specific moderating variables, and to probe their effect within the CDmHAM and on the catalog of design principles. Since potential users assessed the relevance of the adoption factors, we suggest focusing on the most relevant ones while investigating mHealth adoption and developing mHealth devices.

Concluding, we obtained an adoption model as well as a catalog of design principles specifically applicable in LUTS management and supposed to apply to other chronic diseases as well. The comprehensiveness of factors and principles and the proven applicability for LUTS are valuable for research. We invite researchers to build upon our findings and validate and enhance both the model and the catalog.

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