



Usability of Telehealth Technologies

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Editorial

Usability of Telehealth Technologies

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In recent years, telehealth technologies are diffusing rapidly into all aspects of healthcare practices, ranging from traditional medical consultations to various patient-centric areas. These new uses bring a promise of integrating computerized support and Internet functionality into the deeper recesses of our community, addressing the intractable problems of access and population-specific health disparities. To ensure the promised benefits of these new telehealth systems, usability has become an ever-present and pressing issue for the research community.

Effective design and implementation of Health Information Technology (HIT) is foundational to providing health providers and patients effective, efficient, safe, and timely access to healthcare. The US Agency for Healthcare Research and Quality and the National Institute of Standards and Technology (NIST) have both stressed the need to measure and improve HIT usability. Usability, as defined by NIST, refers to “effectiveness, efficiency and satisfaction with which intended users can achieve their tasks in the intended context of product use.” This special issue presents original research articles that address the “usability” of telehealth systems. The articles presented illustrate how concepts of usability, cognitive support, and safety gain new complexities when HIT becomes more embedded into the everyday lives of different populations and settings. A range of populations can be served by telehealth, for example, those living in underserved urban communities, patients with a specific chronic illness, and older adults who are isolated from the community. Effective implementation of HIT can result in a dramatic increase in the reach of the healthcare system.

Maximizing the benefit of telehealth applications requires deepening our understanding of usability in context, as each of the following studies illustrate.

The paper by S. George et al. aims to study the acceptability of telemedicine systems among urban underserved. This study uses the Diffusion of Innovation framework to examine the perceived advantages and readiness of telemedicine systems in underserved populations. The findings suggest that the adoption of new technologies is not merely a technical issue, but is situated in the social, cultural, and historical context. The same systems may not be successful in all settings, since the users have preperceptions about the technologies. The authors note that it is often nontechnical factors such as preconceptions about the technology that are related to patient satisfaction and effective patient-provider communication in a telehealth setting. The urban underserved poor have complex social relationships and unique needs and backgrounds that directly impact the use of telehealth. These insights have profound implications for other mHealth and eHealth systems, suggesting telehealth systems should be tailored and promoted according to users’ backgrounds and preferences to avoid misperceptions and adoption failures.

In contrast to the needs of a whole social group, the study by C. Stepnowsky et al. focuses on telehealth applications tailored to a specific disease. This study reports on an interactive website designed for patients with obstructive sleep apnea (OSA) in order to improve the adherence of continuous positive airway pressure (CPAP). It was found that if the design is tailored to the needs of individual users, the

interactive portals could successfully improve adherence and patient education as well as foster clinical information. This study has valuable implications for the design of interactive systems designed for health management in chronic care illness.

In addition to the need to tailor systems to specific individuals or social groups, the paper by C. Diana et al. illustrates the need to address the diversity of settings in which mobile devices are used. This paper reports on a usability study of an application that collects symptom data for Fibromyalgia via a mobile device. The final goal of the project was to collect context-sensitive data on chronic pain using Experience-Sampling Methodology (ESM). Users in the study had low to medium experience with computers and touchscreens. To adjust to the complexities of using a system in all settings and times, it was suggested that the small mobile screen environment required stronger color contrast, redundant instructions, more response feedback, and more flexibility in positions for use. Although the study itself measured only qualitative information from a small number of users and a narrow set of concerns, the results do have some generalizability to the design of mobile applications. Future work on mobile devices might explore the ability to build in cross-senses instructions (e.g., audio and visual) and the importance of conducting usability studies in actual environments.

The paper by S. Spinsante et al. reports on the development of a systematic method of comparing types of health monitoring platforms targeted at older adults with heart failure. The authors compared 3 specific platforms in order to provide a generalizable method that could identify functional requirements for these types of information and communication technologies. The authors identify technical and user criteria for remote monitoring of physiological criteria, but information about how the model was actually used by older adults was not provided, limiting its generalizability. Nevertheless, the modeling of requirements and rating methods will be useful to generalize to other systems. Future work should focus on generalizability and integrating this system into other clinical areas as well as usability standards already in use.

The paper by M. Tabbara et al. reviews a new and growing area of wearable mHealth technologies. The use of wearable mHealth devices is a rapidly growing area of telehealth. In the consumer electronic space, there has been rapid growth in the number of personal wearable devices such as wearable activity, mood, and sleep monitors. The authors present their experience with a wearable device, the Swiss Limmex emergency wristwatch, designed as a medical emergency communication tool for older adults. Data on user's perceived needs, concerns, and willingness to adopt a simple device like the Limmex watch is presented. Because of the limitations of evaluating technologies in full context, little data on effectiveness, efficiency, or safety in an emergency scenario was provided. This study highlights the complexities of conducting usability research on wearable mHealth devices.

By compiling this special issue, we hope to draw our readers' attention to the complexities and importance of

addressing human factors and usability aspects of telehealth. Traditional telehealth research often includes supervised clinician-patient interactions that occur in the exam room. In this model, patients are passive recipients of telehealth care, and usability is often not addressed or is considered only from the clinicians' perspective. However, recent growth of patient-centric technologies, including mHealth and eHealth technologies (e.g., web portals, mobile phone applications, and wearable mHealth devices for patients), requires a reemphasis on usability from the perspective of patients and family caregivers. The special issue highlights studies that address issues of diversity, social interdependencies, individual difference and mobility, and the need for greater emphasis on usability as telehealth moves into this new era of diverse users.

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Research Article

Patient Perspective on Use of an Interactive Website for Sleep Apnea

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Incomplete patient adherence with nasal continuous positive airway pressure (CPAP) limits the effectiveness of treatment and results in suboptimal obstructive sleep apnea (OSA) outcomes. An interactive website specifically designed for patients with OSA was designed and utilized in a randomized clinical trial to test its effect on increasing CPAP adherence. The goal of this paper is to report on CPAP adherence, internet use, privacy concerns and user satisfaction in using the website. The original project was designed as a randomized, controlled clinical trial of Usual Care (UC, control) versus MyCPAP group (intervention). Questionnaires were administered to evaluate the patient perspective of using the MyCPAP website. Participation in the MyCPAP intervention resulted in higher CPAP adherence at the two-month time point relative to participation in the UC group (3.4 ± 2.4 and 4.1 ± 2.3 hrs/nt; $P = 0.02$; mean \pm SD). Participants randomized to the MyCPAP website increased their use of the internet to obtain OSA related information, but did not increase their use of the internet to get information on general health or medical conditions. Users had very little concern about their CPAP data being viewed daily or being sent over the internet. Future studies should consider the use of newer evaluation criteria for collaborative adaptive interactive technologies.

1. Introduction

Obstructive sleep apnea (OSA) is a disorder characterized by repeated cessations of breathing during sleep, which can result in a number of potentially serious consequences affecting cardiovascular, physiological, neurocognitive, emotional, and psychosocial functioning [1]. OSA is the most common sleep disorder, affecting about 4% of men and 2% of women aged from 30 to 70 years old in the USA [2]. OSA is a chronic disease that is estimated to contribute \$3 billion in additional medical costs in the USA, with a total economic burden greater than \$100 billion when including loss of workplace productivity, occupational injury, and greater health care utilization [3]. In addition to its economic burden, OSA is associated with serious long-term adverse health consequences such as hypertension [4], metabolic dysfunction [5], cardiovascular disease [6], neurocognitive deficits [7], and motor vehicle accidents [8].

Nasal continuous positive airway pressure (CPAP) [9] is the treatment of choice for OSA [10], with meta-analytic reports of numerous randomized controlled trials showing that CPAP improves both objectively and subjectively measured daytime sleepiness [11] as well as health-related quality of life [12]. CPAP has been shown to normalize sleep architecture [13] and reduce blood pressure [14]. Emerging evidence suggests that CPAP treatment reduces physician's costs and hospital utilization rates in the two years after the start of treatment in OSA patients when compared to age-, gender-, and location-matched controls [15].

Despite the documented efficacy of CPAP, many—perhaps most—patients have difficulty adhering. It is estimated that over 50% of those started on CPAP will not be using it one year later [10]. A number of CPAP adherence interventions have been studied to date, with most offering extra education or clinical support [16]. Some of these are considered intensive or augmented support [17, 18] and

require significant extra time by the provider, upwards of 20 hours of extra contact or more. These kinds of interventions are difficult to incorporate into our fee-for-service healthcare system. We took the opportunity to design an interactive website to help automate educational and clinical support efforts and add the ability to track CPAP adherence data and OSA-related symptoms.

Identifying the factors or correlates associated with increased CPAP adherence could help inform more effective interventions. Most studies examining the correlates of CPAP adherence have considered patient-related, disease-related, and treatment-related variables [16, 19, 20]. No reliable (i.e., consistent) and modifiable (i.e., amenable to change) determinants measured *prior* to treatment initialization have been found in any of these categories [19, 20]. Interestingly, while the main complaints from patients concern comfort related issues (i.e., mask fit, pressure tolerance, dry mouth), any technological solution (i.e., improvements in mask design, autoadjusting pressure or pressure relief, and humidification) all have been found to have little to no impact on CPAP adherence and outcomes [21]. Use of autoadjusting PAP has been found to improve adherence on average 11 minutes per night, which is not a clinically important amount of use [21]. However, there is increasing evidence that variables measured after the start of treatment might predict future adherence. For example, the amount of perceived benefit from treatment (e.g., improvement in sleepiness level) is associated with higher CPAP adherence [22–24]. A past review of the literature pointed to the need for increased research on the role of psychosocial variables in CPAP adherence behavior [20]. Research examining the relationship between social-cognitive variables is accumulating. Social cognitive variables are associated with CPAP adherence in studies of first-time CPAP users when CPAP adherence measured both at one month [25] and at 3 and 6 months [26]. Another study found that cognitive beliefs (health value, health locus of control, self-efficacy) are associated with CPAP adherence at 3 months in new users [27].

The advantage to this class of CPAP adherence factors are that they are theoretically-based, modifiable, and can provide the basis for interventions to improve use of CPAP [28]. Our group has begun work on a Sleep Apnea Self-Management Program that is based on this previous work [28]. The intervention described in this manuscript is based in part on lessons learned from the Sleep Apnea Self-Management Program and is in part adapted to an interactive website format.

The percentage of adults in the United States that use the Internet was approximately 74% in 2011, with no difference between men and women [29]. Of those American adults who use the Internet, 80% look for health or medical information such as a specific disease or treatment [30]. This translates to 59% of all US adults. Information sought includes that regarding a specific disease or medical problem (66%) or a certain medical treatment or procedure (56%). Increasingly, online users are becoming more active users (i.e., doing more than just reading): 14% have signed up to receive email updates, 6% have posted comments, and 25% are now accessing videos to learn more about health and

medical issues. Two factors associated with higher rates of participatory activities online include: (a) internet users with 3 or more chronic conditions and (b) those who access the internet wirelessly. In an earlier study those with chronic conditions are more likely than other patients to report that their online searches affected their treatment decisions (75% versus 55%), their interactions with their doctors (69% versus 52%), and their ability to cope with their condition (57% versus 36%), as well as their diet and physical activity regimen (56% versus 42%).

There are less positive data to report. While patients with chronic conditions do have positive experiences with their online health searches, 30% said they felt overwhelmed by the amount of information they found online and 31% said they felt frustrated by the lack of information or their inability to find what they were looking for [31]. Further, 80% said the most common barrier to health/medical websites are concerns about the information quality [32]. These issues speak to the need for websites to better understand what information users are looking for online, the need to organize and display that information in a user-friendly manner, and the need to address issues concerning the accuracy and quality of the information presented.

The goal of the manuscript was to describe the use of the MyCPAP website for OSA patient management and the effect on CPAP adherence and outcomes.

2. Methods

2.1. Overview. The design was a randomized parallel group trial with blinded evaluation that compared an Internet intervention based on the wireless telemonitoring of CPAP data (i.e., Internet-based positive airway pressure care, or MyCPAP) versus a usual care CPAP treatment protocol (i.e., Usual Care, or UC). Participants completed a baseline, 2-month and 4-month assessments. The project took place over a 3-year period. Usual care was comprised of pre-determined clinical contacts while MyCPAP was comprised of as-needed clinical contacts, based on objectively measured CPAP adherence and efficacy data and access to a patient-oriented Web site. Participants underwent identical instruction and education on OSA and CPAP therapy and used identical CPAP units. The study was designed as a practical clinical trial that compared one clinical care method against another, with the goal of informing clinical decision making [33]. It was comparing the effect of clinical care methods on a behavioral outcome (i.e., CPAP adherence) and was considered in large part a behavioral trial.

2.2. Participants. The target population for this study was all patients referred to the University of California, San Diego Healthcare System (UCSD) Sleep Medicine Center, by physicians for suspicion of OSA. Participants were recruited and screened in the Sleep Center. Inclusion criteria included a diagnosis of OSA (apnea-hypopnea index ≥ 15) [34], CPAP therapy prescription, and age ≥ 18 years. Exclusion criteria included residence in a geographical area outside of San Diego County (which could make regular contact and

TABLE 1: Descriptions of the components of the MyCPAP patient website.

Component	Description
The learning center	Basic education to inform patients about sleep apnea, CPAP, and collaborative management.
My CPAP data	Easy-to-read charts that show CPAP adherence (in hrs/nt) and CPAP efficacy data (disease severity as measured by number of apneas and hypopneas per hour) and amount of air leak (in liters/min).
My graphs	This section included both easy-to-complete individual items for patients to track, including sleepiness levels and other patient-selected OSA-related symptoms.
Troubleshooting guide	Interactive guide that allows patient to select the CPAP problem they are having; possible causes are discussed and solutions are listed.
CPAP user's manual	This component created animations for how to use the CPAP machine and it's associated features; how to clean mask and hose; how to use the humidifier.

participation difficult); fatal comorbidity (life expectancy less than 6 months as indicated by treating physician); or significant documented substance/chemical abuse. All participants signed informed consent and the study was approved by the University of California, San Diego IRB. The participants were offered financial reimbursement for participating and completing the study and to modestly offset travel-related expenses.

2.3. Intervention. Participants randomized to UC were followed according to both the usual and standard care for OSA patients who are treated by the UCSD Sleep Center and by the published literature [10]. These standards include diagnostic sleep study, CPAP instruction and setup by trained health care provider, and followup at predetermined times (1 week, 1 month) by CPAP clinic staff. Beyond these pre-determined clinic contacts, patients were encouraged to call whenever they had a problem or concern. Adjustments or changes in the mask interface might be warranted at any point, so it is not uncommon for patients to switch from nasal to full-face masks or nasal pillows, for example. Pressure level changes are often warranted as well. If the patient brought in their CPAP unit, the data was downloaded and utilized.

An individual working for a VASDHS-contracted home medical supply company conducted comprehensive CPAP instruction in a group format per the study protocol. Participants were given a choice between full face and nasal mask types, given the opportunity to wear the masks, experience the positive airway pressure, and work through any initial problems or issues. Each CPAP used in this study was equipped with a digital data smart card, which recorded the amount of time the machine was used therapeutically. Data were downloaded from the smart card after the four-week intervention period to measure the amount of daily CPAP use.

2.4. MyCPAP Website. The main goals of the MyCPAP intervention was to (a) allow both the patient and provider access to telemonitored adherence and efficacy data on a daily basis, (b) act on that data collaboratively to guide CPAP management and troubleshoot problems early and effectively, and (c) emphasize ways for the patient to express their preferences and needs. Below we describe both the patient and provider portals, which are set up differently given the

different needs of patients and providers. Table 1 provides a list of the MyCPAP components.

Patients randomized to MyCPAP had objective CPAP data monitored as frequently as every day throughout the active 2-month treatment period. The frequency and nature of the clinical interactions were largely dependent upon patient-defined needs, subjective patient report of symptoms and progress, and the objectively measured nightly data values. Participants were assigned a unique username and password to access the website and provided with an initial overview of the website and its components. They were told that they could access the learning center to learn more about sleep apnea and CPAP, track their CPAP adherence and efficacy data, track symptoms that were important to them, troubleshoot problems that they experienced in using CPAP and access an animated site to learn how to use their device and mask. They were not required to use the site and there was no penalty nor incentive to use the site.

2.5. Apparatus. Participants in this study were provided with a Positive Airway Pressure device (PAP; Autoset II, ResMed, San Diego, CA). A wireless modem was attached to their PAP device, which could then send the data from the device to a Web-portal accessible by our team. The web-portal ("Restraxx Data Center," or RDC), is comprised of the wireless module and the server/database, which houses the data and, fully compliant with the Health Insurance Portability and Accountability Act of 1996 (HIPAA) restricts access to authorized health care professionals. The wireless module connects to the flow generator via a docking mechanism that allows the connection to an existing 15-pin expansion port at the rear of the flow generator. All PAP devices were outfitted with a humidifier.

2.6. Measures. Measures were assessed at both pre- and postintervention and included participant sociodemographics, OSA symptoms, Epworth Sleepiness Scale (ESS), Sleep Apnea Quality of Life Index (SAQLI) and the Center for Epidemiologic Studies—Depression (CES-D), computer use and experience survey, and items that assessed patient satisfaction with MyCPAP. Demographic information assessed included age, gender, education, marital status, height, and weight. The apnea-hypopnea index (AHI) is a count of the total number

TABLE 2: Baseline characteristics (Mean \pm SD).

	Both groups (N = 241)	MyCPAP (N = 126)	Usual care (N = 114)	P value
Age	52.1 \pm 13.3	52.7 \pm 13.4	51.5 \pm 13.2	0.52
Body mass index (BMI)	32.5 \pm 8.0	32.6 \pm 8.1	32.4 \pm 8.1	0.86
Apnea-hypopnea index (AHI)	36.5 \pm 25.9	36.3 \pm 25.0	36.7 \pm 27.3	0.91
Epworth sleepiness scale (ESS)	10.6 \pm 5.3	10.7 \pm 5.2	10.5 \pm 5.4	0.75

of apneas and hypopneas per hour of sleep and was measured by overnight sleep study.

The Epworth Sleepiness Scale (ESS) is an 8-item validated measure of daytime sleepiness [35]. It asks respondents to estimate how likely they are to doze in 8 different situations. The ESS is able to discriminate the sleepiness level of OSA patients from that of normal [35]. The score is based on a 0–24 point scale, with higher scores representing greater levels of sleepiness. Self-rated sleepiness was also assessed via a modified Visual Analog Scale (VAS). The score was the number circled on a range from 0 to 10, with the higher score indicating more sleepiness.

2.6.1. Sleep Apnea Quality of Life Index (SAQLI). The SAQLI is an OSA-specific measure of health-related quality of life that is comprised of several sections: (1) Domain A: 14-item measure of daily activities, social interactions, and emotional functioning; (2) Domain B: OSA symptom list; and (3) Domain C: treatment-related symptom list. At baseline, the SAQLI total score is comprised of domains A and B [36, 37]. Once on therapy, domain C is assessed and included in the total score.

Depressive symptoms were measured using the Center for Epidemiological Studies-Depression Scale short form (CES-D). The CES-D is a 10-item self-report measure of depression [38]. The 10-item version has adequate predictive accuracy when compared to the original full-length 20-item version, as well as adequate test-retest correlations and discriminative validity [39].

2.6.2. Computer Use and Experience Survey. The Computer Use and Experience Survey was given to participants at baseline and 4 month followup. This 14-item questionnaire is designed to assess participants' familiarity with using a computer and the internet. Participants are also asked whether they use the internet to search for health-related information and whether they feel confident in the information that they find [40].

2.6.3. Patient Satisfaction. This short questionnaire was administered at the 4-month followup to assess satisfaction with various aspects of the intervention, including the technical and personal manner of the provider with whom they interacted, the likelihood of continuing to use CPAP and whether they had concerns about their CPAP data being viewed daily by research staff or whether they had concerns about their data being sent over the internet [41].

2.6.4. MyCPAP OSA Symptom Tracking. Participants could track up to 5 of their most important OSA-related symptoms on the MyCPAP website. OSA symptoms were originally selected from a list of 25 symptoms from the symptom list of the Sleep Apnea Quality of Life Index [37]. The most important 5 symptoms were then rated in terms of how much of a problem each symptom has been for the patient, and were anchored by the following rating scale: 1 = no problem and 5 = severe problem. Participants were given the option to track these symptoms on a weekly basis.

3. Results

Two hundred forty-one participants were enrolled over the project period (115 to Usual Care and 126 to the MyCPAP group). The total number of withdrawals during the course of the project was seven. These were due to CPAP intolerance or subsequent self-withdrawal from the study. Baseline rates of OSA patients with CPAP intolerance or refusal is estimated to be about 20% in clinical practice. In our project, this worked out to be about 3%, so appeared to be significantly lower.

The average Body Mass Index (BMI) was 32.5 indicating that the majority of the participants enrolled in the study were overweight (defined as having a BMI greater than 30). The average Apnea-Hypopnea Index (AHI) for participants in the study was 36.5, which is categorized as being within the severe level of sleep apnea. The mean ESS score was 10.6, indicating that most participants had a significant level of excessive daytime sleepiness. There were no significant differences at baseline between the groups on age, BMI, AHI, or ESS (see Table 2).

3.1. CPAP Adherence. Figures 1 and 2 show the difference in CPAP adherence between the two groups at the 2-month and 4-month time points. Those who were randomized to the MyCPAP used CPAP on average nearly one hour per night longer than those in the Usual Care group at the 2-month time point (3.4 \pm 2.4 and 4.1 \pm 2.3 hrs/nt; $P = 0.02$; mean \pm SD), and those results held at the 4-month time point (3.2 \pm 2.4 versus 3.9 \pm 2.3 hrs/nt; $P = 0.03$).

Figure 1 provides the nightly data from the first 14 days of use. Those randomized to the MyCPAP intervention appear to have a slight increase in use early in the treatment initialization process and that effect appears to sustain itself over time. These data are important because the literature suggests that adherence patterns are established relatively early in the treatment initialization process.

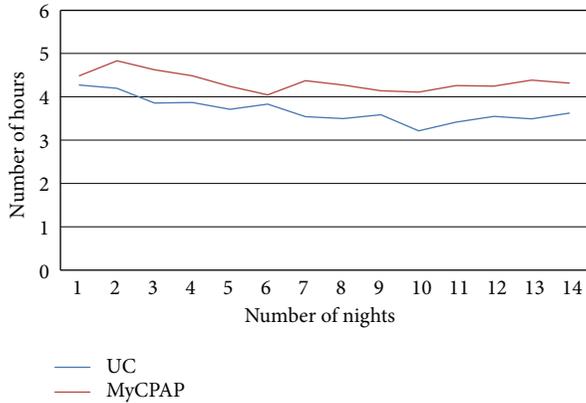


FIGURE 1: Adherence data over first 14 nights of CPAP usage.

Despite the difference in adherence in the two groups, no differences were found on self-reported measures of OSA symptoms. Table 3 provide data on the Epworth Sleepiness Scale, Sleep Apnea Quality of Life Scale, and the Center for Epidemiological Studies—Depression.

3.2. MyCPAP Group and Internet Use. Figure 2 provides the frequency of response to how often the internet was used to get information on sleep apnea at baseline and at the 4-month time point. The data shows that at baseline approximately 38% searched the internet for OSA information (21% “some,” 11% “fair amount,” and 6% “a lot”). At 4 months, the percentage who reported using the internet to search for OSA information increased to 62% (33% “some,” 21% “fair amount,” and 8% “a lot”). One can see the shift in the distribution from baseline to the 4-month time point.

Figure 3 provides the frequency of response to how often the internet was used to get information on health in general at baseline and at the 4-month time point. The data shows that there was very little difference in the frequency with which the internet was used to access general information at health between baseline and the 4-month time point.

Figure 4 provides the frequency of response to the confidence of the participants about the accuracy of the health information found on the internet and how often the internet was used to get information on health in general at baseline and at the 4-month time point. The data shows that there was very little change in the confidence of the accuracy for general health information on the internet across the time points, with approximately 50% agreeing or strongly agreeing at each time point. About 40% said they were not sure about the accuracy of the health information on the internet.

3.3. OSA Symptom Tracking. One aspect of the MyCPAP website was the ability for the participants to track their OSA symptoms over time. Users could select the symptoms that most affected them, and then track those symptoms over time on a rating scale that was anchored with 5 being a severe problem and 1 being no problem. Figures 5(a)–5(c) includes baseline ratings of those symptoms. The figures are line graphs of both the tracking of the symptoms over

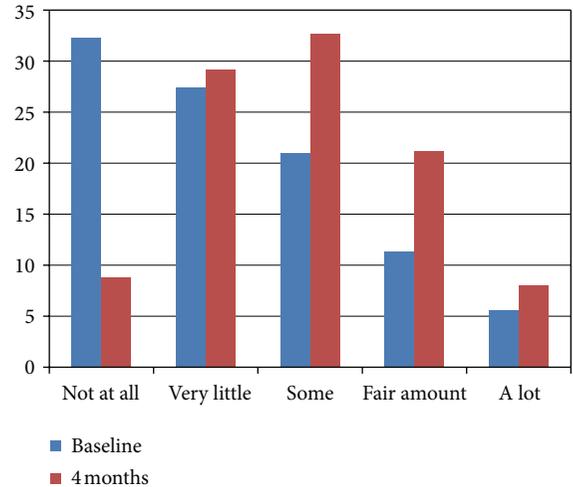


FIGURE 2: Frequency of response to how often the internet is used to get information on sleep apnea, at both baseline and four months (intervention group, only).

time (1–5 scale) and CPAP adherence (in hrs/nt). The data from these three case examples were included because each included over 11 weeks of symptom tracking and CPAP adherence of greater than 4 hours per night. While each of the three cases show some symptom improvement, even in good users of CPAP, only one symptom is rated as being very low in its impact. These data provide support for the idea that CPAP, even in those with adequate or better CPAP adherence, may help to control OSA during the time it is used, but may ultimately ineffectively manage all sleep-related problems that an OSA patient may be experiencing. This data are important for the sleep physician to monitor and work collaboratively with the patient to find ways to improve OSA clinical management.

3.4. Patient Satisfaction and Privacy. Several items assessed the satisfaction of the participants in the MyCPAP group on the technical skills and personal manner of the provider responsible for the care given in this group. For technical skills (thoroughness, carefulness, competence), only 5.6% rated these skills as fair or poor, and 94.4% rated them as good or better. For the personal manner (i.e., courtesy, respect, friendliness), 2.8% rated these skills as poor, 9.3% as fair, and 88% rated them as good or better. In terms of likelihood of continuing to use CPAP in the future, 64% rated themselves as “extremely” likely to continue to use CPAP and 21% rated themselves as “highly” likely. Because the MyCPAP website required use of the internet to track both CPAP data and their own symptom data, patients were asked about their concerns about viewing the data daily or about being concerned about the information being sent over the internet. The majority of users indicated that they were “not at all” concerned about these issues.

TABLE 3

Measure	2 month visit				4 month visit			
	Both groups	UC (N = 114)	PC3 (N = 126)	P value	Both groups	UC (N = 114)	PC3 (N = 126)	P value
Epworth sleepiness scale	8.5 ± 5.4	8.1 ± 5.5	8.9 ± 5.3	NS	6.5 ± 4.2	5.7 ± 3.6	7.1 ± 4.5	NS
Sleep apnea quality of life	4.7 ± 2.1	4.5 ± 2.3	4.9 ± 1.9	NS	4.8 ± 2.3	4.6 ± 2.6	5.1 ± 2.0	NS
CES-D	8.5 ± 5.4	8.1 ± 5.5	8.9 ± 5.3	NS	7.9 ± 5.2	7.1 ± 4.9	8.6 ± 5.5	NS
Patient satisfaction	1.7 ± 1.2	1.8 ± 1.3	1.7 ± 1.1	NS	1.8 ± 1.2	1.9 ± 1.3	1.7 ± 1.1	NS

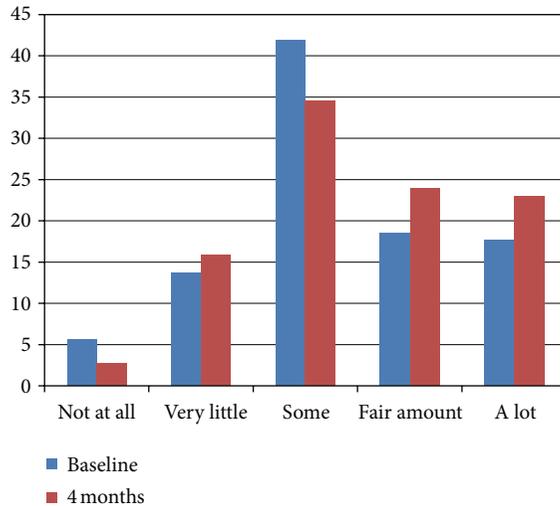


FIGURE 3: Frequency of response of how often the internet is used to get information on health, at both baseline and at four months (intervention group, only).

4. Discussion

The study examined the patient perspective in using the MyCPAP website to help manage OSA. The study found that those sleep apnea patients who were randomized to the MyCPAP group had higher levels of CPAP use than those in the Usual Care group. When the nightly data over the first 2 weeks was plotted, it appeared that the use of the website had an effect that began early in the treatment initialization process and was sustained over time.

Despite the significant change in CPAP adherence, there were no differences on the self-reported measures of OSA symptoms. The two groups did not differ at baseline on any of these measures, which meant that randomization worked in that the groups were similar on sleepiness level, OSA-specific quality of life and on depressive symptoms. It may be that a difference of one hour of CPAP use has minimal effect on improving OSA symptoms. Alternatively, it may be that the usual care group's level of CPAP use is enough to improve OSA symptoms. Rather than look at group differences, if we look at the magnitude of change for the groups, we see that for the Epworth Sleepiness Scale, both groups dropped about three points, to a mean of about 8. The cut-off for ESS is about 10, so that anything below is considered to be low sleepiness. For the SAQLI, the SAQLI user manual suggests

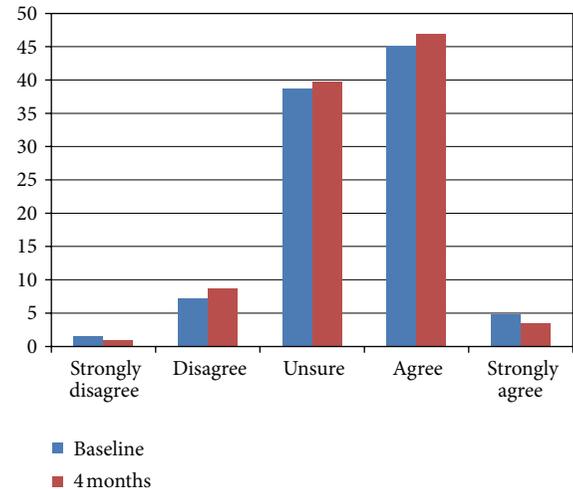
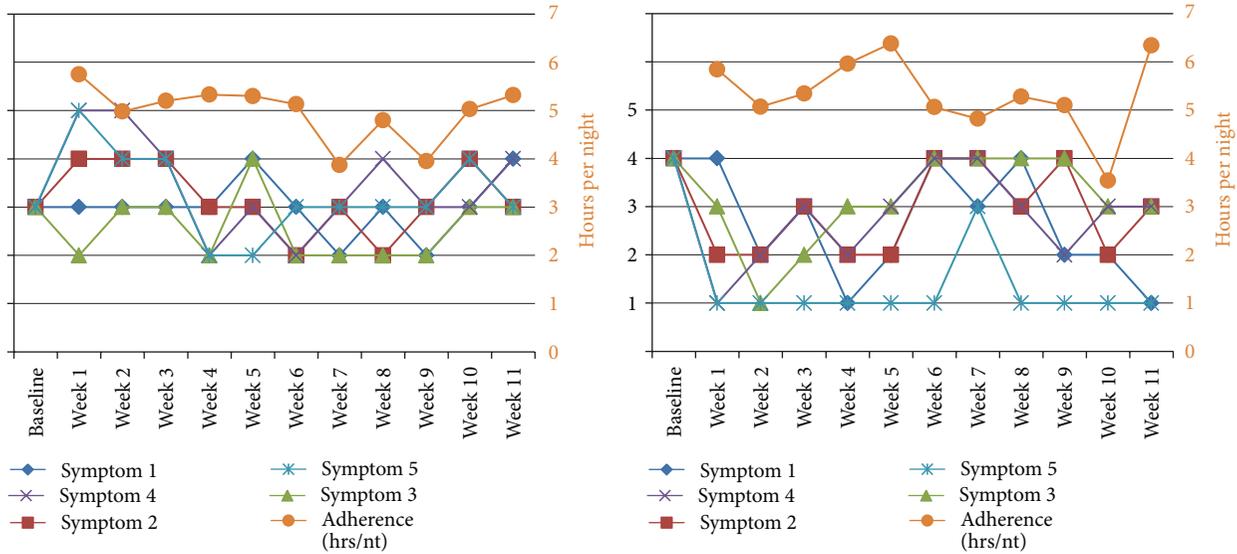


FIGURE 4: Frequency of response of the confidence about the accuracy of the health information found on the internet at baseline and at four months.

that a change of 0.1 is a clinically meaningful change. If this is indeed the case, then both groups improved a clinically meaningful amount (each improved by 0.2 points on the SAQLI total score).

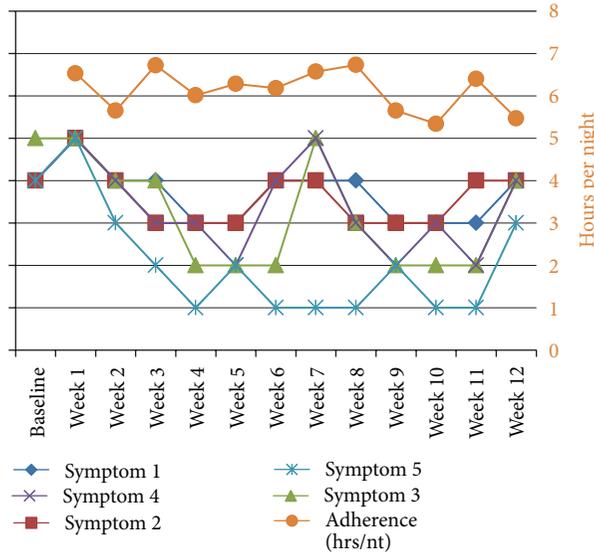
Future studies will need to evaluate the change in symptoms over longer periods of time to see whether the use of an intervention has a longer-term impact on OSA symptoms. One might expect that if usual care does not include any followup (which is often the case clinically) versus scheduled ongoing follow-up sessions, the potential for maintenance or improvement in CPAP use might be expected for the intervention group. Only studies with longer-term follow-up periods, on the order of 1-2 years, can begin to answer this question.

This study was conducted at the Veterans Affairs Medical Center and was required to follow the policies and procedures in place at the time for the conduct of research studies. Some of the planned features for the website were deemed as possible privacy or security risks and were therefore not designed as part of the website, including email correspondence with providers, the use of forums or discussion boards for group members, the use of any open-ended questions or the use of an online diary, and website use tracking. Future iterations of an interactive website may benefit from including any one of these or other similar components. Clearly, lessons we learned from a previous study on group self-management



(a) Patient 1

(b) Patient 2



(c) Patient 3

FIGURE 5: Tracking sleep apnea symptoms over time: example of three users.

intervention for OSA patients was that peer support was an important part of the management process [28]. Kate Lorig and colleagues have long espoused the importance of peer support [42].

When those participants in the MyCPAP group were asked about their use of the Internet and website, results showed that they significantly increased their use of the Internet to obtain information about sleep apnea from baseline to 4 months. But while they may have used the internet more to obtain information about sleep apnea, they did not increase their use of the internet to find information about their general health, nor did use of the MyCPAP website increase their confidence about the accuracy of health information found on the internet. In large part, this would appear to make sense because the MyCPAP website was known to

them, as was the researcher team who developed it. In fact, we would have been surprised if knowledge and use of one disease-specific website generalized to others on the internet. This likely speaks to the discretion of those enrolled in our research study.

We had an opportunity to take a closer look at the tracking of sleep apnea symptoms by those enrolled in the MyCPAP group. What seems to be apparent from Figures 5(a)–5(c) is that there is not a clear resolution of OSA-related symptoms even for these very good users of CPAP (i.e., use of CPAP more than 4 hrs/nt), if clear resolution is defined as a symptom rating of 2 or less (i.e., mild or no problem). This is consistent with one interesting unpublished result from one of our previous studies, which was that 60% of the sample still had self-reported disturbed sleep, as measured

by the Pittsburgh Sleep Quality Inventory, even while being “compliant” with CPAP therapy at the 2-month time point. And Wickwire and colleagues found that those OSA patients with the complaint of insomnia had lower rates of CPAP use [43]. While placebo controlled trials of CPAP indicate that CPAP is highly efficacious at controlling apneas and hypopneas during sleep [44], it is becoming increasingly clear that this does not necessarily translate into the reduction of OSA symptoms to normal levels. Future studies will need to examine this issue in more depth, especially using new remote data capture methods that allow for more frequent assessments of OSA symptoms when using CPAP.

Our group has examined the quality of sleep apnea information on the internet and found that only 2% of sleep apnea-related websites contained any graphical interactivity [45]. Since that time, other more general disease-oriented sites such as *curetogether.com* or *patientslikeme.com* have included the ability to track OSA-related symptoms to users who sign up for those kinds of services.

The results of this paper found that while the confidence of OSA patients in the accuracy of the MyCPAP website increased over time, this did not generalize to other health-related websites. Our group also reviewed OSA-specific websites for measures of credibility (such as web certification, references, or display of authorship [46]), finding that fewer than 20% of the reviewed OSA websites included these kinds of measures of website credibility [45]. This makes sense given that the OSA participants in the current study knew the developers and the source of the MyCPAP website, while they may not know the source of the information in other health-related websites. And given that our review of OSA websites found that 80% did not include basic measures of website credibility, it is understandable that our OSA patients are leary of the information they found on the internet. Indeed, results of the 10th annual Health on the Net (HON) survey on health and medical information on the internet found that trustworthiness/credibility (96%) and accuracy of information (95%) to be the two most important factors related to the use of medical/health information on the internet [32]. When verifying whether the medical/health website is credible or not, users look to the source of the information (88%), the motivation of the owners of the website (68%), the URL (i.e., whether it is a commercial website or not; 66%), and the source of the funding for the website (55%). The reliability and quality of health information online continues to be a source of debate [47].

In terms of new ways to evaluate the credibility and accuracy of health and medical information on the internet, especially in this new era of interactive technologies, a recently published study provides such a framework [48]. Traditionally, these kinds of evaluations have included elements such as content credibility, interface usability, and overall appeal of website design. However, given the new “web 2.0” technologies that allow for more collaborative, adaptive and interactive components, the need for more “dynamic” evaluative criteria are important to account for the more interactive nature of these newer technologies. In particular, user-generated data, whether from online questionnaire tracking (e.g., Figures 5(a)–5(c) in this study)

physiological measurement (e.g., blood pressure, weight), or from medical devices (e.g., CPAP or glucometer), is rapidly increasing. Also, the social nature of these websites is a rapidly expanding component, whether in terms of allowing peers to connect with each other, or allowing patients to connect with providers. The new framework includes formative, summative and outcome evaluation measures for five themes: people, content, technology, computer-mediated interaction, and health systems integration. While the utility of this framework will only be known over time, such efforts are needed to improve the design, development and efficiency of health-information websites. Ultimately, the goal is to improve the ability to provide accurate, reliable information and interactive applications for patients so that their health can be improved.

The present study shows that the use of an interactive sleep apnea website can improve CPAP adherence, but that future iterations of such an intervention are needed to effect change in OSA outcomes. The use of such an intervention has the potential to be an important supplement to usual clinical care because of the power to provide educational and clinical information to the patient that is typically not provided to them.

Conflict of Interests

All authors acknowledge their responsibility to disclose any new reportable financial interest obtained during the term of the project. All authors have no financial interest.

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References

- [1] A. G. Bassiri and C. Guilleminault, “Clinical features and evaluation of obstructive sleep apnea-hypopnea syndrome,” in *Principle and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W. C. Dement, Eds., pp. 869–878, W.B. Saunders, Philadelphia, Pa, USA, 2000.
- [2] T. Young, M. Palta, J. Dempsey, J. Skatrud, S. Weber, and S. Badr, “The occurrence of sleep-disordered breathing among middle-aged adults,” *The New England Journal of Medicine*, vol. 328, no. 17, pp. 1230–1235, 1993.
- [3] N. Alghanim, V. R. Comondore, J. Fleetham, C. A. Marra, and N. T. Ayas, “The economic impact of obstructive sleep apnea,” *Lung*, vol. 186, no. 1, pp. 7–12, 2008.
- [4] A. V. Chobanian, G. L. Bakris, H. R. Black et al., “The seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report,” *Journal of the American Medical Association*, vol. 289, no. 19, pp. 2560–2572, 2003.
- [5] S. K. Sharma, S. Agrawal, D. Damodaran et al., “CPAP for the metabolic syndrome in patients with obstructive sleep apnea,” *The New England Journal of Medicine*, vol. 365, no. 24, pp. 2277–2286, 2011.

- [6] K. Monahan and S. Redline, "Role of obstructive sleep apnea in cardiovascular disease," *Current Opinion in Cardiology*, vol. 26, no. 6, pp. 541–547, 2011.
- [7] B. El-Ad and P. Lavie, "Effect of sleep apnea on cognition and mood," *International Review of Psychiatry*, vol. 17, no. 4, pp. 277–282, 2005.
- [8] A. T. Mulgrew, G. Nasvadi, A. Butt et al., "Risk and severity of motor vehicle crashes in patients with obstructive sleep apnoea/hypopnoea," *Thorax*, vol. 63, no. 6, pp. 536–541, 2008.
- [9] C. E. Sullivan, F. G. Issa, M. Berthon-Jones, and L. Eves, "Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares," *The Lancet*, vol. 1, no. 8225, pp. 862–865, 1981.
- [10] D. I. Loubé, P. C. Gay, K. P. Strohl, A. I. Pack, D. P. White, and N. A. Collop, "Indications for positive airway pressure treatment of adult obstructive sleep apnea patients: a consensus statement," *Chest*, vol. 115, no. 3, pp. 863–866, 1999.
- [11] S. R. Patel, D. P. White, A. Malhotra, M. L. Stanchina, and N. T. Ayas, "Continuous positive airway pressure therapy for treating sleepiness in a diverse population with obstructive sleep apnea results of a meta-analysis," *Archives of Internal Medicine*, vol. 163, no. 5, pp. 565–571, 2003.
- [12] J. Wright, R. Johns, I. Watt, A. Melville, and T. Sheldon, "Health effects of obstructive sleep apnoea and the effectiveness of continuous positive airways pressure: a systematic review of the research evidence," *British Medical Journal*, vol. 314, no. 7084, pp. 851–860, 1997.
- [13] N. McArdle, R. Kingshott, H. M. Engleman, T. W. Mackay, and N. J. Douglas, "Partners of patients with sleep apnoea/hypopnoea syndrome: effect of CPAP treatment on sleep quality and quality of life," *Thorax*, vol. 56, no. 7, pp. 513–518, 2001.
- [14] J. C. T. Pepperell, S. Ramdassingh-Dow, N. Crosthwaite et al., "Ambulatory blood pressure after therapeutic and subtherapeutic nasal continuous positive airway pressure for obstructive sleep apnoea: a randomised parallel trial," *The Lancet*, vol. 359, no. 9302, pp. 204–210, 2002.
- [15] A. Bahammam, K. Delaive, J. Ronald, J. Manfreda, L. Roos, and M. H. Kryger, "Health care utilization in males with obstructive sleep apnea syndrome two years after diagnosis and treatment," *Sleep*, vol. 22, no. 6, pp. 740–747, 1999.
- [16] A. M. Sawyer, N. S. Gooneratne, C. L. Marcus, D. Ofer, K. C. Richards, and T. E. Weaver, "A systematic review of CPAP adherence across age groups: clinical and empiric insights for developing CPAP adherence interventions," *Sleep Medicine Reviews*, vol. 15, no. 6, pp. 343–356, 2011.
- [17] C. J. Hoy, M. Vennelle, R. N. Kingshott, H. M. Engleman, and N. J. Douglas, "Can intensive support improve continuous positive airway pressure use in patients with the sleep apnea/hypopnea syndrome?" *American Journal of Respiratory and Critical Care Medicine*, vol. 159, no. 4, pp. 1096–1100, 1999.
- [18] D. S. C. Hui, J. K. W. Chan, D. K. L. Choy et al., "Effects of augmented continuous positive airway pressure education and support on compliance and outcome in a Chinese population," *Chest*, vol. 117, no. 5, pp. 1410–1416, 2000.
- [19] P. Collard, T. Pieters, G. Aubert, P. Delguste, and D. O. Rodenstein, "Compliance with nasal CPAP in obstructive sleep apnea patients," *Sleep Medicine Reviews*, vol. 1, no. 1, pp. 33–44, 1997.
- [20] H. M. Engleman and M. R. Wild, "Improving CPAP use by patients with the sleep apnoea/hypopnoea syndrome (SAHS)," *Sleep Medicine Reviews*, vol. 7, no. 1, pp. 81–99, 2003.
- [21] M. Haniffa, T. J. Lasserson, and I. Smith, "Interventions to improve compliance with continuous positive airway pressure for obstructive sleep apnoea," *Cochrane Database of Systematic Reviews (Online)*, no. 4, Article ID CD003531, 2004.
- [22] N. B. Kribbs, A. I. Pack, L. R. Kline et al., "Objective measurement of patterns of nasal CPAP use by patients with obstructive sleep apnea," *American Review of Respiratory Disease*, vol. 147, no. 4, pp. 887–895, 1993.
- [23] R. N. Kingshott, M. Vennelle, C. J. Hoy, H. M. Engleman, I. J. Deary, and N. J. Douglas, "Predictors of improvements in daytime function outcomes with CPAP therapy," *American Journal of Respiratory and Critical Care Medicine*, vol. 161, no. 3, part 1, pp. 866–871, 2000.
- [24] N. Pelletier-Fleury, D. Rakotonanahary, and B. Fleury, "The age and other factors in the evaluation of compliance with nasal continuous positive airway pressure for obstructive sleep apnea syndrome. A Cox's proportional hazard analysis," *Sleep Medicine*, vol. 2, no. 3, pp. 225–232, 2001.
- [25] C. J. Stepnowsky, M. R. Marler, and S. Ancoli-Israel, "Determinants of nasal CPAP compliance," *Sleep Medicine*, vol. 3, no. 3, pp. 239–247, 2002.
- [26] M. S. Aloia, J. T. Arnedt, C. Stepnowsky, J. Hecht, and B. Borrelli, "Predicting treatment adherence in obstructive sleep apnea using principles of behavior change," *Journal of Clinical Sleep Medicine*, vol. 1, no. 4, pp. 346–353, 2005.
- [27] M. R. Wild, H. M. Engleman, N. J. Douglas, and C. A. Espie, "Can psychological factors help us to determine adherence to CPAP? A prospective study," *European Respiratory Journal*, vol. 24, no. 3, pp. 461–465, 2004.
- [28] C. J. Stepnowsky, J. J. Palau, A. L. Gifford, and S. Ancoli-Israel, "A self-management approach to improving continuous positive airway pressure adherence and outcomes," *Behavioral Sleep Medicine*, vol. 5, no. 2, pp. 131–146, 2007.
- [29] Project PIAL, "Internet activities," October 1, 2008, http://www.pewinternet.org/trends/Internet_Activities.722.08.aspx.
- [30] S. Fox, "The Social Life of Health Information, 2011, Pew Research Center's Internet & American Life Project," 2012, <http://pewinternet.org/Reports/2011/Social-Life-of-Health-Info.aspx>.
- [31] J. Fox, E. Black, I. Chronakis et al., "From guidelines to careflows: modelling and supporting complex clinical processes," *Studies in Health Technology and Informatics*, vol. 139, pp. 44–62, 2008.
- [32] N. Pletneva, S. Cruchet, M. A. Simonet, M. Kajiwara, and C. Boyer, "Results of the 10 HON survey on health and medical internet use," *Studies in Health Technology and Informatics*, vol. 169, pp. 73–77, 2011.
- [33] S. R. Tunis, D. B. Stryer, and C. M. Clancy, "Practical clinical trials: increasing the value of clinical research for decision making in clinical and health policy," *Journal of the American Medical Association*, vol. 290, no. 12, pp. 1624–1632, 2003.
- [34] AASM, "Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research. The Report of an American Academy of Sleep Medicine Task Force," *Sleep*, vol. 22, no. 5, pp. 667–689, 1999.
- [35] M. W. Johns, "A new method for measuring daytime sleepiness: the Epworth sleepiness scale," *Sleep*, vol. 14, no. 6, pp. 540–545, 1991.
- [36] W. W. Flemons, "Measuring health related quality of life in sleep apnea," *Sleep*, vol. 23, supplement 4, pp. S109–S114, 2000.

- [37] W. W. Flemons and M. A. Reimer, "Development of a disease-specific health-related quality of life questionnaire for sleep apnea," *American Journal of Respiratory and Critical Care Medicine*, vol. 158, no. 2, pp. 494–503, 1998.
- [38] L. S. Radloff, "The CES-D scale: a self-report depression scale for research in the general population," *Applied Psychological Measurement*, vol. 1, pp. 385–401, 1977.
- [39] E. M. Andresen, J. A. Malmgren, W. B. Carter, and D. L. Patrick, "Screening for depression in well older adults: evaluation of a short form of the CES-D," *American Journal of Preventive Medicine*, vol. 10, no. 2, pp. 77–84, 1994.
- [40] H. I. Goldberg, J. D. Ralston, I. B. Hirsch, J. I. Hoath, and K. I. Ahmed, "Using an Internet comanagement module to improve the quality of chronic disease care," *Joint Commission Journal on Quality and Safety*, vol. 29, no. 9, pp. 443–451, 2003.
- [41] J. E. Ware Jr. and R. D. Hays, "Methods for measuring patient satisfaction with specific medical encounters," *Medical Care*, vol. 26, no. 4, pp. 393–402, 1988.
- [42] K. R. Lorig and H. R. Holman, "Self-management education: history, definition, outcomes, and mechanisms," *Annals of Behavioral Medicine*, vol. 26, no. 1, pp. 1–7, 2003.
- [43] E. M. Wickwire, M. T. Smith, S. Birnbaum, and N. A. Collop, "Sleep maintenance insomnia complaints predict poor CPAP adherence: a clinical case series," *Sleep Medicine*, vol. 11, no. 8, pp. 772–776, 2010.
- [44] C. McDaid, K. H. Durée, S. C. Griffin et al., "A systematic review of continuous positive airway pressure for obstructive sleep apnoea-hypopnoea syndrome," *Sleep Medicine Reviews*, vol. 13, no. 6, pp. 427–436, 2009.
- [45] T. Zamora and C. J. Stepnowsky, "Surfing for sleep apnea: a review of the quality of information for patients on the internet," *Sleep*, vol. 32, pp. 225–226, 2009.
- [46] J. J. Seidman, D. Steinwachs, and H. R. Rubin, "Design and testing of a tool for evaluating the quality of diabetesconsumer-information web sites," *Journal of Medical Internet Research*, vol. 5, no. 4, p. e30, 2003.
- [47] S. A. Adams, "Revisiting the online health information reliability debate in the wake of "web 2.0": an inter-disciplinary literature and website review," *International Journal of Medical Informatics*, vol. 79, no. 6, pp. 391–400, 2010.
- [48] L. O'Grady, H. Witteman, J. L. Bender, S. Urowitz, D. Wiljer, and A. R. Jadad, "Measuring the impact of a moving target: towards a dynamic framework for evaluating collaborative adaptive interactive technologies," *Journal of Medical Internet Research*, vol. 11, no. 2, p. e20, 2009.

Research Article

Experience-Sampling Methodology with a Mobile Device in Fibromyalgia

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This work describes the usability studies conducted in the development of an experience-sampling methodology (ESM) system running in a mobile device. The goal of the system is to improve the accuracy and ecology in gathering daily self-report data in individuals suffering a chronic pain condition, fibromyalgia. The usability studies showed that the developed software to conduct ESM with mobile devices (smartphones, cell phones) can be successfully used by individuals with fibromyalgia of different ages and with low level of expertise in the use of information and communication technologies. 100% of users completed the tasks successfully, although some have completely illiterate. Also there seems to be a clear difference in the way of interaction obtained in the two studies carried out.

1. Introduction

Chronic pain is one of the most common causes of disability, affecting millions of people around the world. Fibromyalgia (FM) is a chronic musculoskeletal pain condition with unknown etiology, characterized by widespread pain accompanied by fatigue and disturbed sleep and mood [1]. Patients remain symptomatic and do not improve over long periods of time.

There is a growing interest in the study of fibromyalgia in order to understand the mechanisms underlying this condition and to offer a better treatment response to the individuals who suffer this impairing disease.

In order to achieve this goal it is important to improve the assessment of key variables like pain and fatigue intensity and mood, among others. One methodology that could be very useful in this field is experience-sampling methodology (ESM) aimed to explore the daily experience of individuals suffering different pathologies (in our case fibromyalgia). ESM is a within-day self-assessment technique in which participants are prompted at established or random intervals

to report on relevant variables related to their health condition. This method presents several advantages over traditional assessment. Some authors [2–5] highlight the main advantages of ESM, including: (a) enhances ecological validity because it assesses participants in their normal daily environment; (b) minimizes retrospective bias by assessing the participant's experience in the moment; (c) allows for an examination of the context of experiences. Ecological momentary assessment (EMA) is a repeated sampling of behaviors and experiences of the subject in real time and in real environment. EMA reduces the effects of retrospective biases and provides ecological information to a better understanding of the processes of psychiatric or medical disorders [6, 7].

According to Trull and Ebner-Priemer [3], one clinical application of ESM/EMA could be to monitor treatment progress. Also, they state that mobile electronic devices can be used successfully to administer treatments, suggesting that ESM/EMA data can be helpful in clinical assessment, specifically, to provide a detailed account and understanding of an individual's problems as experienced in daily life [3].

In other recent study, focused on exploring prospective associations between daily behavioral anger expression and daily chronic pain intensity, Bruehl and colleagues [8] assert that electronic EMA diary methods have numerous advantages over others. Data are less influenced by various potential sources of bias in recalled memory of pain: recency effects, peak experiences, biasing of mood, and the impact of current pain intensity.

Mobile devices are a good means of conducting ESM and one of the research lines of our team is to explore the utility of mobile devices in the psychological assessment and intervention of chronic pain.

With the evolution of mobile devices, the concept of *context* of use has gained relevance from the usability point of view [9–11]. Mobile devices allow having access to a wide number of situations in which technology was too invasive or inaccessible until recently. Its small size and portability are their main advantages; however, these same features make design and usability an important challenge. First, a small size screen involves not being able to design interactive elements smaller than the fingers, and second, the size limits the number of functions to be implemented [12]. Optimizing the number of steps and functions and the size and colour of the elements constitute important issues in the design process. Fortunately, since the emergent of the first smartphones until now, a wide number of usability guidelines have appeared, showing the growing interest from the human-computer interaction (HCI) field for mobile devices [13–16].

The features of the mobile device, the context of use, and the final user are essential variables to take into consideration in the development of any application. In the case of fibromyalgia sufferers, they are between 40 and 60 years old [17]. Besides, it is important to take into consideration that most of these users are on the other side of the *digital divide* [18] and their difficulties in the use of ITC could be bigger than the ones observed in younger individuals [19].

This work describes the usability study conducted in the development of an application which goal is to adapt three self-report scales to mobile devices. The final goal is to have available an experience-sampling methodology (ESM) for the ecological evaluation of key variables in chronic pain that could be used by individuals of different ages and different level of expertise in the use of ICT (Information and communications technology).

2. Method

2.1. Professionals Involved in the Design. In order to assure that the objectives of the study were met a multidisciplinary team participated in the usability studies. The team of professionals involved in the design of the application included a clinical psychologist with expertise in the field of chronic pain, a psychologist with expertise in usability, and a computer engineer.

2.2. Pilot Study 1: Evaluation of High Fidelity Mockups. The objective of study 1 was to conduct a user test with nonfunctional prototypes in the form of high fidelity mockups.

2.2.1. Initial Specifications. The aim of the software for mobile devices (smartphones) was to gather in real time self-report measures key in chronic pain: intensity of pain, intensity of fatigue, and general mood. Data are daily downloaded to the database automatically.

The self-report scales are perceived pain intensity, perceived fatigue intensity (11-point scales), and general mood (7-point scale, represented with emoticons):

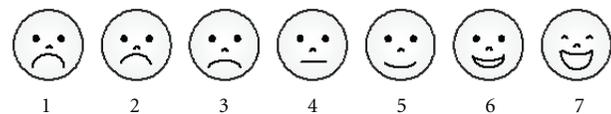
“Please, indicate the number that best describes the intensity of the pain you are feeling now:”



“Please, indicate the number that best describes the intensity of the fatigue you are feeling now:”



“Please, indicate the face that best describes your current mood:”



The design should adapt these scales including all the features to a screen of 240×320 pixels.

Taking into account that the final users are middle age and older, with very low or no expertise in the use of smartphones, it is very likely that they experience a low control over the technology. On the other hand, it is necessary, given the final use of the application, that they are confident in the ratings they give. In order to increase the perceived control over the ratings, one feature included in the three scales was to confirm the ratings. In order to achieve this goal the metaphor of pushing the button was used. In this way the selection of the rating was visible. After this the application required to press an OK button to confirm the selection. In Figure 1, the pain scale is displayed. On the left we offer the image of the scale before the selection of the user, and on the right the image of the scale after selecting number 4. Besides, in order to make easier that the user understand the meaning of the scale the colour of the buttons were graduated from green (less pain or fatigue) to red (more pain or fatigue).

The size of the typography was also considered to make easy reading the numbers and words. 22-point size sans-serif was established for the words and 72-point size for the numbers.

The system gathered the data in the following two ways: *Predetermined and Automatic*. The assessment will be carried out three times a day. A default scheduled was determined: at 9, 15, and 21 h. It was possible to change these times in order to meet the daily schedules of the different users.

An audio signal will indicate the user that it is the time to give the ratings in the three scales. If the user does not give

TABLE 1: Study 1: Sample description.

ID	Gender	Age	Level of education	Level of expertise computers/internet/e-mail	Level of expertise cell phone	Level of expertise touch screen
User 1	Female	66	Primary study level	Low	Moderate	Moderate
User 2	Female	40	primary study level	None	Moderate	Moderate
User 3	Female	64	Primary study level	None	Low	Low
User 4	Female	55	Secondary school level	High	High	None

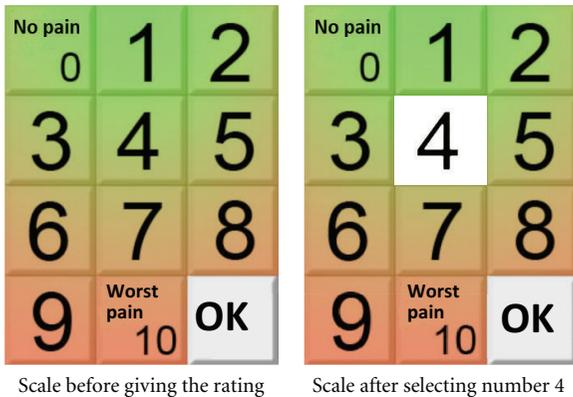


FIGURE 1: Specification: before pushing the OK button.

the ratings the audio signal will sound again every 15 minutes for the first hour and once an hour until 2 hours before the next assessment. After that time, the application will consider that the user is absent and that the assessment has not been performed.

Free Access. The users will be able to access the scales when they want. To access the application they just have to touch the screen and confirm the intention of giving ratings by pushing the button: Accept.

2.2.2. Sample. The sample included 4 women who met the American College of Rheumatology (ACR) fibromyalgia criteria [17]. Table 1 summarizes the characteristics of the sample. Their age ranged from 40 to 66 years. Three users had a primary study level and one a secondary school level.

Regarding the technological profile of the participants, 3 different areas could be identified as follows.

- (i) Level of use of computers/Internet/e-mail: frequency of use of each technology.
- (ii) Level of use of cell phone: Frequency of use, perceived ease of use, being able to read SMS and being able to write SMS.
- (iii) Level of use of touch screen: use of touch screen devices, perceived ease of use.

None of the users had any previous experience with the use of smartphones.

With regard to the technological profile, the sample has a very low level of expertise in the use of computers/Internet/e-mail, an heterogeneous level of expertise in the use of the cell phone (low = use of cell phone just to talk; moderate = use

of cell phone to talk and read SMS; high = use of cell phone to talk read and write SMS); and an heterogeneous level of expertise in the use of touch screens.

The participants did not present any cognitive impairment. Their auditory and motor skills were suitable in order to follow a conversation and interact with the touch screen.

2.2.3. Procedure. The participants were referred by the rheumatology unit of the major hospital in the area (Hospital General de Castellon) in order to receive psychological treatment for chronic pain management. All were volunteers and signed an informed consent.

The researchers contacted each participant to set a date in order to conduct the usability study. The study was conducted at the Psychology and Technology Lab (Labpsitec) at Universitat Jaume I in Castellon, Spain.

Each user participated in a session that was recorded in order to make the suitable analysis. The experimental session had an average duration of 30 minutes and the four sessions were conducted in a single day.

The materials used in the test were as follows.

- (i) High fidelity mockups representing the instructions and assessment scales. A picture of the mobile device (real size) was also included in order to facilitate a context of use and to make more understandable the tasks to be performed (see Figure 2).
- (ii) Questionnaire designed *AD HOC* for this study.

The participants were told that they will be asked to make a simulation of the assessment of pain intensity, fatigue intensity and general mood using a mobile device with three scales. They were asked to act as if they were alone, encouraging them to say out loud any thoughts regarding the use of the device.

The main evaluation protocol used in this study was the empirical method of task performance measures, obtaining quantitative measures of performance: success/failure rate in each task and time to complete the task. Besides, the participants were asked about the experience using a questionnaire designed for this study. The main objective of the questionnaire was to assess ease of use and the users' opinion regarding the different elements.

2.2.4. Results and Usability Issues Identified. All users interacted with high fidelity mockups using the index finger.

The task of giving ratings in the three scales was successfully performed by all the participants. The opinion regarding the application (represented by high fidelity mockups) was very positive (see Table 2). All participants said the

TABLE 2: Users' opinion (Mockups).

Questions	Answers user study 1
Do you think the device was easy to use?	Yes 100%
Would you change anything?	The accept button (100%)
Do you think the size of the elements was adequate?	Yes (100%)
Do you like the design?	Yes (100%)
Do you think you would be able to use this device at home without help?	Yes (75%)

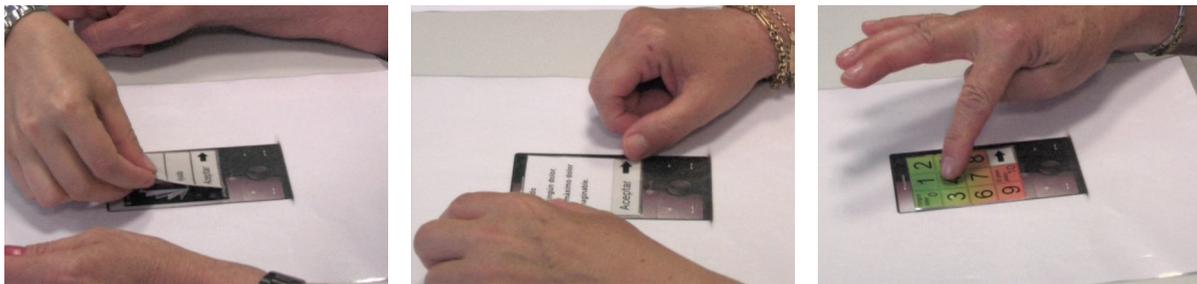


FIGURE 2: Mockups.

device was easy to use and they consider the design and the size of the elements suitable. Besides, 75% of the users thought they would be able to use the device.

The 75% of the users show some difficulties to understand how to advance. Initially, they did not understand the metaphor of the button, represented by an arrow. Despite this, they learnt fast and the difficulties showed just in the two first screens (out of 12). All participants suggested a change in the design of this element. Some users also suggested that the use of the system involved too many steps.

2.2.5. *Recommendations to Improve the Application.* After the test, the following recommendations were done to respond to the difficulties found by the participants.

- (i) Increase the intensity of the colour in the scales (see Figure 3).
- (ii) Change the accept button, including the “Accept” label text.
- (iii) Add audio to the written instructions.

All the recommendations were successfully implemented. The result was the development of the software FEMA-M v.1.0 (Fibromyalgia Ecological Momentary Assessment-Mobile v.1.0.). This software was tested in study 2.

2.3. *Pilot Study 2: First Functional Prototype. User Test.* The objective of study 2 is to test the first functional prototype of the software FEMA-M v.1.0.

2.3.1. *Sample.* The sample included 5 women meeting ACR fibromyalgia criteria [17]. Their age ranged from 36 to 66 years. Only one of the participants had a university degree. The other 4 had a primary study level.

As it can be seen in Table 3 regarding the technological profile of the sample, the level of expertise in the use of

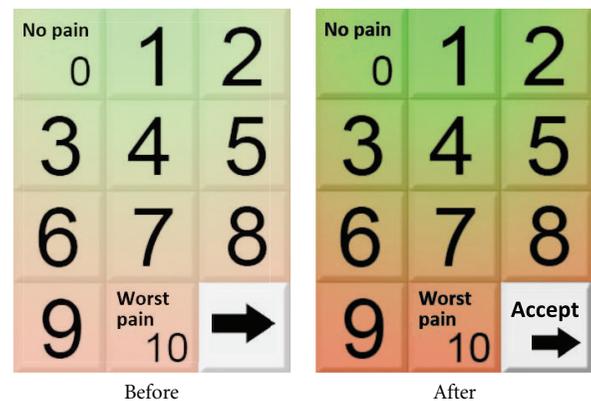


FIGURE 3: Colour of the scales, before and after performing the evaluation.

computers/Internet/e-mail is very low, the level of expertise in the use of the cell phone is either low or high. Finally, they reported a heterogeneous level of expertise in the use of touch screen.

The participants did not present any cognitive impairment. Their auditory and motor skills were suitable in order to follow a conversation and interact with the touch screen.

2.3.2. *Description of the Application.* The system is designed to gather self-report information about three key variables in chronic pain: perceived pain intensity (on an 11-point scale), perceived fatigue intensity (on an 11-point scale), and general mood (on a 7-point scale represented with emoticons). The different ratings are represented in 80 × 80 pixel buttons with a gradation in colour from green (for ratings representing less pain and fatigue and positive mood) to red (for ratings representing more intense pain and fatigue and negative mood).

TABLE 3: Study 2: Sample description.

User number	Gender	Age	Education	Level of expertise computers/internet/e-mail	Level of expertise cell phone	Level of expertise touch screen
User 1	Female	65	Primary study level	High	High	High
User 2	Female	64	Primary study level	None	High	Moderate
User 3	Female	40	Primary study level	None	Low	Low
User 4	Female	66	Primary study level	None	Low	Low
User 5	Female	36	University degree	None	High	High

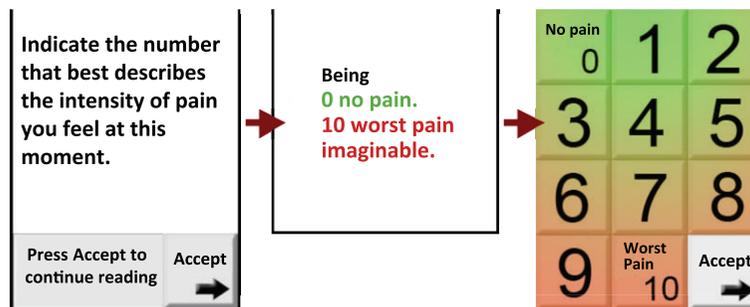


FIGURE 4: Pain intensity scale.

The system includes 12 screens with lineal navigation. The instructions are presented using text accompanied by audio (a male voice).

The chosen typography was 21-point sans-serif in order to facilitate the reading on the screen by the final users (middle age and older individuals). The inconvenient of using this size is that it is necessary to divide the information in several screens (2-3 screens by scale). In Figure 4 an example of the information and the pain intensity scale is displayed. (Figure 4—pain intensity scale).

In order to highlight the visibility of the “Accept” button, the icon of the arrow appears and disappears with a 2 second lapse.

The hardware used was a smartphone HTC Diamond 1: 51 × 102 × 11.5 mm; ROM 4352 MB; RAM 192 MB; 480 × 640 display resolution; 2.8” display diagonal; 16 bit/pixel display colour depth; audio stereo sound.

2.3.3. Procedure. The five participants were referred from the rheumatology unit of the major hospital in the area (Hospital General de Castellon) in order to receive psychological treatment for chronic pain management. All were volunteers and signed an informed consent.

The researchers contacted each participant to set a date in order to conduct the usability study. The study was conducted at the Psychology and Technology Lab (Labpsitec) at Universitat Jaume I in Castellon, Spain.

Users were instructed to answer the questions showed by mockups, trying to think that they were in a real situation, interacting with the smartphone alone, and answering the questions posed by the program without the possibility of getting any help during the task.

In this way, if the users asked for help during the task performance, this was rated as not completed or failed.

Each user participated in a session that was recorded in order to make the suitable analysis. The experimental session had an average duration of 35 minutes and the five sessions were conducted in a single day.

The recordings were subsequently reviewed by a usability expert and an engineer.

An example of the system and the evaluation process (study 1 and 2) is offered at: <http://www.labpsitec.uji.es/eng/multimedia/videosFM1.php>.

2.3.4. Results and Usability Issues Identified. The task: “Give a rating for each of the three questions that the application presents” was successfully completed by all the participants. The participants reported a positive view of the application. Participants reported that:

- (i) the device was easy to use (100% of users),
- (ii) they relieve they could use the system at home without help (100% of users),
- (iii) they liked the system (100% of users),
- (iv) they liked the design of the system (100% of users),
- (v) the size of the elements was adequate (100% of users),
- (vi) the typography was readable (100% of users).

Most users (80%) reported that the touch technology was easy to use.

The element of the system that the users disliked most (2 users) was the characteristics of the voice (they did not like the intonation and fact that it was a male voice).

One user said that the system had too many screens, but 80% (4 users) reported that they liked the length and the fact that it is possible to advance at a low pace.

The review of the video recordings showed that 100% of users used the smartphone with one hand, interacting with the thumb. This way of holding the device provoked some difficulties during the interaction. An example of this can be seen in the video aforementioned at the end of the procedure section (from minute 1:45 to minute 2:06).

3. Conclusion

One of the first lessons learned in this work, although it may be obvious, is the valuable contribution of the users to the design of any tool. In our case their participation in the study allows us to develop a suitable design, meeting both the clinical requirements and the needs of the users. One of the main challenges of the design was to strengthen the prevention of response errors. Given that this software is aimed at collecting mental health data, the interaction was guided by the following issues.

- (a) That the user was able to understand completely the instructions to provide a rating to each of the three scales.
- (b) That the user was able to visualize the chosen option and confirm that choice.

In order to implement these goals, several specifications were conducted. First, the size of the text was maximized to ensure the understanding of the instructions. This decision involved that the number of screens to present the 3 scales was 12. Some of the users reported that going through the total system was too long (20%), but, at the same time, most users reported that the rhythm and length of the presentation of the scales was adequate (80% of users). From a clinical point of view, this finding led us to take the decision of maintaining the size of the text despite the fact that going through the system was longer; that is, we sacrificed the comfort of the user in order to ensure the clinical utility of the application.

On the other hand, one of the results of study 2 that we consider relevant was that most users used the thumb to interact with the touch screen. This fact made us think that the use of this finger could increase the likelihood of making mistakes related with the selection of the ratings on the scales. Because of that we added to the design a feature that makes the user confirm the selection of the ratings: the user pushes the selected “button,” this adopts the image of a pushed button, and then the user pushes “Accept” to confirm the selection and continue. This feature was the most difficult to understand for the users. However, although the reported difficulties, a 100% of the users were able to complete the task and the learning curve was so fast (2-3 screens) that the difficulties disappeared very quickly. Our conclusion with regard to this issue was that despite this action decreased the intuitive value of the tool, provoking some puzzlement in the users (who expected that the system reacted automatically when they pushed the button), the learning curve was very fast and the benefits that this feature added to the application increased its utility and accuracy, given that the user could select an option and change it before confirm that choice (see Figure 3).

The design of the elements (metaphors, colours, size of the text, etc.) and the choice of the text labels are particularly important when the space is tight. However, the findings from study 1 and 2 related to the “Accept” button indicated that it was preferable to sacrifice some size in the text of the button and maintain the label to guide the users.

One of the issues we would like to emphasize is that although both studies had positive results in the resolution of tasks (a 100% success rate in both studies), we observed a clear difference in the way of interaction observed in each study. In study 1, conducted with high fidelity mockups, 100% of users interacted with the index finger. The mockups, displayed in paper, were placed on a table. However, in study 2, users took the device in their hand, and interacted with the thumb of the same hand. The graphical user interface (GUI) in both cases was the same, however using hardware support added value to the assessment of the GUI, since users changed their behavior when presented the GUI in a smartphone. This hardware influence in the interaction, and taking in to account the variety of types and sizes of smartphones available today, makes us reflect about the need of using definitive hardware models in the usability evaluation, even in early development stages.

Another issue that it is worth mentioning is that, despite the users quickly learnt to use the smartphone, a clear learning curve existed. Whereupon, giving these devices to end users, it may be beneficial to include a brief period of training with a professional (e.g., 10 minutes).

In a future line of work, we want to compare the way users interact with mobile devices of different sizes, and observe how they pick up the device, which hand they use to interact with the device, if they use only one hand or both, and the acceptability of the software depending on the hardware selected.

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References

- [1] R. M. Bennett, J. Jones, D. C. Turk, I. J. Russell, and L. Matalana, “An internet survey of 2,596 people with fibromyalgia,” *BMC Musculoskeletal Disorders*, vol. 8, article 27, 2007.
- [2] L. H. Brown, T. Strauman, N. Barrantes-Vidal, P. J. Silvia, and T. R. Kwapiil, “An experience-sampling study of depressive symptoms and their social context,” *Journal of Nervous and Mental Disease*, vol. 199, no. 6, pp. 403–409, 2011.
- [3] T. J. Trull and U. W. Ebner-Priemer, “Using Experience Sampling Methods/Ecological Momentary Assessment (ESM/EMA) in clinical assessment and clinical research: introduction to the special section,” *Psychological Assessment*, vol. 21, no. 4, pp. 457–462, 2009.
- [4] S. Consolvo, K. Everitt, I. Smith, and J. A. Landay, “Design requirements for technologies that encourage physical activity,” in *Proceedings of the Conference on Human Factors in*

- Computing Systems (CHI '06)*, pp. 457–466, Montréal, Canada, April 2006.
- [5] S. Consoivo, B. Harrison, I. Smith et al., “Conducting in situ evaluations for and with ubiquitous computing technologies,” *International Journal of Human-Computer Interaction*, vol. 22, no. 1-2, pp. 107–122, 2007.
 - [6] A. A. Stone and S. Shiffman, “Ecological momentary assessment (EMA) in behavioral medicine,” *Annals of Behavioral Medicine*, vol. 16, no. 3, pp. 199–202, 1994.
 - [7] A. A. Stone and J. E. Broderick, “Real-time data collection for pain: appraisal and current status,” *Pain Medicine*, vol. 8, no. 3, pp. S85–S93, 2007.
 - [8] S. Bruehl, X. Liu, J. W. Burns et al., “Associations between daily chronic pain intensity, daily anger expression, and trait anger expressiveness: an ecological momentary assessment study,” *Pain*. In press.
 - [9] N. Bevan and M. MacLeod, “Usability measurement in context,” *Behaviour & Information Technology*, vol. 13, pp. 1–2, 1994.
 - [10] N. S. Shami, G. Leshed, and D. Klein, “Context of use evaluation of peripheral displays (CUEPD),” in *Proceedings of the IFIP TC13 International Conference on Human-Computer Interaction (INTERACT '05)*, vol. 3585 of *Lecture Notes in Computer Science*, pp. 579–587, 2005.
 - [11] P. Thomas and R. Macredie, “Introduction to the New Usability,” *ACM Transactions on Computer-Human Interaction (TOCHI)*, vol. 9, no. 2, pp. 69–73, 2002.
 - [12] J. Nielsen, “Mobile Usability Update,” 2011, <http://www.useit.com/alertbox/mobile-usability.html>.
 - [13] S. Hong and S. C. Kim, “Mobile web usability: developing guidelines for mobile web via smart phones,” in *Proceedings of the Design, User Experience, and Usability. Theory, Methods, Tools and Practice*, vol. 6769 of *Lecture Notes in Computer Science*, pp. 564–572, Springer, Berlin, Germany, 2011.
 - [14] H. Rita, “Accessibility and usability guidelines for mobile devices in home health monitoring,” *ACM Sigaccess Accessibility and Computing*, vol. 84, pp. 26–29, 2006.
 - [15] J. Clark, *Tapworthy iPhone Design and User Experience*, O’Reilly Media, San Francisco, Calif, USA, 2011.
 - [16] W. Park, S. H. Han, S. Kang, Y. S. Park, and J. Chun, “A factor combination approach to developing style guides for mobile phone user interface,” *International Journal of Industrial Ergonomics*, vol. 41, no. 5, pp. 536–545, 2011.
 - [17] P. Baldry, M. B. Yunus, and F. Inanici, *Myofascial Pain and Fibromyalgia Syndromes: A Clinical Guide to Diagnosis and Management*, Churchill Livingstone, Edinburgh, UK, 2001.
 - [18] W. Wresh, *Disconnected: Haves and Have-Nots in the Information Age*, Rutgers University Press, New Brunswick, Canada, 1996.
 - [19] K. Coyne and J. Nielsen, “Web Usability for Senior Citizens: 46 Design Guidelines Based on Usability Studies with People Age 65 and Older,” Nielsen Norman Group Report, 2002, <http://www.nngroup.com/reports/seniors/>.

Research Article

Technological Approaches to Remote Monitoring of Elderly People in Cardiology: A Usability Perspective

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Moving from the experience gained in home telemonitoring of elderly patients with Congestive Heart Failure, that confirmed a reduction of the rehospitalization rate and an improved monitoring of drugs assumption by the patients, this paper extends the evaluation of technological approaches for remote health monitoring of older adults. Focus of the evaluation is on telemedicine effectiveness and usability, either from a patient's or a medical operator's perspective. The evaluation has been performed by testing three remote health platforms designed according to different technological approaches, in a realistic scenario involving older adults and medical operators (doctors and nurses). The aim of the testing activity was not to benchmark a specific solution with respect to the others, but to evaluate the main positive and negative issues related to the system and service design philosophy each solution was built upon. Though preliminary, the results discussed in the paper can be used as a set of guidelines in the selection of proper technological equipments for services targeted to elderly users, from a usability perspective. These results need to be complemented with more focused discussions of the ethical, medical, and legal aspects of the use of technology in remote healthcare.

1. Introduction

The impact of ICT (Information and Communication Technology) on the healthcare sector is a double-face phenomenon. On one hand, many effective and significant advances are continuously taking place, especially in the field of medical treatments, and devices designed for their delivery. Also the management of medical data and patients' records is experiencing a kind of digital revolution; thanks to the widespread introduction of the electronic health record to gradually replace traditionally heterogeneous, and often partially hand-processed, data management services. On the other hand, however, although appropriate technology is available, a very limited spreading of remote health monitoring solutions is evidenced, especially among those users that could really benefit from it, such as elderly people or physically disabled people.

Since several years, research studies and projections show that most of the developed countries are experiencing a demographic shift [1]; as an example, the life expectancy for males and females in Europe has increased from 45.7 and 49.6 to 75.0 and 79.9 years, respectively, in less than a century. Looking at long-term projections, the process of ageing is set to increase at an even faster pace; moreover, there is a growing concern about the low birth rate in industrialized countries. Demographic changes affect a wide range of economic and social fields, as well as policies concerned with health, social welfare, housing, and many other issues. Basically, most of the available research reports and studies claim that, despite a necessary significant financial investment at a first stage, the adoption of ICT in the delivery of remote health services among population can really allow strong resource savings. As a matter of fact, population ageing will lead to an increase in the proportion of the population with

disabilities or chronic illnesses, that will lead to increasing expenses to cope with, by healthcare systems and social welfare, in general. With the adoption of ICT and related services [3], elderly or disabled people will be able to stay in their home environment while being medically supervised and possibly treated. This is of particular importance for older people, as the prevalence of chronic diseases generally increases with growing age.

National systems of social care will be confronted with challenges regarding the *income side*, as demographic ageing means that the number of older people is growing, while the share of those of working age (15–64 years) is decreasing. The demand for health services and social welfare will considerably increase in coming years: this will yield problems in financing the social benefits, under the corresponding social security systems. Within European national healthcare systems, due to the needs for assistance of elderly people, most member states spend currently between 30 and 40% of total health expenditures on elderly persons (i.e., those aged over 65), as well as they are making expenditures on long-term care for the elderly. Given this scenario, the widespread adoption of health provisioning solutions based on ICT becomes unavoidable. Technology may help in limiting the impact of costs faced to provide social and medical services: some assistance requests may be solved, for example, without moving health operators, by establishing a direct and “live” communication session between doctors and patients. With monitoring and data transmission both occurring daily, patients might be able to avoid numerous trips to a physician’s surgery, and physicians could quickly act and tailor medical treatments to variations of the patient’s health condition. Despite the well-recognized positive effects that a widespread adoption of telemedicine could bring, not so many legacy systems are already operating, especially in Italy. Several pilot and experimental initiatives have been carried on [4], but it is possible to say that a standard adoption of telemedicine, as a way of delivering health services, is still lacking.

Previous experiences, by some of the authors, in telemedicine for the home monitoring of elderly patients with Congestive Heart Failure (CHF) [5–7] provided positive outcomes, in terms of reduction of the rehospitalization rate, and improvements in the regular assumption of drugs and medications by the patients. Moving from this background, the paper discusses the preliminary results of an experimental study concerned with the evaluation of different kinds of technological platforms for the delivery of remote healthcare services to elderly people. The target users selected for the study may feature a number of possible health-related problems, but the telemedicine solutions were chosen with a focus on cardiology-related diseases. Comorbidity in geriatric population poses strong limitations in the patients’ lifestyle and may greatly reduce their physical or mental independence: this motivates the need of evaluating a technological platform designed for remote health monitoring under strict usability and accessibility criteria [8–10]. The ideal telemedicine system should enable users, even older ones, the ability to easily self-monitor various health parameters, and provide important information to medical

operators, thus facilitating timely healthcare decisions [2, 11].

The purpose of the present study is to assess different technological approaches to the design of remote health-monitoring platforms, with respect to specific requirements that are defined according to the target elderly patients. The comparison is based on three sample solutions, but the outcomes herein discussed are intended as general ones and not referred to a specific system. Because of the low number of users that it has been possible to involve in the experiment up to now, at this time the data provided can be considered as a pilot study for the validation of telemedicine solutions for the elderly.

2. Materials

2.1. Subjects. The expected users for the services and systems tested in the experiment are older adults of age ≥ 65 years. The target diseases to monitor are heart-related pathologies, with a specific focus on heart failure (HF); the availability of several biomedical sensors, such as the ECG monitor, makes it possible to extend the monitoring activity also to other pathologies, such as atrial fibrillation, arrhythmia, and suspected heart-attack related symptoms. In any case, due to the comorbidity that typically affects elderly patients, it is expected that a number of physical and/or cognitive impairments could prevent the patients from efficiently performing some basic operations needed to interact with the technological platforms. As a consequence of this quite common condition, it is foreseen to test the usage of telemedicine systems also by caregivers or nurses, that are often in charge of the older patient’s care. The experimental tests performed up to now on the available systems involved three older adults at their homes (one of them was supported by a caregiver, the other two were independent), and a professional nurse in charge of a residential structure for retired elderly people. From the operators’ side, the experiment involves a couple of students approaching their degree (a professional nurse and a medical doctor, resp.), a cardiology specialist, acting as supervisor and dealing with the clinical evaluation of the health data collected, and an electronic engineer dealing with the technical issues related to the proper set up and configuration of the systems tested.

2.2. Monitoring Systems. Three sample telemedicine systems have been adopted for the experimental tests. As previously stated, the focus of this work is not on benchmarking a specific system with respect to the others, but on evaluating different design approaches, such as the architecture upon which the solution is built, the kind of devices and connection techniques used, and the way according to which data are collected and made available to the medical operators.

The systems under evaluation will be referred to as *System A*, *System B*, and *System C*.

System A was originally conceived for adoption in emergency conditions. The system is designed to be portable: all the medical devices used to collect the patient’s vital parameters (blood pressure monitor, ECG device, weight scale, pulse oximeter, expiratory flow meter, stethoscope,

and blood glucose monitor), together with the central box they shall be connected to, are stored within a watertight case. The case also contains the power supply unit, that needs a grid plug to work, and a video monitor integrated into the upper case side. When connected to the central box, that runs a Linux-based OS, the medical devices allow remote monitoring of a patient's vital signs, as and when required. Measurement results are stored in a central database, reached through a wireless data connection supplied over UMTS/HSDPA. The box is able to set up a video-communication session over a wireless data link, between the patient and the remote medical center, and to manage the exchange of biomedical data between them, during the video session. Medical devices may be connected to the box through Bluetooth, Infrared technology, or via USB. For the connection of the stethoscope, a custom audio cable is provided, that allows to transfer the audio signal captured by the stethoscope to the remote medical operator, over the same audio channel set up during the A/V communication session.

System B is designed according to a similar concept, that is, a set of medical devices connected to a central box. In this case the box is conceived to be a desktop unit, that is expected to work in a home environment, once located in a fixed position. The box is actually provided through a touchscreen-enabled desktop PC unit, running the Microsoft Windows XP O.S., and the patient interacts with the system only by means of the touchscreen interface. The central unit may be connected to the remote health center either over a wired connection (xDSL, Ethernet) or a wireless one (UMTS/HSDPA, Wi-Fi). A video communication session may be established through the system, exploiting an integrated webcam and the touchscreen monitor. The set of medical devices is the same of *System A*, and a Bluetooth enabled stethoscope is also supported, for the remote patient auscultation.

System C features a mobile-oriented approach: the central unit, to which the different medical sensors may connect, becomes a portable device, such as a mobile phone or a tablet PC running Android O.S., acting as a gateway between each biomedical sensor and a remote data repository. The repository is accessed by the mobile client in a secure way through a wireless broadband connection established over UMTS/HSDPA or Wi-Fi. The gateway can interact with the same devices of *System A* only over Bluetooth links, with the exception of the stethoscope that is not supported. The medical operator is enabled to access a remote web platform that interfaces the data repository; a video communication session may be set up from the patient to the remote healthcare center, through the remote web platform acting as a bridge.

Table 1 provides a summary of the systems' description, with respect to the technologies adopted.

3. Methods

3.1. System Rating Criteria. Dealing with technological solutions aimed at enabling the user (i.e., the patient) to self-manage the collection of his health data, for their analysis

and evaluation by a remote medical operator, different rating criteria shall be defined. Besides a technical evaluation, based on the features provided by each system, that can be tested and rated according to quantitative figures, it is necessary to provide also a user-related evaluation, that can be further itemized into a patient's perspective and an operator's perspective.

3.1.1. Technical Rating Issues. A telemedicine system is typically obtained by integrating different technologies and subsystems, each of them covering specific functionalities needed to provide the requested services. In this case, the focus is on remote monitoring of health-related parameters, that may help in preventing or limiting the impact of heart failures and related symptoms. According to the short description of the systems under test, provided in the previous Section, it is possible to identify some common blocks composing the architectures herein considered as follows:

- (i) client side: the set of biomedical sensors used to monitor the patient's parameters;
- (ii) client side: the central unit acting as a gateway among the patient's premise and the remote health center;
- (iii) server side: a remote platform including a data repository and a software interface to access it and to perform the requested data analyses.

Each of these blocks may provide specific functionalities, with different degrees of performance. As already stated, the *set of biomedical sensors* used by *System A*, *B*, and *C* is the same, apart from the stethoscope device, that is not supported by *System C*. Each sensor is available in different flavors, that is, with a wired or wireless connection to the central unit, and the selection of the specific sensor to use shall be based on technical issues (the possibility of integrating or interfacing the sensor to the client central unit), but also on usability-related aspects. With the aim of defining general rating criteria, that can fit almost any sensor device, and due to the target users the system should support (elderly or partially disabled patients), it is expected to assign higher scores to those solutions that integrate wireless sensors, instead of wired ones; sensors that are able to provide a visual or acoustic feedback about the proper data acquisition and transfer to the central unit; sensors that notify their battery power level; sensors that do not require an initial configuration by the user, or at least, that do minimize the number of configuration steps necessary before collecting the desired data. Assuming a rating parameter defined as s and a scale from 5 (highest rate) to 1 (lowest rate), the rating criteria for each sensor the system is equipped with, may be defined according to Table 2. By scoring each device in the set of sensors, it is possible to get a global score for the system sensor set, named S , so that

$$S \equiv \sum_{j=1}^N \left(\sum_{i=1}^M s_i^j \right), \quad (1)$$

TABLE 1: Systems technology summary.

	<i>System A</i>	<i>System B</i>	<i>System C</i>
System topology	Centralized	Centralized	Centralized
System use	Portable	Residential	Mobile
OS	Linux based	Windows XP	Android
Power supply	Grid	Grid	Battery
Central unit	PC-based box	PC-based desktop	Mobile phone/tablet
Data connection	WAN	xDSL/WLAN/WAN	WAN/WLAN
Device connection	Bluetooth, USB	Bluetooth, USB	Bluetooth
User I/O interfaces	Remote control video, audio	Touchscreen video, audio	Touchscreen video, audio
Audio/video communication	Yes	Yes	Yes

TABLE 2: Technical rating criteria: sensors.

Issue i th	Rating $s = 5$	Rating $s = 1$
(1) Connection	Wireless	Wired
(2) Feedback on data acquisition	Acoustic + visual	No feedback
(3) Battery life status	Notified	Not notified
(4) Configuration steps	Not needed	More than 1 step

where N is the number of sensors in the set, M is the number of sensor rating issues ($M = 4$ in our model), and s_j^i is the score assigned to each i th rating issue, for each j th sensor in the set. The S parameter is not normalized, in order to properly account for the different number of sensors each telemedicine system may provide.

About the *central unit* at the client side, that is in charge of collecting the sensors' data and interfacing the patient to the remote healthcare center, it is possible to identify a number of features for its technical rating. The features are selected to be applicable to different solutions, but, at the same time, they are enough detailed to allow for a meaningful rating process. According to the amount and nature of the data the unit has to manage and transfer to the remote center, and one of its basic feature is the network interface the unit is equipped with. Assuming that an "ideal" solution should enable the joint transmission of audio, video, and data streams, corresponding to the information flows that take place during a remote, but "live" medical check, where a doctor is able to interact with the patient in real time, the highest score should be assigned to systems supporting broadband network connections, and the lowest score should be given to systems provided with narrowband interfaces. On the other hand, assuming the technological platform may be decomposed into "atomic" services (e.g., the transmission of the blood pressure data only, or the transmission of the ECG data only) a narrowband connection could be also accepted, but this would limit the potential benefits obtainable from the platform itself, as a whole.

The flow of information, during a data collection session with no active video communication, is basically asymmetric, with the client side mainly uploading data towards the remote repository. However, the amount of data is limited, so that we assume that symmetric or asymmetric connections

may be rated the same score. Besides that, it is important also to check if the network interface supported is a wired or a wireless one. This scoring criterion, however, also depends on the target users the system is designed for. Limiting the present discussion to systems designed for the elderly or partially disabled people, it is assumed to provide higher scores to wireless solutions, because they result less invasive with respect to the patient's home environment and do not require any cabling operations to be set up. To this aim, we assume that the initial set up of the client central unit wireless connection is provided by technicians involved in the service delivery. The performance of the data transfer process may be optimized if some audio and video compression techniques are applied: the client central unit should be designed in order to trade off compression efficiency and audio/video quality. Highest score will be given to systems providing compressed video at CIF resolution (355×288 pixels) as a minimum and compressed audio at a tunable quality (the highest one required when transmitting the patient's auscultation audio signals). Another feature that may be critical to the effective use of the telemedicine system is the possibility offered by the client central unit of automatically switching between synchronous and asynchronous data management: the former enables a real time data transmission to the remote center, and the latter allows for a temporary storage of the collected data within the unit itself, and a delayed transmission, as soon as the network connection becomes available. This feature is a basic one if the central unit adopts a wireless network interface, in order to avoid data losses due to temporary connection outages. In order to minimize the user's actions on the system, to configure the central unit or to update its software components, it is expected to assign higher scores to solutions supporting a remote client management, that provides automatic software updates and configurations. Finally, the evaluation will assess positively the solutions ensuring data privacy and security, by means of protected data connections established between the patient and the remote healthcare center. The technical rating criteria defined for the client central unit are summarized in Table 3. Again, it is possible to define a central unit global score, named CU, as

$$CU \equiv \sum_{k=1}^K cu_k, \quad (2)$$

where K is the number of rating criteria ($K = 7$, in our model), and cu_k is the score assigned to each criterion.

The *server side* evaluation of the telemedicine system typically involves two basic components: a data repository, where the data collected by the remote patients are stored, and a software interface, that allows the operators to access the data and to perform the requested evaluation. About the data repository, the recent evolutions in the field of cloud-based data management [12, 13] suggest the adoption of the SaaS (Software as a Service) paradigm, instead of the more traditional PaaS (Platform as a Service) one. The former ensures higher reliability, because data are not physically located in a machine but are spread across a cloud of nodes, cooperating towards the provision of a specific service. As a consequence, once defined a rating parameter rp referred to the remote platform composing elements, it is assumed to assign the highest score ($rp = 5$) to a telemedicine solution that relies on a SaaS paradigm, a medium score ($rp = 3$) to a solution adopting a PaaS approach, and the lowest score ($rp = 1$) to solutions requiring a dedicated local storage server.

Given the specific nature of the data collected by the remote clients and transferred to the repository, a number of security services shall be ensured for any service provisioned through the remote platform, such as data integrity protection, by the adoption of secure transmission protocols and certificates between the client gateway and the remote platform; separation of legally valued and identity-related data; safe management of the remote platform within the data center adopted (backup policies, continuous monitoring, and system access control); access control and tracking, with specific focus on the personal patients' data; authenticated and controlled accounts; security policies for passwords management. Different scores may be assigned to each issue, according to the specific security solution adopted, its strength and robustness.

About the technical features related to the software interface used by the operators to access the set of data collected by each patient, highest rate is assigned to solutions providing a web-enabled access, so that the operator may perform the requested evaluation irrespective of his physical location (mobility support), simply by resorting to a web browsing application. Software interfaces designed for multimodal and multichannel access (i.e., by a PC or a mobile device) are preferable to solutions requiring specific plugins or software components to be installed, or executed on specific OSs. Finally, the implementation of security services for access authentication and tracking is another issue, ranked according to the robustness of the specific solution adopted. The set of ranking criteria defined for the remote platform is summarized in Table 4. As previously done, a global remote platform score, named RP , may be defined as

$$RP = \sum_{z=1}^R rp_z, \quad (3)$$

where R is the number of ranking criteria adopted ($R = 10$ in our model), and rp_z is the score assigned to each ranking issue.

TABLE 3: Technical rating criteria: client central unit.

Issue k th	Rating $cu = 5$	Rating $cu = 1$
(1) Network interface	Broadband	Narrowband
(2) Network connection	Wireless	Wired
(3) Video compression	Yes, resolution \geq CIF	Yes, resolution $<$ CIF
(4) Audio compression	Yes, tunable	Yes, not tunable
(5) Data management	Synchronous and asynchronous	Only synchronous, or only asynchronous
(6) Remote system management	Yes	No
(7) Data privacy and security	Yes	No

Once the technical rating criteria for each subsystem have been identified, and the corresponding rating parameter defined, it is possible to derive a global system rating parameter, referred to the technical features of the telemedicine solution as a whole, as

$$TTP = \alpha \cdot S + \beta \cdot CU + \gamma \cdot RP, \quad (4)$$

where TTP is the *technical telemedicine system parameter*, α , β , and γ are weighting factors used to differentiate the impact of each subsystem on the global technical rating of the telemedicine solution. We assume to have $\{\alpha, \beta, \gamma\} \in [0; 1]$. The value assigned to each weighting factor during the assessment process depends on the expected or estimated impact of each sub-system on the effectiveness, reliability, and performance of the whole system. As an example, if the telemedicine solution is expected to provide a second-opinion service among health operators, the weighting factors will satisfy the following condition: $\alpha < \beta \ll \gamma$. On the other hand, a telemedicine system designed to provide remote healthcare services in underserved areas (such as rural areas) will feature a different condition, like: $\alpha \cong \beta$ and $\{\alpha, \beta\} > \gamma$. The specific value assigned to each weighting factor is consequently related to the service model implemented through the telemedicine system.

3.1.2. User-Related Rating Issues: Patient Side. The definition of suitable rating criteria from a patient's perspective is a critical point to the proper evaluation of the global telemedicine solution. As a matter of fact, it is not possible to completely generalize the definition of such criteria, as they are strictly dependent on the target users the system is designed for.

This work is focused on elderly or partially disabled people, so it is mandatory to account for their specific needs, related to the variety of physical or cognitive impairments that may characterize the patient's condition. In the case of elderly patients, several rating criteria may be defined to assess the telemedicine system from a usability perspective. Among them, we consider the ergonomics of the medical devices the patient should use to collect his health data

TABLE 4: Technical rating criteria: remote platform.

Issue zth	Rating rp = 5	Rating rp = 3	Rating rp = 1
(1) Platform paradigm	SaaS	PaaS	Dedicated storage server
(2) Data integrity protection	Strong	Weak	No
(3) Data separation	Yes	//	No
(4) Safety management	Strong	Weak	No
(5) Data access control and tracking	Strong	Weak	No
(6) Authenticated accounts management	Yes	//	No
(7) Secure password management	Strong	Weak	No
(8) Web enabled access	Yes	//	No
(9) Multimodal and multichannel support	Yes	Partial	No
(10) Authenticated access	Strong	Weak	No

(not too small dimensions, effective visual or acoustic signalling, and easy switch on/off); suitably formatted and delivered instructions to guide the user; easy and quick switch on/off of the client central unit; clearness and easiness-of-use of the Graphic User Interface (GUI) the client central unit is equipped with; reliability of the application used to manage the sensor devices and to collect the patient's data (e.g., robustness against user's misbehaviour or unexpected commands, automatic restart of the application in case of unexpected crashes, and robustness against lacking data connection); cognitive support and feedback messages provided by the application to the user, during the execution of different tasks; user's satisfaction, given by the rate of successful execution of the desired task. The rating of these criteria is not as straightforward as the previous ones, so it is assumed to provide a score that may vary from a minimum value of 1 (the criterion is completely not satisfied) to a maximum value of 10 (the criterion is completely satisfied). The assessment of a specific system from the patient's perspective may be performed through the submission of a questionnaire to the user, asking to rate each single issue.

3.1.3. User-Related Rating Issues: Operator Side. The operator's perspective in the evaluation of a telemedicine system basically deals with the impact of the implementation on the work processes, that are typically well defined and standardized. Assuming that the service model related to the provisioning of remote health assistance has been defined, the operator will typically assess the effectiveness of the telemedicine system, intended as the set of available functionalities and their performance. The way according to which patients' personal records and health data are organized and made accessible through the software interface, the available tools to search and select specific data, and the design of the GUI are critical to the successful acceptance of the telemedicine system as a "real" diagnostic procedure

[14]. In this sense, it is very important to have the possibility of customizing some of the interface features, according to the requirements expressed by the medical operators, derived from the daily clinical practice. As a consequence, one of the ranking criteria that may be defined deals with the degree of customization that may be allowed by the system design. The easiness-of-use, the clear organization of the information provided by the system interface, and the availability of specific planning tools (such as online agendas, shared folders, and collaborative management of data certification processes) may be ranked according to a score varying in a range of values, as for the patient's evaluation scale.

Table 5 summarizes the patient's and operator's rating criteria discussed above.

3.2. Measurements. Measurements may be provided about the system technical functionalities and performance. They support an objective evaluation of a telemedicine solution and its reliability. A first issue that is taken into account is the agreement between the data collected by means of the telemedicine system and the data collected in a traditional way (i.e., by a medical operator). This is a basic issue upon which the validity of the remote health monitoring service relies. In this work, given the application focus on heart-related diseases, the reliability of the ECG and blood pressure measurements has been evaluated by the contemporary acquisition of these parameters through a standard modality and through the platform. Other issues that have been considered are the average number of attempts requested to establish a connection between the patient and the remote health center, the incidence of connection losses during a remote health examination, the incidence of malfunctions or crashes during parameters' acquisition by the patient, and the amount of lost or corrupted (not readable) measurements. Among the other elements that may be evaluated, even if in a not strictly quantitative way, it is possible to cite the stability of the audio/video communication session, the quality of the audio and video signals, and the effectiveness of the audio session in enabling a remote heart and pulmonary auscultation of the patient.

4. Results and Discussion

4.1. Technical Evaluation. The available telemedicine systems, A, B, and C, have been tested first with respect to the agreement of the ECG measurements and blood pressure values collected by the platform or by the traditional procedure. All the systems tested have provided corresponding values of the diastolic and systolic blood pressure and of the heart rate estimated by the blood pressure monitor. Figures 1(a), 1(b), and 1(c) show the Bland-Altman plots obtained by comparing the traditional methodology (parameters collected by the medical operator: nurse or doctor) to the telemedicine-based methodology, over 52 measurement sessions, respectively, for the systolic, the diastolic blood pressure and for the heart rate value.

About the correct acquisition of ECG patterns, different performances have been obtained by the three systems.

TABLE 5: User rating criteria: patient and operator sides (score in [1, 2]).

Patient's side	Operator's side
Ergonomics of the medical devices	Available functionalities and tools
Suitably formatted instructions	Data management and organization
Quick switch on/off	GUI design
Easy-to-use GUI	Possible customization
Software reliability and robustness	Easy-to-use GUI and tools
Cognitive feedback	Intuitive functions and design
Satisfaction in task execution	Availability of planning tools

In the case of *System A* and *System C*, both adopting a wireless broadband connection on UMTS/HSDPA links, some ECG patterns that were correctly transmitted from the ECG monitor device to the client central unit, did not arrive to the remote repository, reasonably due to problems during transmission over the WAN radio connection. Figure 2 refers to *System C* and shows that over a set of 52 collected ECG patterns, 21% of them were not transmitted, 77% of them were correctly transmitted to the remote repository, and 2% of them were correctly received but could not be evaluated by the cardiology specialist, due to the complexity of the ECG patterns related to specific heart diseases. It is interesting to point out that 26 monitoring sessions over 52 used a mobile phone as the gateway (i.e., the client central unit) and 26 monitoring sessions used a tablet. Missing ECG patterns are to be referred only to the monitoring sessions performed with a tablet (42.3% over 26 sessions). Among the 42.3% missing transmissions, 81.8% may be referred to connection problems, but 18.2% are to be referred to erroneous use of the device by the operator. This result, though preliminary, evidences the basic role of operators or patients in correctly handling the medical equipments and the telemedicine systems to ensure the effectiveness of the process.

System B, that uses a wired network connection, should not exhibit missing transmission events. However, we found that if the ECG acquisition is performed offline (e.g., when the network connection is not available, or the client central unit is not connected), the ECG patterns are not always transferred to the repository once the system goes online again. Of course, this issue is to be solved to avoid missing data when the patient or the operator performs the measurements. In similar conditions (lacking network connection), *System A* did not work properly, whereas *System C* was able to store the data collected by the user, for a successful later transmission to the repository.

With respect to the proper acquisition of ECG patterns, it is necessary to point out that, even when an ECG measurement is correctly transferred to the remote repository, it is possible that the ECG pattern may not be evaluated by the cardiology specialist. This is the case for ECG patterns

in which possible artifacts (due to the acquisition or to the transmission process) modify the ECG curve and make it not useful to evaluate some heart diseases (like those determining low voltage values in the ECG signal). In the case of patients suffering from Atrial Fibrillation (AF), this condition may avoid the acquisition of useful ECG patterns. Figure 3 provides details about the incidence of these situations on the 52 measurement sessions performed, when looking at the *P* curve amplitude and the *PR* interval duration.

For the ECG patterns that have been evaluated, Bland-Altman plots of Figures 4(a) and 4(b) show the agreement of the traditional and the telemedicine-based methodologies in the estimation of the *P* curve amplitude and the *PR* interval duration, from DI derivation. The same agreement is confirmed also for the *PR* interval and the *QRS* complex, from different derivations. The only significant remark about the analysis of ECG patterns collected by the telemedicine system is the difficulty of evaluating patterns in which the ECG signal amplitude is reduced (<0.5 mV), due to an increased amount of artifacts, with respect to ECG patterns obtained by the traditional methodology, under the same conditions.

Looking at the performance of all the systems tested, in terms of ECG and blood pressure-related parameters, we may state that if a telemedicine solution relies on a wireless network connection, it is of primary importance to ensure an effective storage capability for the parameters collected when the connection is lacking. Assuming the wireless connection is reliable, it is necessary to pay maximal attention to the parameter acquisition process (especially the ECG measurement), in order to minimize the impact of source artifacts (e.g., due to patient's baseline wander). From a technical point of view, the telemedicine system should possibly apply some coding techniques to improve the signal robustness against errors due to the channel (at the transmitter side) and suitable techniques at the receiver to recover possibly missing data due to link outages (e.g., signal concealment techniques).

In order to clarify how the proposed methodology may help in comparing different technological platforms, with respect to a specific service requested by a patient, Table 6 shows the proposed rating criteria collected in a features chart, together with a requirements definition that may be representative of the service under consideration. Similar charts can be arranged for different services, by resorting to the set of ranking criteria previously defined. By checking a given platform versus the features chart corresponding to the requested service, it is possible to estimate if the platform adheres to the expected capabilities or not. In the event several platforms comply with the requirements expressed by a features chart, it will be possible to select the best platform by comparing the level of requirement compliance provided (e.g., the platform that provides the greatest local storage capability should be preferred over the other ones).

4.2. Test Use Case. The three systems available for experimental purposes have been tested towards the same target service, that is, to provide a comprehensive healthcare service to older adults. Such a service includes heart monitoring,

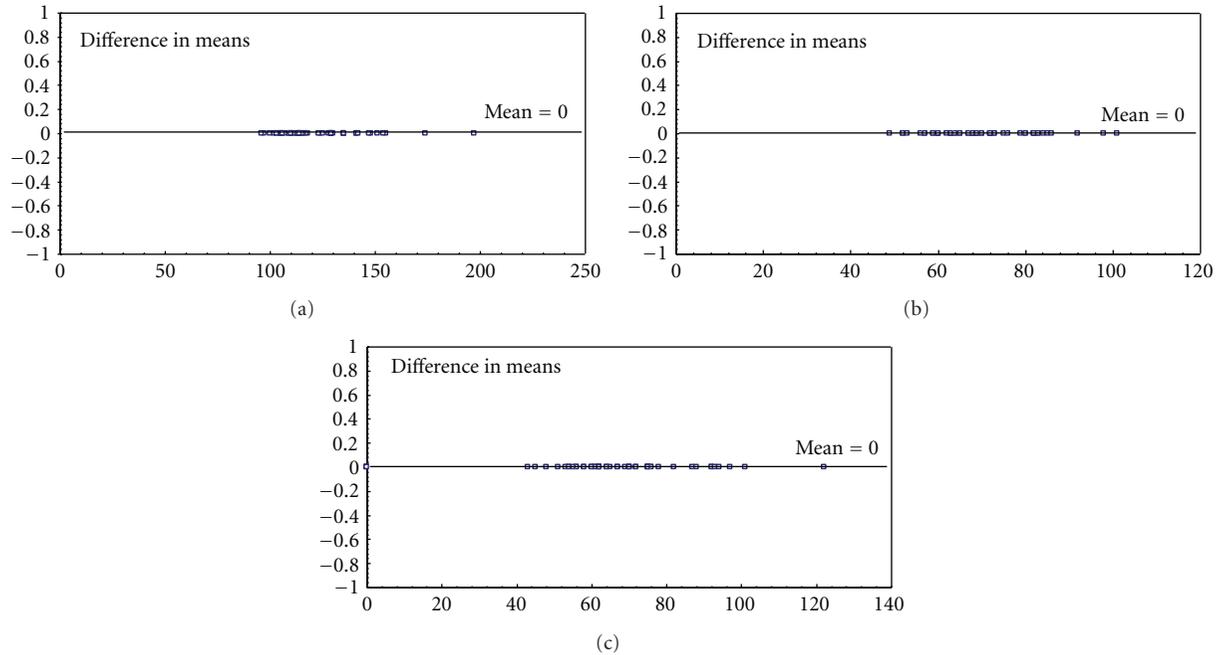


FIGURE 1: Bland-Altman plots comparing the agreement between traditional and telemedicine-based acquisition of: (a) systolic blood pressure, (b) diastolic blood pressure, and (c) heart rate values (*System C*).

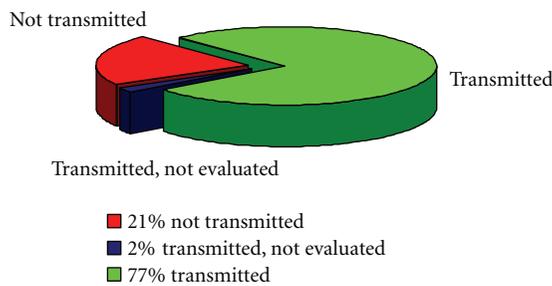


FIGURE 2: Percent amounts of correctly received ECG patterns, not received ECG patterns, and ECG patterns that were received but could not be evaluated, over 52 monitoring sessions (*System C*).

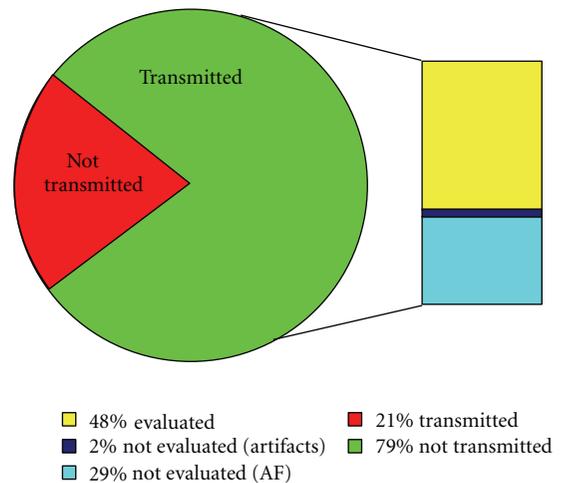


FIGURE 3: Percent amounts of ECG patterns that were correctly received but could not be evaluated.

blood pressure monitoring, weight monitoring, and A/V connection capability to possibly perform real time remote auscultation through the stethoscope. The ranking criteria introduced for sensors, central unit, and remote platform evaluation were applied, to objectively evaluate the available systems. Looking at (4), it is possible to say that irrespective of the values assigned to α , β , and γ , these weighting can be the same for *System A*, *B*, and *C*, as we are considering the same target service. For the specific use case under evaluation, the weighting factors were set as $\alpha = 1$, $\beta = 0.8$, and $\gamma = 0.6$, motivated by the fact that the technical features of sensors and central unit have a stronger impact on older users than the technical features of the remote platform. The numerical figures obtained for the three systems under test by applying the technical evaluation criteria introduced in Tables 2, 3, and 4 are summarized in Table 7.

The objective technical evaluation provides the highest score for *System C*, followed by *System B* and *System A*. Looking at Table 7, we may say that *Systems A* and *B* provide similar technical performance about the client central unit, better than *System C*; *System B* features the best set of sensors among the solutions tested, whereas *System C* provides the best performance for its remote platform. The objective evaluation results confirmed the opinions provided by the users, and also the expectations expressed by the medical operators. An ideal optimized solution should include the best features revealed by the analysis of each system.

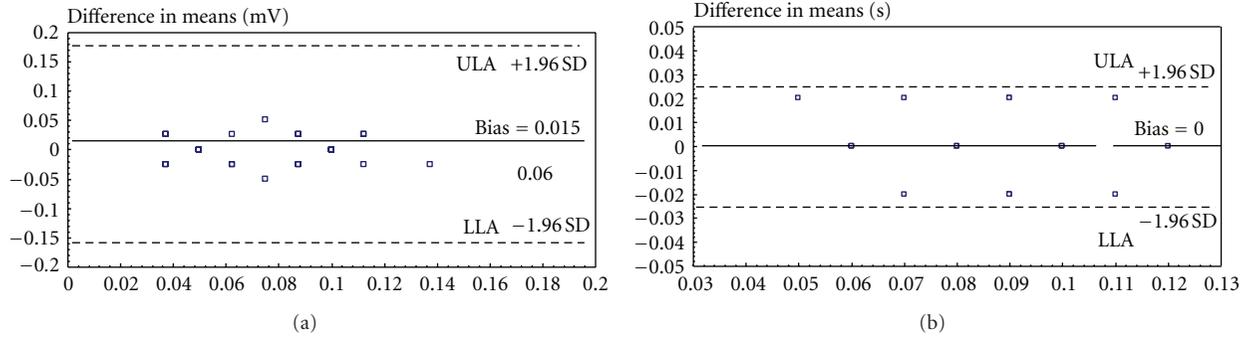


FIGURE 4: Bland-Altman plots comparing the agreement between traditional and telemedicine-based estimation of (a) P curve amplitude and (b) PR interval duration, from DI derivation (ULA: upper limit of agreement, LLA: lower limit of agreement).

TABLE 6: Sample platform features chart for the heart monitoring service and related requirements.

Platform Feature	Requirement
Wireless ECG device	Preferred
Local storage capability	Requested
Feedback on data acquisition	Mandatory
Battery life status notification	Requested
No user configuration steps	Mandatory
Broadband network interface	Preferred
Narrowband network interface	Mandatory
Wireless network connection	Preferred
Local storage capability	Mandatory
Data management	Asynchronous and Synchronous

TABLE 7: *Systems A, B, and C* technical ranking ($\alpha = 1$, $\beta = 0.8$, and $\gamma = 0.6$).

System	no. of sensors (N)	S	CU	RP	TTP
<i>System A</i>	$N_A = 7$	$S_A = 106$	$CU_A = 31$	$RP_A = 30$	148.4
<i>System B</i>	$N_B = 7$	$S_B = 109$	$CU_B = 31$	$RP_B = 42$	159
<i>System C</i>	$N_C = 6$	$S_C = 108$	$CU_C = 28$	$RP_C = 50$	160.4

About the other technical features that may be evaluated according to the ranking criteria introduced, it is possible to provide general remarks, according to which

- (i) *System A* featured the highest number of attempts necessary to establish a connection, followed by *System C*. In some conditions, also *System B* required several attempts, even if equipped with a wired interface;
- (ii) the incidence of connection losses, and system malfunctions or crashes, was the highest for *System A*, followed by *System B*. *System C* is the most robust against link outages, with a satisfactory storage capability of collected data at the client gateway;
- (iii) *System B* provided the best quality for the audio/video sessions, the strongest stability of the connection, and the best performance in remote patient

auscultation (especially the pulmonary one). It is possible to say that, reasonably, a wired connection, when properly established, may ensure better real time multimedia sessions between the patient and the remote operator.

4.3. Usability Evaluation. Due to the limited number of patients that could test the available telemedicine platforms, up to now, it is possible to provide only a general overview of the usability issues that were evidenced during the experimental activities. Dealing with elderly or partially impaired people, one of the main barriers to the effective empowerment of the user is given by the ergonomics of the devices composing the telemedicine platforms. Sensors are typically small and usually have small displays to provide feedback information about the collected data. The client central unit should be designed to have easy-to-handle I/O interfaces: with respect to this issue, *System B* probably represents the best solution, given its quite big touchscreen monitor, whereas *System A* represents the most critical one, due to its small remote control and to the number of different steps that need to be performed by pressing one or more buttons, before activating the service. These issues joint the need of a clear and intuitive GUI expressed by the users and highlight the need of a specific technological design suitable for elderly or impaired people, by taking into account their requirements, either physical or cognitive ones. *Systems B* and *C* provided the highest rates in patient's satisfaction when performing a specific task, with *System B* also assessed first with respect to the easy-to-use GUI, and *System C* ranked first for its quick switching on/off.

From the operators' perspective, the three systems provided a satisfactory set of sensors, apart from *System C* that does not yet support a wireless stethoscope; it is actually very important for the followup of specific heart-related diseases, like CHF. The operators were particularly interested in the possibility of customizing the structure and the organization of the software interface used to access the remote platform and the data repository. Critical issues, from the operators' point of view, are the possibility of establishing real time audio/video communication sessions with a patient or a caregiver and the mobility support provided by the

telemedicine system, that makes it possible to assist the remote patients even out of the health center premises.

5. Conclusion

This paper presented a possible methodology for the technical and usability-related evaluation of three remote health platforms, designed according to different technological approaches in a realistic scenario involving older adults and medical operators. The aim of the testing activity was not to benchmark a specific solution with respect to the others, but to evaluate the main positive and negative issues related to the system and service design philosophy each solution was built upon. The preliminary results presented by the paper may represent a set of guidelines in the selection of proper technological equipments for services targeted to elderly users. The evaluation activity is currently ongoing, in order to get statistically significant figures and to come to the definition of an objective procedure for the evaluation of telemedicine solutions.

Disclosure

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References

- [1] Ambient Assisted Living, "Europe is facing a demographic challenge: ambient assisted living offers solutions," European Overview Report, Berlin, Germany, 2006.
- [2] G. Paré, M. Jaana, and C. Sicotte, "Systematic review of home telemonitoring for chronic diseases: the evidence base," *Journal of the American Medical Informatics Association*, vol. 14, no. 3, pp. 269–277, 2007.
- [3] European Senior Watch Observatory Inventory, "A market study about the specific IST needs of older and disabled people to guide industry, RTD and policy," IST-1999-29086, Bruxelles, Belgium, 2002.
- [4] "Case history: ospedale molinette," 2012, <http://www.nuvolaitaliana.it/verticali/nuvola-it-home-doctor/>.
- [5] R. Antonicelli, C. Ripa, A. M. Abbatecola, C. A. Capparuccia, L. Ferrara, and L. Spazzafumo, "Validation of the 3-lead tele-ECG versus the 12-lead tele-ECG and the conventional 12-lead ECG method in older people," *Journal of Telemedicine and Telecare*, vol. 18, pp. 104–108, 2012.
- [6] R. Antonicelli, I. Mazzanti, A. M. Abbatecola, and G. Parati, "Impact of home patient telemonitoring on use of β -blockers in congestive heart failure," *Drugs and Aging*, vol. 27, no. 10, pp. 801–805, 2010.
- [7] R. Antonicelli, P. Testarmata, L. Spazzafumo et al., "Impact of telemonitoring at home on the management of elderly patients with congestive heart failure," *Journal of Telemedicine and Telecare*, vol. 14, no. 6, pp. 300–305, 2008.
- [8] A. Czapke, J. Loeschke, and T. Lueth, "Concept and modular telemedicine platform for measuring of vital signs, ADL and behavioral patterns of elderly in home settings," in *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, (EMBC '11)*, pp. 3164–3167, Boston, Mass, USA.
- [9] F. Ligons, K. Romagnoli, S. Browell, H. Hochheiser, and S. Handler, "Assessing the usability of a telemedicine based medication delivery unit for older adults through inspection methods," in *Proceedings of the AMIA Annual Symposium*, pp. 795–804, 2011.
- [10] K. Bowles, A. Hanlon, and H. Glick, "Clinical effectiveness, access to, and satisfaction with care using a telehomecare substitution intervention: a randomized controlled trial," *International Journal of Telemedicine and Applications*, vol. 2011, Article ID 540138, 13 pages, 2011.
- [11] H. Zheng, C. Nugent, P. McCullagh et al., "Smart self management: assistive technology to support people with chronic disease," *Journal of Telemedicine and Telecare*, vol. 16, no. 4, pp. 224–227, 2010.
- [12] W. Luo and G. Bai, "Ensuring the data integrity in cloud data storage," in *Proceedings of the International Conference on Cloud Computing and Intelligence Systems (CCIS '11)*, pp. 240–243, 2011.
- [13] F. Liu, W. Guo, Z. Q. Zhao, and W. Chou, "SaaS integration for software cloud," in *Proceedings of the 3rd IEEE International Conference on Cloud Computing, (CLOUD '10)*, pp. 402–409, July 2010.
- [14] S. Franc, A. Daoudi, S. Mounier et al., "Telemedicine: what more is needed for its integration in everyday life?" *Diabetes & Metabolism*, vol. 37, pp. 71–77, 2011.

Research Article

How Do Low-Income Urban African Americans and Latinos Feel about Telemedicine? A Diffusion of Innovation Analysis

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Introduction. Telemedicine is promoted as a means to increase access to specialty medical care among the urban underserved, yet little is known about its acceptability among these populations. We used components of a diffusion of innovation conceptual framework to analyze preexperience perceptions about telemedicine to assess its appeal among urban underserved African Americans and Latinos. *Methods.* Ten focus groups were conducted with African American ($n = 43$) and Latino participants ($n = 44$) in both English and Spanish and analyzed for key themes. *Results.* Both groups perceived increased and immediate access to multiple medical opinions and reduced wait time as relative advantages of telemedicine. However, African Americans expressed more concerns than Latinos about confidentiality, privacy, and the physical absence of the specialist. This difference may reflect lower levels of trust in new health care innovations among African Americans resulting from a legacy of past abuses in the US medical system as compared to immigrant Latinos who do not have this particular historical backdrop. *Conclusions.* These findings have implications for important issues such as adoption of telemedicine, patient satisfaction, doctor-patient interactions, and the development and tailoring of strategies targeted to each of these populations for the introduction, marketing, and implementation of telemedicine.

1. Introduction

Telemedicine involves using computer information and telecommunication technologies to provide health care when the provider and care recipient are in separate geographic locations. It has been promoted as a vehicle to increase access to specialty care among the urban underserved minorities, yet little is known about its acceptability among such populations. The literature on the adoption and diffusion of new technology, such as telemedicine, suggests that stakeholders' perceptions about a new innovation and the extent to which they see it as a "relative advantage" are central to the rate of diffusion and adoption [1]. The objective of this study is to explore perceptions regarding telemedicine among African Americans and Latinos in South Central Los Angeles.

It is well documented that racial/ethnic minorities and socioeconomically disadvantaged individuals face significant barriers to receiving basic health care [2–6]. African Americans and Latinos make up the largest proportion of minority populations who experience the most severe and concentrated types of health disparities. Much of this disparity in health is thought to be due to lack of timely access to appropriate health care [3]. Medically underserved populations experiencing health disparities tend to be concentrated in either inner city or rural areas. These areas are plagued by low physician-to-population ratios, limited specialty care, and health care facilities that suffer from overcrowding, inadequate infrastructure, and inefficient organizational structures [2–5, 7–11]. Given that the Institute of Medicine's report on quality of health care has already identified

illiteracy and distrust of technology as potential barriers to the delivery of telemedicine in urban underserved settings, it is important to assess community perceptions of this technology [8]. South Central Los Angeles serves as a prime example of such an inner city setting, making it an excellent location for a case study.

Telemedicine has been promoted as an innovative approach to bridging the health care delivery gap by increasing access to services for medically underserved communities. The role of telemedicine in facilitating increased access to care has traditionally been framed in terms of its ability to mitigate geographic barriers. Accordingly, remote rural communities have been the primary beneficiaries of telemedicine implementation [12]. However, limited access to appropriate medical care, particularly specialty care, is a major challenge for inner city communities as well.

Although telemedicine has the potential of redressing the health care delivery problems of the inner city, there is little in the existing literature on telemedicine or health care in general that sheds light on perceptions about telemedicine among the general population and, more specifically, the urban underserved population [9, 10, 13, 14]. It is important to examine the concurrence (or divergence) between the medical aims that drive such solutions and “on-the-ground” perceptions of those receiving care, particularly among inner city African American and Latino populations. In a study of an urban urgent care dermatology clinic, while patients generally reported high levels of satisfaction, 36% of the study sample expressed self-consciousness around the camera and 17% were uncomfortable having facial pictures taken [15]. In terms of outcomes, the Informatics for Diabetes Education and Telemedicine (IDEATel) project [5] found that African American and Hispanic American participants were less adherent to the diabetes self-care intervention than white participants, suggesting the need for culturally tailored interventions [16, 17]. The issue of community acceptance of such new techniques has yet to be resolved.

Diffusion of innovation (DOI) theory is useful in understanding the importance of assessing perceptions about a new technology such as telemedicine among a population before its introduction in order to promote likelihood of adoption. Though there are several components to DOI theory, here we focus on its applicability to characteristics of the innovation itself, that is, how an innovation spreads from innovators to others within a social system. Rogers' classic DOI model points to five factors that shape the rate of diffusion of new innovations among stakeholders: (a) the perception of relative advantages, (b) the compatibility with past experiences and existing values, (c) the complexity of the innovation, (d) observability of benefits, and (e) trialability of the innovation on a limited basis. For example, according to this framework, if patients perceive the relative advantages of using telemedicine to be greater than existing options with regard to savings in time/money, increases in comfort, social status, and so forth, they will be more likely to adopt telemedicine. The compatibility factor points to the importance of consistency of telemedicine use with “past experiences, existing values and needs of potential adopters” [18]. Whereas the first two factors focus on the

stakeholders' needs, experiences, and values, the latter three factors (complexity, observability of benefits, and trialability) focus on aspects of the innovation. It seems important to understand which of these factors maybe most relevant at baseline for specific type of populations within particular geographical contexts vis-à-vis a new innovation in order to best promote the diffusion of the innovation.

Most of the studies that examine patient perceptions about telemedicine tend to question participants on their past experiences of receiving health care through telemedicine [19, 20]. However, preexperience perceptions are important to the success of telemedicine adoption since they shape a patient's initial decision to (a) sample a telemedicine service and (b) use the service on a continual basis [21]. There is scant research on viewpoints about telemedicine among the target population before the introduction of telemedicine. Some exceptions include studies by Bashshur [22], Brick et al. [23], and Turner et al. [21]. The first two studies found that patients do not perceive telemedicine as preferable to seeing a doctor in person, even though they appreciated the usefulness of telemedicine for emergency situations and minor problems. Turner and colleagues found that the greater the perceived relative advantage and the greater the perceived compatibility of the innovation, the greater the intent to adopt it with varying levels of openness depending on the task situation (e.g., their respondents were more open to telemedicine care in emergency situations than for specialist care). However, none of these studies examines the perceptions of urban inner-city populations regarding telemedicine and the specificities of their care contexts.

Given that there is little research on the perceptions about telemedicine among African American and Latino underserved populations, we examined the pretelemedicine perceptions of these groups and the differences between them. In addition to our focus on these two populations, we were interested in identifying the differences between elders in these groups (over 65) and younger adults (parents of school-aged children) since these are the two groups most likely to utilize and benefit from telemedicine services with a clear source of health care reimbursement. We hypothesized that the elderly would be less amenable to the idea of new technology and parents would be more willing to consider trying the technology to meet the needs of their children.

2. Methods

2.1. Setting: South Central Los Angeles. The research was conducted in South Central Los Angeles, which is home to more than 1.4 million individuals, most of whom are racial/ethnic minorities (62.7% Hispanic, 33.4% African American). South Central is the most socioeconomically disadvantaged community in Los Angeles, with 28% of the population living below the federal poverty level [24]. The population faces several barriers to receiving timely care: in 2005, 40.2% reported that they could not afford to see a physician when needed and 27.5% of adults reported transportation problems as a barrier that kept them from obtaining needed medical care [25].

2.2. Procedures. Focus group methodology was utilized to explore the range of individual opinions within relatively homogeneous groups (described below), using a standardized set of questions [26–29]. The research team consisted of the authors and two research associates who assisted with the recruitment and moderation of the focus groups.

Community-based recruiting efforts were used to develop a sample population for the focus groups. Flyers about the focus groups were posted in community centers and public housing complexes. Interested individuals called the number on the flyer. When 8–10 individuals from the priority populations (African American and Latino parents of school-aged children and seniors) responded to these efforts, focus groups were assembled (see Table 1 for group composition). The focus groups took place in community and senior centers. Informed consent was obtained from all participants. All participants completed a background questionnaire and were paid \$20 at the end of the focus group.

After introductions, participants were asked for their definitions of the word “telemedicine.” After a short discussion, a brief video presentation—a dramatization of a patient, receiving care for ear pain at a telemedicine clinic—was shown to focus group participants. Groups that were Spanish speaking (5 of the 10 groups) were shown a Spanish version of the video. In the video, the patient’s ear pain is assessed by a physician’s assistant (PA) who contacts an ear, nose and throat (ENT) specialist using videoconferencing. This ENT specialist is depicted as being distant from the clinic; he examines the patient using an otoscope with a camera at the end, which transmits images of the patient’s ear to the specialist. All parties (patient, specialist, PA) are able to see each other through videoconferencing technology.

The video was followed by a focus group discussion about participants’ reactions to and perceptions about receiving medical care through telemedicine. The moderator used a semistructured interview script that covered reactions to the video, perceived advantages and disadvantages of telemedicine, diagnoses/health conditions for which telemedicine would be appropriate, and general experiences in receiving health care services (Table 2).

2.3. Data Analysis. All interviews were audio- and videotaped and transcribed, and all Spanish-language transcripts were translated into English by a professional transcription and translation agency. Atlas, it was used for data analysis. The transcripts were analyzed using the constant comparative method of data analysis [30]. Transcripts were initially deductively coded by the second author with questions from the interview script guiding the predominant themes. These themes were summarized and discussed by the research team, and then the data underwent another level of more inductive coding to explicate the range of issues that were raised in response to each question and to compare across categorical groupings (parents versus elders, African American participants versus Latino participants). Through an iterative process of immersion in the data and refining the categories, key themes and DOI theoretical insights were identified and interpreted collaboratively by the authors.

3. Results

Participants emphasized two DOI factors: relative advantages and compatibility with experiences and existing values. There were some differences between African Americans and Latinos in how they viewed these factors. While the two groups had similar perceptions of the relative advantages of telemedicine, they had differing perceptions of the compatibility of telemedicine with their experiences and existing values, resulting in different types of concerns (see Table 3). Participants were understandably less prone to raise innovation-focused factors that are important to rate of adoption (complexity, observability of benefits, and trialability) because they were not familiar with telemedicine. We did not identify consistent discernible differences by age.

3.1. Relative Advantages. For both African Americans and Latinos, there were several relative advantages to telemedicine as compared to their usual modes of health care. The main advantages noted in all of the focus groups were: (1) reduced waiting time, (2) immediate feedback as to diagnosis and course of action, (3) increased access to specialists, and (4) increased access to multiple medical opinions. It is important to note that these perceived advantages are not necessarily correct perceptions of how telemedicine operates, but they do illustrate the values that participants associated with this type of system.

With regard to speed and accuracy of diagnosis, one Latino participant said that telemedicine would be a “novelty” because “it can give you the diagnosis right away cause they’re consulting the specialist so you can get your diagnosis instantly. I think that’s good.” Another Latino participant in another group said: “Science is more advanced and you will be able to see everything through the Internet... It will be like having the doctor in front of you but you won’t have to go to his office. The laboratory won’t take a lot of time and you will really know what you have.”

Telemedicine’s potential convenience in terms of these issues and in terms of logistics (such as location) was perceived to be very appealing. The African American participants felt that telemedicine would be particularly beneficial for children and the elderly. For example, one participant said, “I can see it going places. I can see where people will like it. Young people will love it. Their families, I can see my children, you know, loving it for their children, you know, in many cases. First, because they do not have enough time to do whatever, you know, because they are so busy all the time. So that helps to get an immediate feedback and to give a diagnosis and a solution to a problem.”

While the same four major advantages were discussed in all of the groups, Latino participants also noted several additional advantages and seemed, overall, more positive and enthusiastic about the prospect of telemedicine. They felt that telemedicine could potentially cut down on misdiagnoses, particularly because the computer gives “exact data.” This idea of the precision of computers was raised in three of the Latino focus groups. One group felt that telemedicine might result in more choice over which doctor is assessing

TABLE 1: Focus group composition.

	African Americans <i>N</i> = 43		Latinos <i>N</i> = 44	
	Groups	<i>N</i>	Groups	<i>N</i>
Seniors, <i>N</i> = 37 (average age = 67; range 61–83 years)	1	9	6	10
	2	8	7	10
	3	7	8	8
Parents, <i>N</i> = 50 (average age = 34; range 21–55 years)	4	9	9	9
	5	10	10	7

TABLE 2: Focus group script—interview themes and examples of questions*.

Broad themes	Example questions
A telemedicine clinic in your community	(i) How do you feel about it? (ii) How did you form this impression? (iii) From what particular experiences?
Perceived advantages and disadvantages of telemedicine	(i) What are specific benefits? (ii) What are potential challenges? (iii) Would telemedicine address any specific gaps/issues you have with your present form of health care?
Ideal recipients of telemedicine care	(i) Would you use telemedicine yourself? (ii) Would you recommend it to a friend? (iii) Would it be particularly suitable for older people/young children?
Conditions and context of use	(i) For what types of health conditions would you be most comfortable using telemedicine? (ii) How often and under what conditions (e.g., weekends only) would you want to use such a clinic?

*These are examples of only some of the initiating questions used. Other more probing questions were asked of participants depending on what their responses were in order to gain more in-depth information.

you and might provide better doctors. One group pointed out that telemedicine would result in more jobs for nurses.

The location and convenience of the clinics were also discussed more extensively in the Latino focus groups, because they felt that the clinics would be easier with children and with transportation. For example, “I would love something like this to open as soon as possible, because we need it. We need it for all of our children, because sometimes we take them all in when one has an appointment. You save time seeing the specialist that one of your children needs, or if another specialist is needed, you don’t waste any time, you save time and see the doctor you want to see and it would be great if Medi-care would pay for these services.”

3.1.1. Concerns about Compatibility with Past Experiences and Existing Values. African Americans and Latinos had very different perceptions about the compatibility of this innovation with their experiences and existing values. Participants’ main

concerns about telemedicine were confidentiality/privacy (considering the use of the Internet for the transmission of personal information) and the process of diagnosis (considering the use of scopes rather than actual clinical observation, i.e., physician’s physical presence). Overall, African Americans were more concerned about these issues, and were especially concerned about the physical absence of the physician and the perceived inability to monitor the (distant) specialist’s qualifications and level of attention. Latino participants were substantially less concerned about these issues and in some cases felt very differently about them. They did, however, express concerns about whether telemedicine would be made accessible to uninsured and undocumented individuals.

3.1.2. Technology Issues: Confidentiality and Privacy. For both African American and Latino participants, the technology critical to telemedicine posed some problems. On a technical level, some participants in both sets of groups discussed the possibility that the computer could go down or the system could fail. More important than this concern, however, was that personal information could be obtained by individuals other than those involved in the telemedicine encounter. For example, there was discussion among African American participants that one’s identity could be stolen and that one’s pictures would be “floating around.” The Internet was perceived as “insecure” and “for anybody.” One African American participant noted, “Internet is the Internet. So that means your name is out there and whatever your problem is, it’s on the Internet. And you know, records are supposed to be a personal thing between you and your doctor, but if it’s going to be on the Internet, then it’s for anybody.” In one group, participants discussed how they did not even like the idea of Internet banking due to the possibility of a breach in privacy. In another group, a participant imagined that children would be able to see medical images on the computer: “The kids, you know, they go to the library and they say, “mamma, guess what I see?” Now if I’m sick and there’s something wrong with me, I don’t want the Internet to know, too. No, no, then the whole world will see.”

In contrast to the African American participants, Latino participants seemed more confident that privacy would be protected, and they were not as concerned that privacy could not be guaranteed. One participant said that the “standard ordinary person” would not even be interested in “anything scientific, and less still related to health.” These participants,

TABLE 3: Advantages and concerns about telemedicine for African American and Latino participants.

	Advantages	Concerns
African Americans	(1) Reduced waiting time (2) Immediate feedback (3) Increased access to specialists (4) Increased access to multiple medical opinions (5) Convenience for children and the elderly	(1) The physical absence of the physician specialist (2) Ability to monitor the specialist's qualifications (3) Privacy/confidentiality issues related to the presence of personal information on the Internet (4) Adequacy of telemedicine scopes to make accurate diagnoses
Latinos	(1) Reduced waiting time (2) Immediate feedback (3) Increased access to specialists (4) Increased access to multiple medical opinions (5) Convenience for children and the elderly (6) Greater accuracy of diagnoses due to precision of computers (7) Avoiding poverty-related embarrassment and in-person physician interaction	(1) Privacy/confidentiality issues related to the presence of personal information on the internet, to a lesser extent (2) Adequacy of telemedicine scopes to make accurate diagnoses, to a lesser extent (3) Concerns about whether telemedicine would be available to uninsured/undocumented

for the most part, expressed that maintenance of confidentiality was the physician's responsibility, and that the physician would not risk his license with a questionable system: "I don't think [the doctor] would risk his degree to give out the files of all the patients that are in the computer because he would be responsible." In another group, participants discussed asking for confidentiality, and they felt that by asking, confidentiality would be assured: "If you tell the person who's going to carry out the treatment that you want confidentiality in your case, I don't think there would be any problem. But you must ask for it. It won't come on its own."

For some Latino participants, the technology assured more privacy. One Latino participant stated, "I feel there's more privacy. I really like the idea because the computer gives you exact data. It makes me feel better, you know? "Cause the fact that you're being looked at through the computer, it removes the self-consciousness, shame, or whatever of talking openly to a doctor. Like this, without being face to face, I can say whatever I wanted." There was some concern about identity theft, but, overall, Latino participants felt confident that transmitted information would remain confidential. As noted above, even for those who were not convinced of the confidentiality, there was typically little concern. One Latino participant said, "It doesn't matter to me that people should see me because the whole world has to know what science is doing."

3.1.3. Diagnosis and the Physical Absence of the Specialist.

One of the main topics addressed in the focus groups was the physical absence of the specialist, which is one of the main distinguishing features of telemedicine. Discussions on this topic revealed the complexity of the doctor-patient interaction, illustrated by the multiple layers of meaning that participants attach to such interactions. Because of the richness of this set of findings, our results regarding the importance of physical presence and touch in telemedicine for these populations will be elaborated upon in a separated publication and here we will provide a summary of the findings. In general, the participants associated the physical presence or absence of the specialist to their (1) satisfaction

with a medical encounter, (2) level of assurance that appropriate information was being conveyed, and (3) ability to accurately gauge the reactions of the specialist and monitor the latter's activities.

Several of the African American participants' concerns about not being physically with the specialist seemed related to sensory experiences of vision and touch, that is, being unable to "see" the specialist in person and/or not having the specialist touch the patient. For example, the physical absence of the physician was related to concerns about being able to assess if "the truth" was being told to the patient. For others, it was about being able to monitor the activities of the specialist (e.g., "How do I know that the doctor ain't on the other side and he's getting high?"). The importance of the physical presence of the specialist, particularly sight and touch, was often related to the specialist's capacity to make accurate diagnoses.

The Latino participants seemed less concerned about the physical absence of the physician in the telemedicine clinic. Having the doctor physically present did not equate with better care for these participants, as expressed in such statements as, "It makes no difference having the doctor in front of you." Participants expressed that even when the doctor is present, they tend to "only ask questions," whereas it is the nurse who provides care. The doctor "bases his opinions on what the nurse tells him," so diagnosis could take place just as well from a distance.

Interestingly, some Latino participants expressed a preference for telemedicine because of the physical absence of the physician. The reasons for this preference seemed to be centered on embarrassment about gender, age, and class differences between the provider and patient. As one participant explained, she preferred gynaecological exams by telemedicine because it would help her avoid in-person interactions with "young, attractive" (male) gynaecologists.

3.1.4. Qualifications and Qualities of the Physicians.

As noted above, some African American participants were concerned that the telemedicine physician would not be giving the patient his/her undivided attention. This relates to an issue

that came up in several of the focus groups, which is how do you trust in the physician who is not in the room with you? How do you know he is qualified and certified?

One African American participant wondered how experienced the telemedicine physicians would be: "How many years of experience have they had? You know, some of them might not even have but six months, some might not even have a year. So you have to take all that into consideration because I myself don't want anything that hasn't been in medicine over a year to be looking at me... I still prefer an experienced doctor, whether he's on telemedicine or I see him in person." There was suspicion that the physician might not be who s/he claims to be, as expressed by an African American participant in the following question: "What is the reassurance that we have that this so-called specialist that's on the screen really is what he's supposed to be?"

Latino participants had more discussions about how they know the qualifications of any physicians, telemedicine or not. Most often, knowledge of a physician's quality and qualifications came from the success of the treatment, the physician's interpersonal qualities, or other people's recommendations. For example, "I have been seeing my current doctor for more than seven years, and he gives you the medicine and so you don't have to come back. And that's how we would know if they are good doctors or not." Another participant responded, "If I go to my doctor, I'm not 100% sure if he is a doctor or not. In terms of whether or not a doctor is good, well, you try him and see. I like the way I was treated."

In two Latino focus groups, participants agreed that one knows of a doctor's quality because "the medicines he gives you do you good." The participants said that the telemedicine personnel would be responsible for assuring the quality of the physicians: "We are trusting in you like we trust in the clinics we go to. We trust that the doctor we are going to see is really a certified doctor who has gone to school and who knows medicine. I think you must take that risk, for it's the responsibility of those who are in charge of the clinic." Latino participants also discussed seeking information on their own as to the qualifications of physicians, for example, by looking on the Internet: "All you do is go to a website and all you have to do is fill in the doctor's name and the clinics you've been to. There are many doctors that have done bad things and they are in jail, and their names are not on the list and that's another way to find out if a doctor is good or not." In general, while both African American and Latino participants shared concerns about the qualifications of the telemedicine physician providing care, the latter tended to think that the risks were not necessarily greater for telemedicine-based physicians as compared to physicians seen in person, and they expressed more trust that the quality of the physicians would have to be acceptable.

4. Discussion

Telemedicine has been promoted as an innovative approach to bridging the health care delivery gap particularly for underserved communities. While inner-city minority communities could potentially benefit from this innovation,

there is little in the existing literature that speaks to the acceptability of such a solution among minority populations. To the best of our knowledge, this is the first study that explicitly examines perceptions about telemedicine among urban underserved minority populations, although some studies on telemedicine have included minority cultural groups [31] and studies of minority perceptions of health care in general have been done [32].

Both African American and Latino focus group participants emphasized two DOI factors that shape the rate of diffusion of an innovation: relative advantage and compatibility with past experience. Participants were less likely to discuss complexity, observability of benefits, and trialability of telemedicine, likely because these factors focus on features of the innovation, with which the study participants were not very familiar. We contend that they were more likely to talk about telemedicine's relative advantages and compatibility since these factors were salient to their current concerns about their health care needs, lived experiences, and existing values, and they could be discussed despite their lack of first-hand experience with telemedicine.

The advantages of any health care innovation are usually assessed by potential users relative to their current experiences of receiving care. This was true regarding telemedicine for the focus group participants. Given their underserved inner-city location, the study participants overwhelmingly identified timely access to care as one of the greatest relative advantages of telemedicine. Telemedicine appears to provide some relatively efficient solutions to issues such as the challenge of transportation to get to specialist care, lack of timely access to specialists, the lack of timely diagnoses and feedback, and the lack of multiple opinions in a specialist-scarce zone.

However, the two groups had different concerns about health care received through telemedicine, reflecting differences in the compatibility of their lived experiences and values with the perceived nature of telemedicine-based care. For African Americans, their experiences as a community with a history of slavery and continuing racism in many aspects of their lives, particularly with health care, may affect their views on new and innovative medical care [33, 34]. The legacy of past abuses such as medical experimentation on slaves and the Tuskegee syphilis experiment and other types of continuing racism in health care contribute to lower levels of trust and a higher level of suspicion [34–37].

A related issue that has been studied in more detail is the attitude of minorities toward enrollment in medical research, where similar findings have been reported about African American attitudes towards research [38–46]. Among African Americans, mistrust is frequently associated with the perception that research will benefit whites or the research institution and not people of color. Furthermore, mistrust of the health care system was a primary barrier that prevented African Americans from participating in medical research [38].

For the African American participants in this study, the emphatic need to "see" and "touch" the physician seemed related to similar issues of trust. The physical absence of the physician, the instability of technology, and the inability to

monitor the specialist's qualifications were all highlighted as concerns with telemedicine for the African American participants. All these concerns reflect a sense of vulnerability when placing trust in a medical system that historically has been unreliable and not trustworthy. African American participants expressed a need to be vigilant and monitor physicians to make sure that they would get quality care, particularly when telemedicine appeared to present greater opportunities for care to be compromised. This concern about quality of care is consistent with literature that indicates African Americans' less than satisfying interactions with physicians [47, 48].

With regard to technology, there were many levels of concern. First, there was concern about whether the scopes used in telemedicine would perform adequately to allow physicians to make accurate diagnoses. Second, there was some concern about the computer system failing. However, the bulk of the apprehension among African Americans regarding technology was about the insecurity of transmitting personal data and images over the Internet when using telemedicine. A third issue of trust reiterated by African American participants was that of being able to trust the qualifications and qualities of the physician who is not in the room. There was concern about the level of experience of the physician, suggesting that these participants were concerned that telemedicine might be a way to unload inexperienced or second-rate doctors on them.

In contrast, the Latino participants had distinctly different responses to telemedicine, which may be explained partly by their different vantage points and lived experiences. Latinos, across age groups, appeared to have a significantly more trusting attitude towards the health care system in general and telemedicine in particular. This difference was reflected in their very different attitudes towards the telemedicine-related issues identified as problematic by African Americans, namely, the physician's virtual presence, the usage of technology, and the qualifications and qualities of physicians. The Latino participants' relative lack of concern about the physical absence of the physician points to the possibility that physical exams and the touch of the physician in time-pressured primary care visits are becoming less frequent [49] and consequently telemedicine is not that different from their expected standards of care.

Latino participants tended to equate the use of technology with access to scientific advances and expressed faith in the appropriate authorities to maintain confidentiality. Technology was seen by many Latinos as assuring greater accuracy (more exact data). Such optimism and openness towards technological innovations among Latinos was markedly different from the attitude found among African American participants. Despite the fact that both groups may experience what is commonly called the "digital divide," they had noticeably different opinions about technology in general.

Latino participants also differed from African Americans in that they trusted the administrators of both telemedicine and non-telemedicine clinics to be responsible for hiring qualified doctors. Finally, the knowledge of the quality and qualifications of the physicians was determined by

the success of the treatment, whether telemedicine or nontelemedicine based.

The qualitative racial/ethnic differences in attitudes about telemedicine-based health care among Latinos and African Americans point to differences in their lived experiences and values. The point of reference for many African Americans is the history of racism and medical experimentation and abuse they have experienced collectively in the United States. In contrast, immigrant Latinos encounter the US medical system without this particular historical backdrop and their point of reference maybe less than optimal health care in their home countries, along with a generally positive perception of the American health care and medical education systems. For many of the immigrant Latinos, access to American health care and especially telemedicine-based care that is perceived as scientifically and technologically cutting edge also seems to be seen as a positive improvement. Thus, in terms of the DOI framework, there appears to be good compatibility between the needs, lived experiences, and values of Latinos with the structure and delivery of telemedicine-based care.

4.1. Implications for Telemedicine. Our findings of differences in attitudes toward telemedicine suggest that it will be necessary to tailor approaches to the introduction, marketing, and implementation of telemedicine among these different populations. It is critical to gather this information before the extensive introduction of telemedicine clinics in inner-city communities for at least three reasons.

First, this information can be important for determining the best manner in which to introduce and market telemedicine among these two groups. Based on the findings from this study, it is important to identify the gaps in knowledge or the misinformation that can lead to distrust of new technology or the overestimation about the benefits of new technology and false expectations. The information gathered from this study can be used to help lower the barriers to acceptance of telemedicine by developing educational materials that address misinformation and gaps in knowledge. Marketing information could be tailored to address the specific concerns voiced by the two racial/ethnic groups, such as clearly informing African Americans about the medical qualifications of the specialists and the security procedures for maintaining confidentiality and level of diagnostic accuracy using telemedicine equipment.

Second, this information can be important in selecting the optimal ways in which to implement new telemedicine clinics. For example, for African Americans, having an initial in-person meeting with a physician may be important in helping establish trust and better preparing the patient for future virtual appointments. For real-time telemedicine consultations, cameras could be set up to make the specialist's activities especially transparent to the patients. Physicians' assistants or the nurses in the clinics and the specialists involved in telemedicine could be better informed about the concerns of each of these groups so that they can address these concerns (such as reassurances about confidentiality), even if the patients do not voice them.

Third, this data can also serve as a baseline point of comparison for studies that will examine changes in patient perceptions over time. As telemedicine becomes implemented in urban settings and becomes more familiar to African American and Latino populations, it will be important to have an understanding of their baseline pre-experience perceptions regarding telemedicine to gauge the changes in attitudes towards telemedicine as it spreads into different communities.

4.2. Limitations. There are several important limitations to our data and study findings. First, we have a relatively small convenience sample and our participants are not statistically representative of the wider population in inner-city settings. However, as is common to qualitative methods, they represent information-rich cases, homogenously stratified across race and age, to allow in-depth understanding of the perceptions about telemedicine among these groups. Another limitation is that for the majority of our participants, the only information about telemedicine came from the video they saw at the beginning of the focus group. While telemedicine was portrayed in a typical setting with a typical health problem, our participants' understanding and consequent reactions to telemedicine were clearly influenced by what we were able to show them in a short video. For example, we represented telemedicine primarily as a diagnostic interaction with a specialist and did not address its other potential uses, such as in the long-term management of chronic diseases. Our finding of no age group differences may be a reflection of the limitations of our study design. We may have needed a more sensitive interview protocol that would have more finely delineated the nuances of age differences in our sample.

5. Conclusion

Using the DOI framework regarding features of an innovation, this study contributes to an underresearched area by exploring the pre-experience perceptions of telemedicine among urban, underserved African Americans and Latinos. Despite reservations, many participants indicated that they would take advantage of telemedicine clinics.

Through this study, we were able to identify components of the DOI framework that spoke to the experiences of the two minority groups—particularly with regards to compatibility with past experiences and existing values. It will be important to develop larger studies in different geographical regions with different populations to further understand the importance of these factors for the introduction/marketing, implementation, and eventual adoption of telemedicine among diverse populations.

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References

- [1] T. Greenhalgh, G. Robert, F. Macfarlane, P. Bate, and O. Kyriakidou, "Diffusion of innovations in service organizations: systematic review and recommendations," *Milbank Quarterly*, vol. 82, no. 4, pp. 581–629, 2004.
- [2] B. L. Chang, S. Bakken, S. S. Brown et al., "Bridging the digital divide: reaching vulnerable populations," *Journal of the American Medical Informatics Association*, vol. 11, no. 6, pp. 448–457, 2004.
- [3] A. Nelson, "Unequal treatment: confronting racial and ethnic disparities in health care," *Journal of the National Medical Association*, vol. 94, no. 8, pp. 666–668, 2002.
- [4] K. A. Phillips, M. L. Mayer, and L. A. Aday, "Barriers to care among racial/ethnic groups under managed care," *Health Affairs*, vol. 19, no. 4, pp. 65–75, 2000.
- [5] S. Shea, J. Starren, R. S. Weinstock et al., "Columbia University's Informatics for Diabetes Education and Telemedicine (IDEATel) Project: rationale and design," *Journal of the American Medical Informatics Association*, vol. 9, no. 1, pp. 49–62, 2002.
- [6] D. R. Williams, "Race, socioeconomic status, and health the added effects of racism and discrimination," *Annals of the New York Academy of Sciences*, vol. 896, pp. 173–188, 1999.
- [7] D. S. Puskin, "Opportunities and challenges to telemedicine in rural America," *Journal of Medical Systems*, vol. 19, no. 1, pp. 59–67, 1995.
- [8] W. C. Richardson, *Crossing the Quality Chasm: A New Health System for the 21st Century*, Institute of Medicine, Washington, DC, USA, 2001.
- [9] P. S. Whitten, F. S. Mair, A. Haycox, C. R. May, T. L. Williams, and S. Hellmich, "Systematic review of cost effectiveness studies of telemedicine interventions," *British Medical Journal*, vol. 324, no. 7351, pp. 1434–1437, 2002.
- [10] W. R. Hersh et al., *Telemedicine for the Medicare Population: Update*, Agency for Healthcare Research and Quality, Rockville, Md, USA, 2006.
- [11] R. S. Baker, N. L. Watkins, M. R. Wilson, M. Bazargan, and C. W. Flowers, "Demographic and clinical characteristics of patients with diabetes presenting to an urban public hospital ophthalmology clinic," *Ophthalmology*, vol. 105, no. 8, pp. 1373–1379, 1998.
- [12] T. S. Nesbitt, D. M. Hilty, C. A. Kuenneth, and A. Siefkin, "Development of a telemedicine program," *Western Journal of Medicine*, vol. 173, no. 3, pp. 169–174, 2000.
- [13] E. L. Carter, G. Nunlee-Bland, and C. Callender, "A patient-centric, provider-assisted diabetes telehealth self-management intervention for urban minorities," Perspectives in Health Information Management/AHIMA, American Health Information Management Association, 2011.
- [14] K. Shahid, A. M. Kolomeyer, N. V. Nayak et al., "Ocular telehealth screenings in an urban community," *Telemedicine and e-Health*, vol. 18, no. 2, pp. 95–100, 2012.
- [15] N. Scheinfeld, M. Fisher, P. Genis, and H. Long, "Evaluating patient acceptance of a teledermatology link of an urban urgent-care dermatology clinic run by residents with board certified dermatologists," *SKINmed Journal*, vol. 2, no. 3, pp. 159–162, 2003.

- [16] P. M. Trief, R. Izquierdo, J. P. Eimicke et al., "Adherence to diabetes self care for white, African-American and Hispanic American telemedicine participants: 5 year results from the IDEATel project," *Ethnicity & Health*. In press.
- [17] R. S. Weinstock, J. A. Teresi, R. Goland et al., "Glycemic control and health disparities in older ethnically diverse underserved adults with diabetes: five-year results from the Informatics for Diabetes Education and Telemedicine (IDEATel) study," *Diabetes Care*, vol. 34, no. 2, pp. 274–279, 2011.
- [18] E. M. Rogers, *Diffusion of Innovations*, Free Press, 1995.
- [19] A. Allen and J. Hayes, "Patient satisfaction with teleoncology: a pilot study," *Telemedicine Journal*, vol. 1, no. 1, pp. 41–46, 1995.
- [20] H. Mekhjian, J. W. Turner, M. Gailiun, and T. A. McCain, "Patient satisfaction with telemedicine in a prison environment," *Journal of Telemedicine and Telecare*, vol. 5, no. 1, pp. 55–61, 1999.
- [21] J. W. Turner, R. J. Thomas, and N. L. Reinsch Jr., "Willingness to try a new communication technology: perceptual factors and task situations in a health care context," *Journal of Business Communication*, vol. 41, no. 1, pp. 5–26, 2004.
- [22] R. L. Bashshur, "Public acceptance of telemedicine in a rural community," *Bioscience Communications*, vol. 4, pp. 17–38, 1978.
- [23] J. E. Brick, R. L. Bashshur, J. F. Brick, and R. M. D'Alessandri, "Public knowledge, perception, and expressed choice of telemedicine in rural West Virginia," *Telemedicine Journal*, vol. 3, no. 2, pp. 159–171, 1997.
- [24] Department of Health Services, L.A.C., *The Health of the Residents in South Service Planning Area of Los Angeles County*, Los Angeles County Department of Health Services, 2007.
- [25] Department of Health, *Los Angeles County Health Survey*, Department of Health, Los Angeles, Calif, USA, 2005.
- [26] M. Agar and J. MacDonald, "Focus Groups and ethnography," *Human Organization*, vol. 54, no. 1, pp. 78–86, 1995.
- [27] R. A. Krueger and M. A. Casey, *Focus Groups: A Practical Guide for Applied Research*, Sage Publications, 2000.
- [28] D. L. Morgan, *Focus Groups as Qualitative Research*, Sage Publications, 1997.
- [29] D. W. Stewart, P. N. Shamdasani, and D. W. Rook, *Focus Groups: Theory and Practice*, Sage, 2007.
- [30] A. L. Strauss, *Qualitative Analysis for Social Scientists*, Cambridge University Press, 1987.
- [31] D. C. Alverson, B. Holtz, J. D'Iorio, M. Devany, S. Simmons, and R. K. Poropatich, "One size doesn't fit all: bringing telehealth services to special populations," *Telemedicine and e-Health*, vol. 14, no. 9, pp. 957–963, 2008.
- [32] M. Lillie-Blanton, M. Brodie, D. Rowland, D. Altman, and M. McIntosh, "Race, ethnicity, and the health care system: public perceptions and experiences," *Medical Care Research and Review*, vol. 57, no. 1, pp. 218–235, 2000.
- [33] W. D. King, "Examining African Americans' mistrust of the health care system: expanding the research question," *Public Health Reports*, vol. 118, no. 4, pp. 366–367, 2003.
- [34] T. A. LaVeist, K. J. Nickerson, and J. V. Bowie, "Attitudes about racism, medical mistrust, and satisfaction with care among African American and white cardiac patients," *Medical Care Research and Review*, vol. 57, no. 1, pp. 146–161, 2000.
- [35] L. E. Boulware, L. A. Cooper, L. E. Ratner, T. A. LaVeist, and N. R. Powe, "Race and trust in the health care system," *Public Health Reports*, vol. 118, no. 4, pp. 358–365, 2003.
- [36] V. N. Gamble, "Under the Shadow of Tuskegee: African Americans and Health Care," *American Journal of Public Health*, vol. 87, no. 11, pp. 1773–1778, 1997.
- [37] S. B. Thomas and S. C. Quinn, "Public health then and now: the Tuskegee Syphilis Study, 1932 to 1972: implications for HIV education and AIDS risk education programs in the black community," *American Journal of Public Health*, vol. 81, no. 11, pp. 1498–1504, 1991.
- [38] D. P. Scharf, K. J. Mathews, P. Jackson, J. Hofsuemmer, E. Martin, and D. Edwards, "More than Tuskegee: understanding mistrust about research participation," *Journal of Health Care for the Poor and Underserved*, vol. 21, no. 3, pp. 879–897, 2010.
- [39] R. BeLue, K. D. Taylor-Richardson, J. Lin, A. T. Rivera, and D. Grandison, "African Americans and participation in clinical trials: differences in beliefs and attitudes by gender," *Contemporary Clinical Trials*, vol. 27, no. 6, pp. 498–505, 2006.
- [40] D. F. Farmer, S. A. Jackson, F. Camacho, and M. A. Hall, "Attitudes of African American and low socioeconomic status white women toward medical research," *Journal of Health Care for the Poor and Underserved*, vol. 18, no. 1, pp. 85–99, 2007.
- [41] C. A. Gadegebeku, P. K. Stillman, M. D. Huffman, J. S. Jackson, J. W. Kusek, and K. A. Jamerson, "Factors associated with enrollment of African Americans into a clinical trial: results from the African American study of kidney disease and hypertension," *Contemporary Clinical Trials*, vol. 29, no. 6, pp. 837–842, 2008.
- [42] P. Herring, S. Montgomery, A. K. Yancey, D. Williams, and G. Fraser, "Understanding the challenges in recruiting blacks to a longitudinal cohort study: the adventist health study," *Ethnicity and Disease*, vol. 14, no. 3, pp. 423–430, 2004.
- [43] V. A. Johnson, K. A. Edwards, S. L. Sherman et al., "Decisions to participate in fragile X and other genomics-related research: native American and African American voices," *Journal of Cultural Diversity*, vol. 16, no. 3, pp. 127–135, 2009.
- [44] H. M. Linden, L. M. Reisch, A. Hart et al., "Attitudes toward participation in breast cancer randomized clinical trials in the African American community: a focus group study," *Cancer Nursing*, vol. 30, no. 4, pp. 261–269, 2007.
- [45] Y. R. Smith, A. M. Johnson, L. A. Newman, A. Greene, T. R. B. Johnson, and J. L. Rogers, "Perceptions of clinical research participation among African American women," *Journal of Women's Health*, vol. 16, no. 3, pp. 423–428, 2007.
- [46] S. B. Wyatt, N. Diekelmann, F. Henderson et al., "A community-driven model of research participation: the Jackson Hearth Study participant recruitment and retention study," *Ethnicity and Disease*, vol. 13, no. 4, pp. 438–455, 2003.
- [47] M. P. Doescher, B. G. Saver, P. Franks, and K. Fiscella, "Racial and ethnic disparities in perceptions of physician style and trust," *Archives of Family Medicine*, vol. 9, no. 10, pp. 1156–1163, 2000.
- [48] R. L. Johnson, S. Saha, J. J. Arbelaez, M. C. Beach, and L. A. Cooper, "Racial and ethnic differences in patient perceptions of bias and cultural competence in health care," *Journal of General Internal Medicine*, vol. 19, no. 2, pp. 101–110, 2004.
- [49] S. Saha, J. J. Arbelaez, and L. A. Cooper, "Patient-physician relationships and racial disparities in the quality of health care," *American Journal of Public Health*, vol. 93, no. 10, pp. 1713–1719, 2003.

Research Article

Do We Need New Personalized Emergency Telehealth Solutions? A Survey of 100 Emergency Department Patients and a First Report of the Swiss Limmex Emergency Wristwatch: An Original Study

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Development of new personal mobile and wireless devices for healthcare has become essential due to our aging population characterized by constant rise in chronic diseases that consequently require a complex treatment and close monitoring. Personal telehealth devices allow patients to adequately receive their appropriate treatment, followup with their doctors, and report any emergency without the need of the presence of any caregivers with them thus increasing their quality of life in a cost-effective fashion. This paper includes a brief overview of personal telehealth systems, a survey of 100 consecutive ED patients aged >65 years, and introduces “Limmex” a new GSM based technology packaged in a wristwatch. Limmex can by a push of a button initiate multiple emergency call and establish mobile communication between the patient and a preselected person, institution, or a search and rescue service. To the best of our knowledge, Limmex is the first of its kind worldwide.

1. Background

Patients with complex comorbidities who receive traditional healthcare services fail to show long-term compliance with prescribed regimens, medications, and dietary restrictions [1]. It has been shown, however, that strategies that include extrinsic motivators promote long-term compliance and reduce recidivism [2]. As the population is aging, chronic disease requiring complex treatment and close monitoring is increasing. Moreover, the number of medical personnel is dropping and both homecare nursing and medical staff are expensive. It has therefore become necessary to search for ambitious alternative solutions, which could help the patient to receive adequate treatment and followup from their doctors and to report any emergency, even in the absence of any caregivers and without having to memorize or save emergency numbers, especially when the primary contact is not available. In an ongoing pilot study at

our university hospital emergency department, 40% of interviewed patients (>65 years) were not able to recall emergency telephone numbers. Forty-two percent (42%) of them did not own a mobile phone. Thirty-three percent (33%) thought that, in an emergency, more than one hour might pass until somebody noticed. Thirty-seven patients (37%) thought that up to 30 minutes might pass before anyone was notified of their emergency. Almost 40% of the patients communicated their wish to have faster access to medical assistance. Telemedicine and telehealth, especially personalized handheld devices, can offer a new approach to these problems.

Telemedicine (TM) is the use of medical expertise, medical equipment, computer hardware and software, telecommunication infrastructure and the Internet as a healthcare system [3]. Telehealth (TH) is the delivery of health-related services and information via telecommunication technologies. This is an extension of telemedicine and

encompasses preventive, promotional, and curative aspects. TH involves the use of the tools to produce, transmit, manage, and share digitalized information and comprises the use of applications that allow medical activities, including teleconsultation, medical telemonitoring, and medical teleassistance, as well as remote monitoring and data devices. The latter are known as televigilance or teledata [4]. The first TH system, operating over standard telephone lines, was used for the remote diagnosis and treatment of patients requiring cardiac resuscitation and was developed and marketed by MedPhone Corporation in 1989 [5].

Advances in the area of mobile and wireless communication for healthcare, along with the improvements in information science, have allowed the design and development of new personalized healthcare services, increasing the patient's independence and improving his ability to control and manage his life [6, 7]. Moreover, many studies have shown that TH can improve the quality of life and clinical outcome and is a cost-effective tool. Noel et al. studied 104 patients with complex heart failure, chronic lung disease, and/or diabetes mellitus who were equipped with a TH device functioning on their home landline. Their twelve-month observational study proved that TH used significantly fewer resources and improved cognitive status, treatment compliance, and the stability of the chronic disease of the homebound elderly with common complex comorbidities [8]. The UK Department of Health's Whole System Demonstrator (WSD) program was launched in May 2008 and is the largest randomized control trial of TH in the world, involving 6191 patients and 238 general practitioners. Three thousand and thirty people (3030) with one of three conditions (diabetes, chronic heart failure, or disease) were included in this trial. The trial showed a 45% reduction in mortality rates, a 20% reduction in emergency admissions, a 14% reduction in elective admissions, a 14% reduction in days in hospital, and an 8% reduction in tariff costs [9]. Similarly, in a systematic review evaluating nine randomized clinical trials on heart failure (967 patients), Dang et al. noted that six studies found a 27%–40% reduction in overall admissions; two studies demonstrated a 40%–46% reduction in heart failure-related admissions; three studies found a significant reduction in mortality (30%–67%); three studies showed significant reduction in healthcare utilization costs; two studies also found a 53%–62% reduction in bed days of care; two studies showed a significant reduction in the number of emergency visits; four studies demonstrated significant overall improvement in outcomes with the use of telemonitoring [10]. TH could also become a very effective tool in providing guidance and support in situations of loss of autonomy, by equipping users with devices that will provide monitoring, continuity of treatment, and reinforcement of social ties. Under no circumstances is TH meant to replace a doctor's presence with a computerized tool but was rather designed to meet the needs and expectations of patients more effectively—people who are vulnerable, dependent, and/or disabled. This paper aims to present (1) an overview of existing technologies, (2) a survey of 100 consecutive ED patients aged >65 years, and (3) the Swiss Limmex emergency wristwatch.

2. Mobile and “Handheld” Teleemergency Devices—Reality or Fiction?

All TH personal devices—including watch-based glucose and ECG monitoring devices—have been used experimentally and are still not commercially available. The main drawback remains the complexity of the devices that are being tested. The problem could lie in the device itself or in the communication technology that is being used. In the hope of detecting out-of-hospital cardiac arrest, Rickard et al. studied the ability of Wriskwatch, a watch-based pulse detection that could notify emergency services of a pulseless state. It was unclear how sensitive or specific this study was in detecting true out-of-hospital cardiac arrest. The authors were also unable to determine whether the device can activate emergency medical systems, and, if so, whether this would improve response times and patient outcomes [11].

TeleAlarm S12 and The Red Cross Emergency equipment (Table 1) consist of an alarm button and a speaker phone with microphone and speakers. The alarm button can be worn on the wrist or around the neck. These systems are being currently used in Switzerland and serve the same purpose to our proposed device “Limmex” with some important differences in some key aspects. The major drawback of these systems is that the watch (alarm button) must be connected to a base station within a range of 50 meters and that this base station must use a standard active phone line (landline) as a mode of communication and needs an electrical power supply. Thus, the watch can only be used within a 50 meters indoor perimeter and no outdoors activities are possible [12].

In addition, these systems are expensive, costing about 250 US dollars for a two month lease, about 600 US dollars for the device, and between 40–60 US dollars monthly rent on a long-term contract. That does not include the price of any technical adjustments (electricians), call charges and the telephone line. They can be complicated to install—in contrast to a plug and play devices—and, above all, these devices somehow label and stigmatize the user as “sick” due to their bulkiness and indiscreet size. Therefore, a simple, reliable, and easy-to-wear device is needed to be able to trigger an emergency call wherever and whenever the patient is in need.

3. Access to Emergency Numbers: A Survey

In an attempt to study the possible role and impact of telemedicine handheld devices on the elderly population, we designed a questionnaire (see Supplementary Material available online at doi:10.1155/2012/736264) and asked 100 consecutive patients older than 65 years who visited our emergency room to complete it. The questionnaire included questions about patients demographics, level of education, reason for admission, emergency numbers memorized by the patient, access to a mobile phone, time needed for the patient to be noticed by someone in case of an accident at home, the need for a device to facilitate call for help in case of an emergency and their willingness to buy such a

TABLE 1: Comparison between telealarm/red cross watch and Limmex watch.

	Telealarm/red cross watch	Limmex watch
Technology	Landline	GSM
Ability to use outdoor	No	Yes
Stigmatize patient	Yes	No
Cost	+++	++
Power supply needed	Yes	No
Rechargeable battery	No	Yes
Waterproof	No	Yes

device. Fifty-seven percent (57/100) of the participants in this survey were males. The mean age of the patients was 75 years. 25% (25/100) held a higher professional degree or a university degree, 48% had professional training, and the remaining 27% had not completed any education after compulsory school. When asked about their living situation, 29% stated that they lived alone, while 71% lived with at least one other person in the household. Thirty-seven percent (37%) thought that in case of an emergency, if they were unable to speak, another person would notice their condition within half an hour or less, 21% answered that it would take between half an hour to an hour for someone to notice them, and 33% stated that it could take more than 1 hour to be noticed. The remaining 9% did not answer this question.

Eighty percent (80%) of the patients stored the phone number of their family doctor, while 56% of patients had this number on their mobile phone or written on a card in their wallet; only 24% knew it by heart. Fifty-eight (58%) stated that they used a mobile phone while 42% did not. More than 60% (63/100) knew the phone number of the ambulance and approximately 25% (23/100) could recall the number for Swiss Air Rescue. In addition, only 49% (49/100) of the interviewed patients knew the emergency numbers of the police and the fire department.

When asked if they would worry that no one would notice them in case of a medical emergency, 57% denied any worry while 43% expressed this fear. Thirty-seven percent (37%) wished for a more rapid method to alarm a helpful person or an emergency service. Approximately 60% (58/100) of those interviewed noted they would feel safer if they had a device which enabled them to alarm a close person of their choice, the family doctor, or an emergency service in any medical emergency. Seventy-five percent (75%) of participants declared they were prepared to spend 500 Swiss francs (~600 US dollars) for a telemergency device, while 25% agreed to spend 1000 Swiss francs or more if they thought that their situation had worsened to a point that required such device.

The numbers on this survey and the lack of a reliable and easy-to-wear device that enables patients to trigger an emergency call indicate the need for a groundbreaking device that facilitates communication between patients and-emergency services.

4. Limmex Telemergency Watch from Switzerland: Just a New “Gadget”—or a True Help in Emergency Situations?

The Swiss company “Limmex AG” and the Centre Suisse d’ Electronique et de Microtechnique (Swiss Center for Electronics and Microtechnology) have jointly developed “Limmex” a new emergency watch (Figures 1 and 2). CSEM SA, founded in 1984, is a private research and development center specializing in microtechnology, nanotechnology, microelectronics, system engineering, and communications technologies [12, 13]. Together with the Department of Emergency Medicine, Bern University Hospital [14], several clinical applications were tested and the watch was further developed. The University Hospital Emergency Department is a tertiary unit and one of the largest in Switzerland.

The Limmex emergency watch features a Swiss-made Ronda Quartz movement. It is waterproof against splashes. It has a lithium-polymer rechargeable battery. If there is no emergency, the battery should be recharged every few months. For security reasons, Limmex suggests recharging the battery after an emergency call. The watch integrates a cloud-based technology, allowing remote configuration of settings. Limmex watch costs about 400 US dollars and the monthly contract charges are 25–35 US dollars. There are no hidden extracosts for technical implementation.

The uniqueness of the Limmex is that the watch enables the wearer to request assistance at the push of a button and to speak with preselected persons or services (e.g., police, hospital, ambulance, etc.). Unlike other TH personal devices, the Limmex watch is based on GSM mobile technology; it contains an irreplaceable SIM card on which the user can save up to ten phone numbers. The diagram (Figure 3) is self-explanatory and summarizes how the Limmex system works. The patient wearing the watch can trigger an emergency call by pressing and releasing the emergency call button; a beep then sounds for 15 seconds. During these 15 seconds, he can stop the alarm by pressing the button again. If he does not press it again during these 15 seconds, the Limmex watch will call the first recipient on his preset list; this could be a family member, his family doctor, an emergency center, or an ambulance service. The recipient is immediately prompted with the following message: “This is an emergency call Limmex. Please press 5 to respond!” If the recipient presses key 5 on the telephone, a connection is established with the patient. If the first recipient does not press key “5” (or if the line is busy or an answering machine answers the call), the following numbers are called one after the other until a person responds to the emergency call by pressing key “5.” If an emergency call is triggered, the watch can be called for 30 minutes to ensure that help has been organized. During this time, the watch will automatically accept incoming calls [13].

The watch currently works all over Switzerland. The potential applications of this emergency watch are numerous and are being investigated by our team. In addition to elderly patients with complex comorbidities, this innovative emergency watch can also increase the quality of life in individuals with illnesses such as epilepsy, cardiac problems



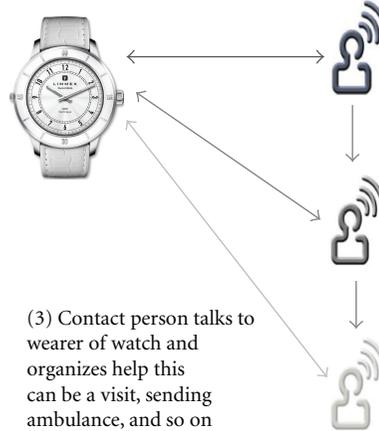
FIGURE 1: Limmex emergency wrist watch: there are two crowns, the one on the left for adjusting time and the one on the right (the larger one) for triggering the emergency call.



FIGURE 2: Limmex emergency wrist watch: wrist shot showing the dimensions of the watch and the microphone.

or severe allergies, pregnant women, or adolescents with juvenile diabetes—any of whom might find themselves in an emergency situation and need immediate assistance. We are currently testing the watch in several patient groups. The use of Limmex can also have a positive repercussion on the healthcare system itself; patients who would have been hospitalized for a longer time for surveillance or for social reasons would be able to be discharged home with a hospital-sponsored Limmex for a limited time; this would allow the patients to call for help at all times once at home and might enhance their quality of life and free hospital beds. The Limmex watch can be used outside or even inside just anywhere where you have wireless coverage, thus the wearer is able to count on a reliable system which operates outside his own four walls, is discreet, and which requires no special

(1) Watch sets up mobile phone connection at the push of a button



(2) Call escalation until first contact person is available (calls can be routed to family members, GP, hospital, emergency call center, and so on)

(3) Contact person talks to wearer of watch and organizes help this can be a visit, sending ambulance, and so on

FIGURE 3: Limmex Emergency Watch—escalating alarm mechanism.

installation. In addition, Limmex provide its users with a wide selection of styles for men and women and not just a standard model such as the tele-alarm.

5. Summary

The Limmex emergency wristwatch can play an important role in the TH system by providing an Alert-Diagnose-Treat service to the patient/person wearing the device and might even save his life. This applies particularly to patients living alone. Furthermore, Limmex could be used for communication between the patient and the caregiver (whether he/she is a family member, a nurse or a physician), in which case the patient can report that he is doing well, or that he has taken the specific treatment at the scheduled time. In contrast to a mobile phone, Limmex is instantly accessible at all times. At the push of a button, an emergency call can be initiated and help arranged. A future prospective study will be designed to look into the social and economic impact of using such device.

Conflict of Interests

We disclose no affiliation with any organization with a financial interest, direct or indirect, in the subject matter or materials discussed in the paper (such as consultancies, employment, expert testimony, honoraria, speakers, bureaus, retainers, stock options, or ownership) that may affect the conduct or reporting of the work submitted.

References

- [1] D. K. Solomon, T. S. Portner, G. E. Bass et al., "Clinical and economic outcomes in the hypertension and COPD arms of a multicenter outcomes study," *Journal of the American Pharmaceutical Association*, vol. 38, no. 5, pp. 574–585, 1998.

- [2] T. T. Fulmer, P. H. Feldman, T. S. Kim et al., "An intervention study to enhance medication compliance in community-dwelling elderly individuals," *Journal of Gerontological Nursing*, vol. 25, no. 8, pp. 6–14, 1999.
- [3] J. Ingenerf, "Telemedicine and terminology: different needs of context information," *IEEE Transactions on Information Technology in Biomedicine*, vol. 3, no. 2, pp. 92–100, 1999.
- [4] <http://www.wikipedia.org/>.
- [5] W. J. Blyth, *Telecommunications, Concepts, Development, and Management*, Glencoe/McGraw-Hill, 2nd edition, 1990.
- [6] S. G. Mougiakakou, E. Kyriacou, K. Perakis et al., "A feasibility study for the provision of electronic healthcare tools and services in areas of Greece, Cyprus and Italy," *BioMedical Engineering Online*, vol. 10, article 49, 2011.
- [7] I. Kouris, S. Mougiakakou, L. Scarnato et al., "Mobile phone technologies and advanced data analysis towards the enhancement of diabetes self-management," *International Journal of Electronic Healthcare*, vol. 5, no. 4, pp. 386–402, 2010.
- [8] H. C. Noel, D. C. Vogel, J. J. Erdos, D. Cornwall, and F. Levin, "Home telehealth reduces healthcare costs," *Telemedicine Journal and E-Health*, vol. 10, no. 2, pp. 170–183, 2004.
- [9] "Whole Systems Demonstrators: an Overview of Telecare and Telehealth," 2009, http://www.dh.gov.uk/prod_digitalasset/consum_dh/groups/dh.digitalassets/documents/dh_100947.pdf.
- [10] S. Dang, S. Dimmick, and G. Kelkar, "Evaluating the evidence base for the use of home telehealth remote monitoring in elderly with heart failure," *Telemedicine Journal and E-Health*, vol. 15, no. 8, pp. 783–796, 2009.
- [11] J. Rickard, S. Ahmed, M. Baruch, B. Klocman, D. O. Martin, and V. Menon, "Utility of a novel watch-based pulse detection system to detect pulselessness in human subjects," *Heart Rhythm*, vol. 8, no. 12, pp. 1895–1899, 2011.
- [12] <http://www.swisscom.ch/res/festnetz/dienstleistungen/telealarm/index.htm?languageId=en>.
- [13] Limmex Website, <http://media.limmex.com/pdfs/manual.fr.pdf>.
- [14] <http://notfallzentrum.insel.ch/de/>.