Designing and Evaluating Online Telehealth Systems for Seniors

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Abstract. The increasing cost of senior healthcare represents a serious challenge to most developed countries. Telehealth has been widely promoted as a technology to make healthcare more effective and affordable, however, current telehealth systems suffer from vendor lock-in and high cost, and are designed for managing chronic diseases rather than preventing them. We propose a novel framework for telehealth systems aimed at overcoming these shortcomings through principles such as extensibility, accessibility, social support and motivational feedback. The framework was employed to develop a patient-centric telehealth system, *Healthcare4Life*, which was evaluated in a user study to draw conclusions about the feasibility and acceptance of such a system by seniors. The results indicate that seniors are capable and motivated to use a web-based telehealth system if it provides suitable health applications. Furthermore, the results suggest that such a system has the potential to affect seniors' attitude towards their own health positively.

1 Introduction

In many developed countries healthcare systems are struggling with an increasing number of seniors, more chronic diseases affecting them, a declining potential support ratio, mounting senior healthcare costs, and a shortage of health professionals. The three main emerging public health issues are: providing access to affordable healthcare, solving chronic health problems and preventing diseases [Edelman 2009]. One promising approach to address these issues is to empower health consumers to better manage and monitor their health [Hibbard and Cunningham 2008]. If patients play an active role in preventing diseases instead of being passive recipients of treatments after getting sick, they are more able to take control of their health.

Home-based healthcare applications such as telehealth can enable users to track their health status and to actively participate in treatment regimens and preventive strategies. Telehealth can be defined as [HRSA 2013]: "*the use of electronic information and telecommunications technologies to support long-distance clinical healthcare, patient and professional health-related education, public health, and health administration*." From the definition it is clear that telehealth is about receiving care from a distance. Research suggests that seniors generally prefer to age independently in their own homes rather than moving to an institutional care setting [Botsis et al. 2008]. Telehealth meets this preference and could therefore be a viable approach for helping seniors to take charge of their health. However, in order to be successful, telehealth systems need to be widely available, affordable and extendable. Most importantly, their design should reflect the needs of the "patients", rather than those of clinicians.

Internet-based solutions are capable of reaching a wider section of the senior population at a low cost, with promising interventions that could affect desired lifestyle changes. Seniors are often said to experience anxiety and usability issues when dealing with technology, but the current trend is changing this. The number of seniors going online is increasing steadily. Recent Internet demographics suggest that more than half (53%) of U.S. seniors are online today [Zickuhr and Madden 2012]. The continued growth in the number of seniors going online indicates an increased utilisation of web-based resources, thereby providing opportunities to address the shortcomings of current telehealth systems by making them more accessible, add social aspects and stimulate integration of third-party applications. Therefore, we choose an approach that leverages the Web as a medium to deliver healthcare services to seniors.

The principle aim of the study presented here is to develop and test new concepts to address the shortcomings of current telehealth systems and Web 2.0 health applications. The intention is to contribute to a novel design for web-based telehealth systems that is closely aligned with consumers' preferences, i.e. telehealth from the perspective of the senior consumer. We propose a framework for an accessible patient-centric telehealth system with social aspects, develop a prototype implementing key concepts, and explore these concepts using the prototype. A patient-centric approach was employed in developing the prototype by working closely with seniors from the outset. Several user studies were conducted with representatives of this target user population.

First, we describe the shortcomings of current health informatics applications, building an understanding of the extent they fulfill the healthcare needs of users. Based on this we propose a novel framework for web-based, patient-centric, affordable and extendable telehealth systems and describe the key design decisions that were applied to create the Healthcare4Life (HC4L) system prototype. Our implementation uses OpenSocial and Drupal to provide social networking functionalities and a Facebook-like plug-in architecture for third-party content [Dhillon et al. 2012]. A six-week user study indicates that seniors welcome the opportunity to

become more proactive in managing their health, and that a system such as HC4L can empower users by giving them more control over managing their health.

Section 2 describes requirements and motivates our work by summarising the shortfalls of current consumer health informatics applications. Section 3 presents the proposed framework for the design of patient-centric telehealth systems. Section 4 describes the evaluation of the HC4L prototype, and Section 5 concludes the paper with a summary of our contributions and future work.

2 Establishing Requirements

This section first provides an overview of current consumer health informatics applications to motivate the development of a novel web-based telehealth system. Then, we describe a small-scale interview study conducted to identify the user interface and functional requirements of a web-based telehealth system.

2.1 Consumer Health Informatics Applications

In recent years an increasing number of healthcare applications has been developed, including consumer health informatics applications designed to interact directly with consumers, with or without the presence of healthcare professionals. In our previous work [Singh et al. 2010], we evaluated common consumer health informatics applications (i.e. telehealth systems, health record management systems, Web 2.0 health applications, serious games and exertainment applications) from the patient's perspective and discussed their strengths and weaknesses for healthcare. Our analysis identifies a number of shortcomings constraining widespread use and health outcomes, as summarised below.

Commercial telehealth applications and most health record management systems are centred on clinical users, health service providers and vendors' interest of generating a continuous revenue stream. Generally such applications perform well in collecting, analysing and monitoring health data, but there is little support for patients to change their lifestyle positively. Most of these applications are expensive and suffer from vendor lock-in, making it difficult to add new content. They usually do not fit into the regular activities of a user, making them disruptive. Most telehealth applications are designed for monitoring and treating patients with chronic diseases, but do little to prevent them.

Health information websites offer an impressive range of information, but it can be difficult to assess its reliability, meaning and implications. Web-based discussion and support groups can provide a more personal experience and add a social factor that can help patients with coping and commencing positive lifestyle changes. Web 2.0 health applications and services (also known as Health 2.0) are rapidly gaining attention from patients and professionals as they extend traditional

healthcare delivery models, facilitate patient self-care and provide social support. However, most of these applications are fairly costly, limited in their functionality, and target younger health consumers [Dhillon et al. 2011a].

Serious games and exertainment applications are arguably the most patient-centric consumer health informatics applications. However, evaluations of their effectiveness report mixed results, especially for long-term use. One of the main problems is their limited content, which means applications can become repetitive and boring, so that lifestyle changes are only temporary [Owens et al. 2011]. In most cases content is controlled by a single vendor and must be purchased. Furthermore, monitoring data is not shared between different games, so that a continuous recording of health parameters and activities is not possible.

In order to promote a more widespread use of health informatics applications and achieve better health outcomes, applications need to offer a wide range of content and functionalities, there needs to be a quality control of content, and different applications must be integrated to deliver a more complete picture of health over time. Furthermore, application should be low-cost (preferably free), easy-to-use, concentrate on the prevention of diseases, and provide motivation and support. The latter suggests the incorporation of social networking features. Such features can also help to reduce loneliness, which has been shown to result in serious health problems [Miller 2011].

2.2 Interview Study

In order to identify requirements for a more accessible patient-centric telehealth system, we performed an interview study with eight potential senior users [Dhillon et al. 2011b]. The study was designed as a qualitative inquiry focusing on seniors' perceptions and preferences. First, a semi-structured interview was conducted. Then, a paper-based prototype of HC4L and screenshots of different existing health informatics applications were presented for evaluation.

The results suggest that the Internet is a suitable platform for the delivery of telehealth applications. In the interviews, the participants suggested several applications such as exercises for different health problems, diet control, and simple network games. They generally favoured user interfaces with a simple layout such as a single horizontal menu at the top, making it easy to identify and choose key functionalities. Buttons with suitable icons or text were preferred over hyperlinks. The results indicate that social support through Facebook-like features can be useful in a community of like-minded users. Social interactions may help users to reduce loneliness, motivate each other, and share experiences.

3 Conceptual Framework

In this section, we describe a novel conceptual framework and key design principles to aid development of patient-centric telehealth systems. The framework presents the big picture (i.e. the overall vision including possible future work) for overcoming the challenges of existing consumer health informatics applications in empowering health consumers to take charge of their healthcare.

3.1 Framework

Based on the above requirements we developed a framework to aid development of patient-centric telehealth systems, illustrated in Fig. 1, which is accessible, extendable by third parties, contains social aspects, encourages cognitive engagement, and aims to put the user in control [Singh et al. 2010]. The framework has an open Facebook-like architecture enabling third-party developers to contribute new content and functionalities. Examples are applications for monitoring, health information, mental fitness and education. Physical fitness and rehabilitation can be supported by adding applications using consumer-level sensing devices [Dhillon et al. 2011a]. Accessibility is facilitated by making the system web-based, so that it can be accessed on desktop computers, tablets and mobile phones. In order to assess the quality of content we propose to employ a ranking system displaying user satisfaction and popularity of each service. The ranking system should contain separate scores from patients and registered clinical/academic users.

In order to share data between different applications, unifying data elements must be introduced that relate different types of data. This can be achieved by using a triplestore database: data entities are composed of subject-predicate-object triples, where the predicate represents the unifying element. For example, different exercise games might use different measures to record users' physical activities, which could be unified using a "calories burned" or "perceived-level-of exertion" scale [Borg 1982] similar to those used in gym equipment. The unified data can then be used by monitoring applications to enable users to design activity plans and track progress.

While commercial telehealth systems put an emphasis on clinical networks, we utilise social networks to help users get in touch with their family, make new friends, and discuss medical complaints with peers and support groups. The aim is to improve emotional health, which is essential for the overall wellbeing. Social networks can also help with motivation, e.g., through family support or competing/exercising together via a video link or in a virtual environment.

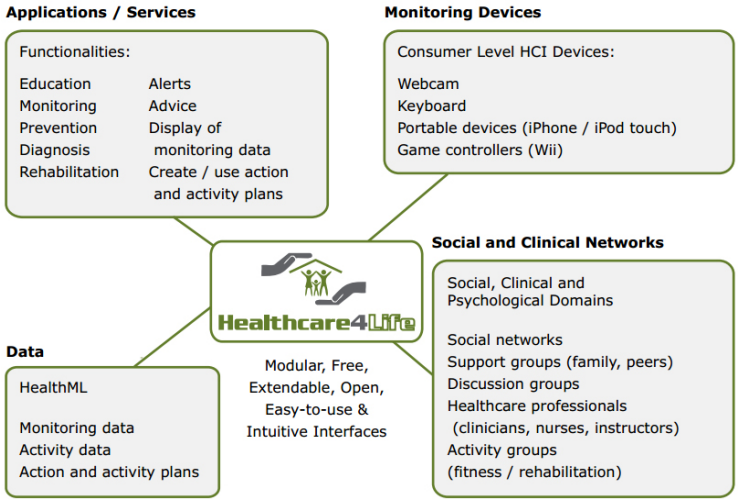

Fig. 1 Conceptual framework for HC4L [Singh et al. 2010]

3.2 Key Design Principles

The above analysis of consumer health informatics applications and the interview study resulted in the following key design principles (ordered by importance):

- **Open and extensible**: The system should offer a wide variety of health-related applications that cater for the various needs and preferences of patients. If the available content is too limited, it will become repetitive and boring for users and result only in short-term lifestyle changes. The system should be "open", so that third parties can contribute and adopters can avoid vendor lock-in.
- **Accessible and affordable**: The system must be accessible with a common web browser on different devices, at low cost or free of charge.
- **Social and emotional support**: The system should foster a caring community, enabling users to provide and obtain social support to and from other users. Social features should be incorporated to reduce loneliness, e.g., help users to become acquainted with other users, to perform health-related activities together (e.g., playing a memory game), and to motivate each other.
- **Feedback and motivation**: The system should provide users with feedback on their health progress and motivate them to become more proactive, e.g., make positive lifestyle changes. Visual feedback via easy-to-understand graphs and charts is particularly important for users with limited health literacy.
- **Privacy control**: User privacy must be maintained and users must have control over their personal data. Sensitive data such as those relating to symptoms, diagnoses and treatments should not be disclosed without explicit consent.

- **Personalised user interface**: Users should be able to customise the system with applications tailored towards their personal needs. Applications should be easy to add and remove. Sufficient information about available applications should be provided to enable users to select desired functionalities.
- **Simple navigation structure and clear instructions**: The system should provide a simple navigation structure to avoid confusion and frustration. For example, the system should allow users to complete health related tasks such as tracking their weight using a linear sequence of simple steps.

4 Evaluation

We evaluated the usability, acceptance and feasibility of the most important framework concepts in a user study involving 43 seniors (16 male, 27 female) aged 60 to 85. In the following, we describe the methodology used in the evaluation and present and discuss the results.

4.1 Methodology

For the study, a prototypical implementation of the framework, Healthcare for Life (H4CL), was created, based on the key design principles laid out in Section 3.2. It was implemented using OpenSocial and Drupal. OpenSocial was preferred over Facebook and other single-platform APIs because it does not constrain developers with vendor restrictions and usage policies [Dhillon et al. 2012]. Developers have full control over their system and the freedom to integrate it with other OpenSocial containers. The Drupal CMS was leveraged for content management because of its support for OpenSocial.

HC4L supports both application users and application developers. Both groups are presented with distinctive functionalities based on their role in the system. System developers can add applications to HC4L, so that they become accessible to users via an application directory. Patients are provided with the following functionalities (see centre of Fig. 2): *Activities* to motivate friends with positive comments and to share their status; *Health Apps* to access applications added by developers; *Profile* to create a basic online health profile to enable others to locate them in the system; *Mail* to send mails to other users that are listed as “friends”; *Friends* to access the profile pages of “friends”, find and add new friends, and invite others to join HC4L; and *Settings* to make changes to general system settings such as privacy settings.

The following applications were created and made accessible via HC4L (see Fig. 2). A *Weight Tracker* allows users to enter their current weight at any time and track their weight over time using a configurable graph visualisation. A multiplayer *Memory Game* fosters interaction between users, allowing them to practice

their memory together (in collaboration or as a competition) in a “Matching Pairs” game with a configurable level of difficulty. An *Exercise Tracker* allows users to track their physical activity over time by entering the time spent on different activities (e.g. walking, housework and swimming), measuring the total physical activity in terms of energy expenditure (i.e., calories burned). A *Vitals Tracker* allows users to enter vital sign measurements (systolic/diastolic blood pressure, resting heart rate and blood glucose) using a simple tabular interface, and track them over time using a configurable graph visualisation. The *Calorie Calculator* is an existing diet tracking application from LabPixies.com. Most of the tracking applications give visual feedback about the normal range of health parameters.

Fig. 2 Screenshots of health support applications embedded in HC4L

Participants were invited to use HC4L over a six-week period. They were asked to complete three questionnaires at different stages of the study: at the start of the study (initial questionnaire), at the end of the third week (interim questionnaire), and at the end of the sixth week (final questionnaire). Furthermore, a short interview was conducted with four selected participants at the end of the study to gain further insights into their experiences with and perceptions of HC4L.

The questionnaires incorporated existing established scales: the Multidimensional Health Locus of Control (MHLC) [Wallston et al. 1978], the Intrinsic Motivation Inventory (IMI) [Ryan 1982], and the System Usability Scale (SUS) [Bangor 2009]. MHLC was used to investigate whether HC4L can positively affect the users’ attitude towards managing their health. IMI was used to evaluate users’ subjective experience, i.e., their intrinsic motivation, in their interaction with HC4L. SUS was used to assess the overall usability of the system. In order to keep the questionnaires simple for seniors, shortened forms of these scales were used, which were known to be equally effective. In order to identify usability issues and evaluate the usefulness of the different functionalities, we used additional, system-specific questions with responses rated on a 6-point Likert-scale.

4.2 Results and Discussion

The majority of the participants were active computer users (88%) using a computer almost every day. Less than half of them (44%) used social networking websites such as Facebook. Less than one third used self-care tools, e.g., blood pressure cuffs, glucometers or health websites.

Fig. 3 depicts the popularity of the various functionalities of HC4L over the trial period. The health applications were most popular among the participants (35% of all activities performed). This demonstrates the importance of having a plug-in feature for increasing the amount of available content. The Facebook-like comment page termed "Activities" was the second-most commonly used feature (22%), followed by the "Friends" page (17%). This indicates that users are interested in sharing experiences and making social connections. Among the applications, the Vital Tracker was most frequently used (29%), followed by the Exercise Tracker (28%), and the Weight Tracker (22%). The Calorie Calculator was least frequently used (8%) because of its comparably complex user interface, the time required to enter data, and because many food items were not relevant for a New Zealand context. This observation emphasizes the need for customising applications according to the users' location, culture and language.

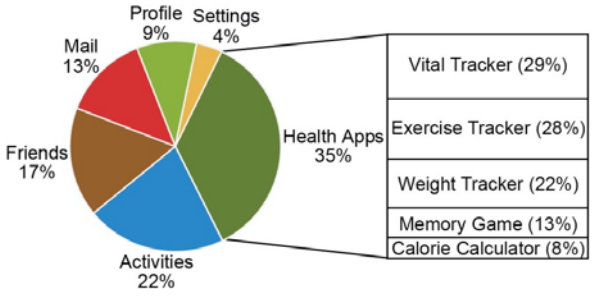

Fig. 3 Participants' activities in HC4L

Table 1 reports the mean score changes for those participants who completed both initial and interim MHLC questionnaires. Score changes for each MHLC subscale were calculated by subtracting baseline scores from follow-up scores. Paired t-tests were used to compare the MHLC mean scores. The findings show that there were some improvements on all the three subscales, although statistically not significant. There was a noticeable difference in the responses for "Powerful Others", which contained three statements to assess whether participants believed their health is controlled by others, e.g. health professionals. The responses to one of the statements, *Health professionals control my health*, showed a significant difference ($t=2.343$, $p=0.03$), indicating that users obtained a better understanding of their health and how it is affected by their own decisions. Although the results were overall not significant, they suggest that HC4L can

affect its users positively. With a richer and more mature implementation, a larger sample and a longer study, we would expect stronger and more significant effects.

Table 1. Change in responses to the MHLC subscales within a three-week period (n = 23)

Subscale	Mean Change	Change SD	Change Range	t	p
Internal	.04	1.04	-4 to 2	-0.44	0.66
Powerful Others	-.29	1.27	-10 to 6	1.21	0.24
Chance	-.10	1.23	-6 to 5	0.51	0.61

Table 2 presents the mean values and standard deviations of five pre-selected subscales of the IMI (range 1 to 7), measured after week 3. It also illustrates the scores of two different senior age groups. Except for the "pressure/tension" scale, the results show mid scores in the range 4.11 to 4.40. The results suggest that the participants were fairly interested in the system, felt adequately competent, made a reasonable effort in using the system, and felt that the system has some value or utility for them. The "pressure/tension" subscale obtained a low score indicating that the participants did not experience stress while using the system. There were notable differences between age groups for "perceived competence" and "value / usefulness". Seniors aged 60-69 considered themselves more competent and found the system more valuable than older seniors, suggesting higher computer literacy.

Table 2. IMI results from 1 (strongly disagree) to 7 (strongly agree), mean ± std. deviation

Subscale	All (n = 24)	Age 60-69 (n = 12)	Age 70-85 (n = 12)
Interest/Enjoyment	4.40 ± 1.68	4.42 ± 1.73	4.39 ± 1.70
Perceived Competence	4.39 ± 1.78	4.89 ± 1.52	3.89 ± 1.94
Effort/Importance	4.11 ± 1.58	4.11 ± 1.57	4.11 ± 1.56
Pressure/Tension	2.61 ± 1.56	2.67 ± 1.45	2.56 ± 1.69
Value/Usefulness	4.25 ± 1.81	4.53 ± 1.83	3.97 ± 1.75

At the end of week 3, 24 participants rated the usability of the system on the SUS scale, with scores ranging from 35 to 100, a median of 65 and an average of 68.33. Only two responses were below 50. The adjective rating of the mean SUS score is "OK", which indicates HC4L is an acceptable system [Bangor 2009]. Participants' open-ended responses were useful in gaining insight into their perceptions of HC4L. Table 3 lists the most frequent responses.

Table 3. Most common positive and negative comments about HC4L (n=24)

Positive Responses	Frequency
I like the idea of it.	26%
It is easy to use.	23%
The health applications are a great help to keep track of one's health.	16%
Negative Responses	
Sorting out calories values for foods seems a lot of trouble (Calorie Calculator).	21%
I am not so keen on the social Facebook-like aspects of the system.	18%
The range of available applications is limited.	15%

In the final questionnaire 13 participants stated that HC4L encourages them to be better aware of their health (80% agreement), that the charts/graphs help to better understand health progress (80% agreement), and that the health applications reduce the need to use different websites for managing health (72% agreement). 65% agreed that HC4L has the potential to positively impact their life, and 56% found that HC4L's applications simplify cumbersome health monitoring tasks.

However, only 33% agreed that the social features motivated them to use the system, and only 31% agreed that the involvement of friends helped them to better manage their health. Four participants of the study expressed disappointment that their friend requests were not responded to. Most of the participants were not comfortable accepting strangers as "friends" in HC4L. A typical comment was: "*I would not share my medical details with someone I don't know*". One participant elaborated on this: "*I find the use of the word 'friends' for people I don't know and will never meet very inappropriate and off-putting. Also it's really important to learn more about the people in your circle so that you care enough about them and their goals to be able to offer support.*"

5 Conclusions and Future Work

We presented a framework for web-based telehealth systems targeted at seniors that are extendable, accessible and include social networking functionality. The framework was used to implement a prototype system, HC4L, which was evaluated in a study involving 43 seniors. The results indicate that most seniors are motivated to use such a system if sufficient and adequate health applications are provided. Furthermore, the results suggest that web-based telehealth systems have the potential to change the attitude of seniors towards their own health positively.

As a future work, systems such as HC4L should be evaluated with a wider and more mature range of health applications, which should ideally be designed in collaboration with health professionals. Furthermore, the long-term effects of such systems need to be explored in a long-term study with a larger sample of seniors.

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