

TESTING USER-TAILORED E-HEALTH SERVICES IN PRACTICE: RESULTS AND LESSONS LEARNED

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ABSTRACT

This paper evaluates a patient self-management system that provides user-tailored e-health services. The system provides a set of health related services (e.g. vital sign monitoring, medication support) to elderly people. These services stem from different vendors and technological origins, yet they can be integrated and tailored to individual care needs. This paper describes the results of an evaluation of the system in a nursing home. Eight clients and 4 nurses of a nursing home tested the system in a pilot study between May and November, 2012.

Results show that it is possible to create a platform that enables patient-specific care. The platform provides useful applications in care. These applications can save time for caregivers, and increase self-management in patients. However, it requires investment in the learning process. The work shows that this platform successfully integrates and tailors heterogeneous sensors, actuators and services from different vendors and technological origins. Adequate personalization of selected e-health services can save time, increase health situation awareness and further patient empowerment.

KEYWORDS

e-health, electronic health, telemedicine.

1. INTRODUCTION

This paper discusses the evaluation of a user-tailored care services platform developed over the last 5 years. This is motivated by a desire for more efficient healthcare, as population ages and care demand and costs increase in many countries [Giannakouris, 2008]. The developed system allows the composition and orchestration of health services from different vendors and technological origins. These services include vital sign monitoring, medication intake support, social activity and interaction support. They can be tailored by caregivers towards specific end-user needs, to provide self-management, even though different users have different care needs. This is generally not possible with current state of art in e-health platforms [Genet, 2011, Mulder et al., 2009]. The system architecture is shown in Figure 1. The services have been elicited and described in [van 't Klooster et al., 2011, Zarifi Eslami et al., 2011]. Here, the focus is on the evaluation in practice rather than in a testbed or living lab. In that way, the tailorability of the system can be verified in real life use cases [Berg, 2001, Broens et al., 2007].

The goals of the evaluation are to demonstrate viable electronic healthcare (e-health) services in a user-friendly and usable way, and to demonstrate a feasible application infrastructure that supports user-tailored e-health services. The relevant evaluation questions are hence defined as follows:

1. Is the system usable in day-to-day care situations?
2. Compared to care as-is, does it provide added value?
3. Is the system user-friendly?
4. Is the application infrastructure feasible?
5. What is the effectiveness of the various system parts?

These are usage-related (1, 2 and 3) and system-related (4 and 5) research questions. To obtain the necessary answers, this paper describes the evaluation process, results and a conclusion referring back to the evaluation questions. Hence, the rest of this paper is structured as follows. Section 2 discusses the methods used in the evaluation, including the pilot study design and the outcome measures that are used. Section 3 presents the results of the pilot. In section 4, these results are discussed and reviewed. Section 5 refers back to the evaluation questions mentioned above, and presents concluding remarks.

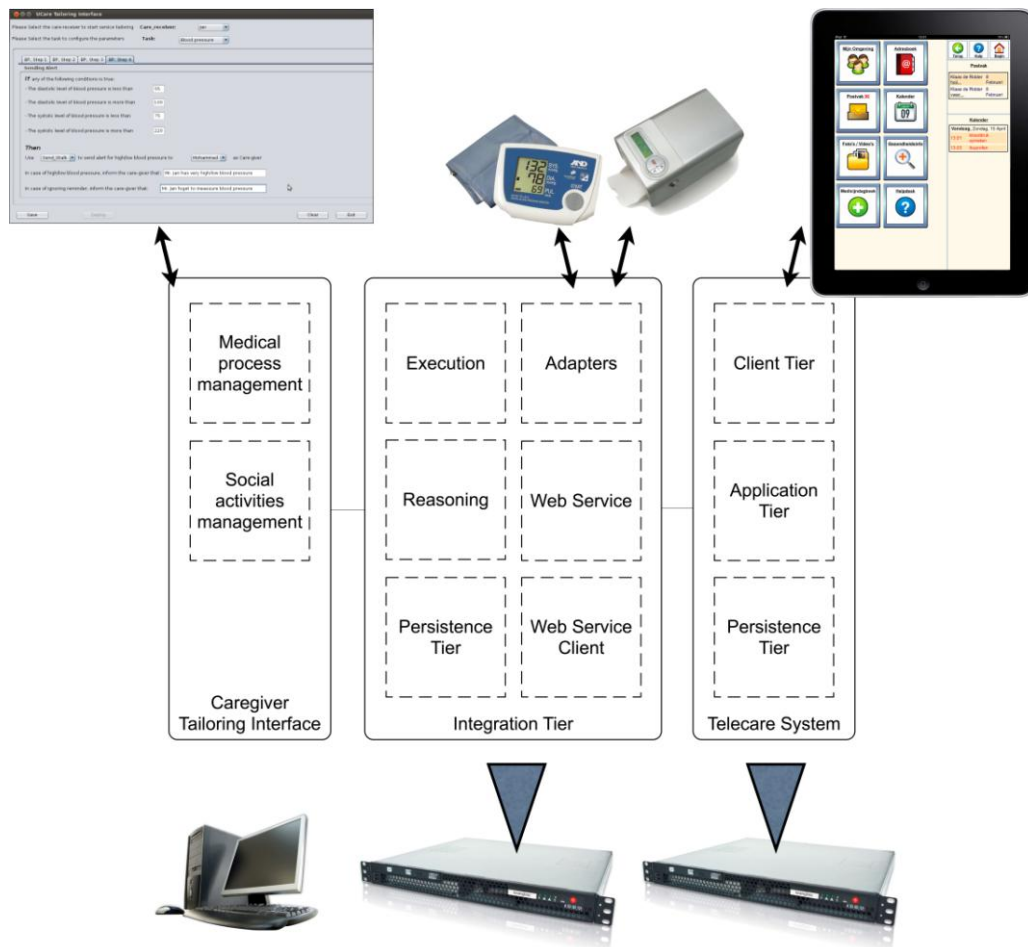


Figure 1. Tailoring system. On the left, tier for caregivers to tailor medical and social services. In the middle, integration tier to execute service plans and to adapt actuators and sensors, such as Bluetooth blood pressure monitor and electronic medication dispenser. On the right, care receiver tier to serve tablet computer with graphical interface.

2. METHODS

2.1 Figures and Tables

In the pilot, we evaluate the four services mentioned: social interaction, social activities, medication intake and compliance, and health monitoring. Before the pilot, caregivers and care receivers are instructed using both workshops and written documentation. The caregivers are trained by the developers to tailor the services. The care receivers are trained by the caregivers using workshops (simultaneous training) and individual training. These are not performed by the developers because of familiarity and privacy reasons.

The pilot is conducted as follows: first the pilot is prepared; then there are 2 pilot phases with technical adjustment in between, then there is an evaluation.

The pilot preparation involves lab-testing the developed services (integration testing) and configuring all the necessary hardware components, network and software settings. The pilot itself is divided in two phases. In this setup, both unexpected circumstances can be dealt with, and desired new functionalities that arise in the first phase, can be realized in between the two phases. Finally, an evaluation is held which is discussed in the following of this paper. The first phase lasted from week 19 till week 26 (7 May – 25 June) 2012. The

second phase lasted from week 40 till week 47 (1 October – 19 November) 2012. Eight female care receivers of nursing home Hoogstaete, The Netherlands (aged 74–98) are voluntarily selected to participate in either of these phases, or both. Due to age and nursing home location characteristics, no male persons were available. They are asked (i) to learn to operate the system, (ii) perform tasks according to different usage scenarios as defined in Table 1, and (iii) participate in questionnaires and interviews.

The motivation to test the system in a real-life pilot, with a limited number of users, stems from the fact that the development is in a stage in which the platform works, but it is too early for large scale testing. It still is a research prototype and resources for large scale testing are not available. On the other hand, just testing the result in a lab, or living lab situation is undesirable: that does not provide real usage results or feedback. The end users who are testing the system are aware that they are using a working prototype, yet they can assume a working system that has been tested.

The scenarios tested in the pilot are executed using stratification because of the limited number of sensors and actuators available. Also different combinations could be tested this way. The tested scenarios are listed in Table 2.

Table 1. Pilot study scenarios

Service plan	Description
MD _m + BP + Weight	MD _m is a manual medication dispenser. Care receivers are asked to take medication. BP and Weight services are used to monitor blood pressure and body weight respectively, based on plan created by caregivers.
MD _m + BP + Weight	Same as above but without measuring body weight. care receivers are asked to monitor their blood pressure (BP) and body weight.
OX + BP + Weight	care receivers are asked to monitor their blood pressure (BP), Oxygen Saturation (OX), and body weight.
MD _e + Weight +	MD _e is an electronic medication dispenser. It is used for routine medication; with monitoring body weight and blood pressure (BP).
SA	Caregivers enter social activities (SA) organised in the nursing home. Care receivers are notified about these activities.
SI	Caregivers, care receivers and family have social interaction (SI) using the system.

Table 2. Pilot study scenarios

Item	Description
# care receivers	8
Age	86 ± 12 years (All female)
# caregivers	4
Gender	3 female, 1 male
Trial location	Nursing home, Sittard, NL
Duration	7 May – 25 June 2012; 1 October – 19 November 2012
Services	Social Activities (8,8)
(# users phase 1,2)	Social Interaction (8,8) MD _m + BP + Weight (1,1) MD _m + BP (1,1) BP + Weight (2,1) OX + BP + Weight (1,1) MD _e + Weight + BP (0,1)

The social activities are entered in the system as soon as the schedule is defined by the caregivers responsible for activities. The activities that are entered are the same for all the participants, and equal to the activities that are announced to the inhabitants that don't use the system.

The social interaction service uses Skype (as it is mature and cross-platform). Skype accounts for all care receivers are configured on tablet computers, and a Skype account for the caregivers is set up on a separate laptop. Also, family and relatives of care receivers can interact with the care receivers.

2.2 Evaluation Methods

When evaluating the proposed system, both the usage of the system and the technical aspects of the system need to be evaluated. This is because the goals and research questions presented in 1 relate to indeed both the user and the system perspective. Indicators related to the perception of the system by its users in real life should therefore be assessed, but also the engineering quality of the system.

In order to measure the user and system perspective, both quantitative and qualitative methods are used. The quantitative techniques are executed using logging and tracing facilities of the application server and the database server.

The qualitative techniques are based on the IBM Computer Usability Satisfaction Questionnaire [Lewis, 1995], the Unified Theory of Acceptance and Use of Technology (UTAUT) [Venkatesh et al., 2003] questionnaire, and a questionnaire with augmented, semi-structured interviews based on the ISO 25010 framework [ISO, 2010]. This way, three things are measured: the usability, the perceived ease of use, and the software quality characteristics.

3. RESULTS

This section discusses the results of the pilot study. First, the results gathered with the four user-facing services (Activities, Social Interaction, Health Monitoring, Medication Intake) are discussed. For each of those, results of the first phase, improvements, and results of the second phase are discussed. Then, the usability study results are presented, related to both care receivers and caregivers. Finally, hardware and infrastructure related issues are discussed.

3.1 Services

3.1.1 Activities

In total, 56269 activities for care receivers have been registered in the system during the complete pilot. 53851 of them are social activities; the others are appointment for other service plans. Over 200 different social activity types have been registered, most of them are organized on a recurring basis.

Since the software that enables the creation of personal service plans is indeed designed for care receiver-specific plans, it was not completely suited for assigning activities to groups of people. This is possible, but it is essentially a quadratic growing process: both recurrence over users and activities. As the persistence of these activities involves operations that cost time in the order of tenths of seconds, it can result in slowness from a perception perspective in case of large operations.

Providing tailored activity schedules for care receivers was valued as time consuming for the caregivers involved, because it was extra work (entering in two systems) and it was not yet arranged substitution. The numbers of activities given above, shows that it is used heavily by the caregivers. Hence, the usability of the software for managing the activities is of great importance.

Currently, only a limited number of care receivers indeed profited from the availability of this online agenda. In larger settings, the benefit as replacement would be bigger, as entering (recurrent) activities then only once yields more gain.

It was valuable that the care receivers got a notification of the activities, and activities that are repeated often, such as coffee drinking, only have to be registered once for all care receivers and scheduled moments, instead of again for every care receiver paper print. Also, it was valued that entered activities immediately are available on the system, which aided verification of the scheduled activities.

Before the second phase started, the system has been improved to increase the speed of saving activities. This was noticed by one caregiver:

“It costs less time than before. If I enter activities and assign to inhabitants, I’m finished earlier than before. It reliefs that the inhabitants get notifications of certain activities.”

3.1.2 Social Interaction

The social interaction services consist of text-based messaging between care receivers and caregivers and video-based communication between care receivers, their family, and caregivers.

The text-based messaging uses a Mailbox application within the end-user system. Latest messages are shown on the right above the calendar. Instant messaging is possible since new messages are automatically pushed (delivered) to the recipient device.

The social interaction facility was preconfigured on the tablet devices, such that it was directly possible for caregivers and care receivers to use video communication. Using the tablet home screen this could be initiated. The main use of the text interaction was one-way; i.e. only towards the care receivers to inform and remind about activities or measurements. The main video interaction was between family and care receivers.

Occasionally, the video possibility was used by caregivers used as replacement for visits. In the pilot, the walking distance between the work place of the caregivers and care receivers was in the order of 10 to 50 meter only. If the walking distance would have been bigger, the advantage of this service would obviously be greater. That has also been found in home care projects where video communication was implemented [Dohmen, 2013].

3.1.3 Health Monitoring

During the pilot, care receivers performed more than 200 self-measurements using the platform. They used sensing devices capable of measuring weight, oxygen saturation (including heart rate) and blood pressure (including pulse rate).

Creating the service plans to schedule these tasks was an easy task for the caregivers involved, because the service plans were explicitly tailored to their needs and they were designed in a simple to use wizard format. In these service plans, the caregivers set which care receiver needs to measure what, personal boundaries for the values measured, and the escalation path, i.e. what to do in case of forgotten measurements, or measurement values outside the set boundaries.

Creating service plans offers a lot of freedom, as many parameters can be set. The program, which functions like a step-by-step wizard, was received well. One caregiver noticed:

“Creating service plans for measurements is accurate and fast. This really saves us time.”

Regarding the question if this service enlightens the tasks of caregivers, this caregiver noticed:

“Yes, especially with respect to the measurements performed by the people themselves. They also got a greater feeling of empowerment and autonomy. Despite the age, this is the concept that worked best. It saves us time, walking, and performing operations. Because of that we can help other care receivers better.”

The escalation path feature, i.e. warning the selected caregiver if measurement values exceeded set bounds, functioned properly. Only one time a warning was not delivered to the caregiver’s cell phone due to one server tier being offline for unluckily planned software upgrade. After this upgrade, the warnings included the measured value that caused the alert. This was regarded as a great improvement, because the caregiver now has information to judge the exceeding of the threshold directly and act accordingly:

“I was pleased to see that the measurement results were directly visible on the smartphone of the caregiver.”

As said, in total over 200 measurements were performed during the pilot. One day of measurement failed due to improper device configuration -it is necessary to couple the measurement devices to care receiver IDs in the rest of the system, and this has to be modified in case a care receiver with a different care receiver ID starts using the devices.

In fact, the number of measurements grew so large that it did not fit on the screen any more. In the second pilot phase, therefore a button was added to show older, archived measurements, and the main health information overview only shows the latest measurements.

3.1.4 Medication Compliance

As found in Table 1, both electronic and manual medication dispensers were tested. The ‘Smint’ used as medication is delivered on rolls of pouches. Care receivers received a service plan in which they had to take them according to the defined schedule, from either a manual box or electronic dispenser.

The electronic device was received much better. One caregiver said: “I absolutely have a preference for the electronic dispenser.” It gave much better compliance results because it was more user-friendly: the electronic device produces a loud noise when medication is due; it already cuts of the medication pouches for easy intake and it registers intake times itself. The manual box on the other hand is just a storage place. The reminder to take the medication and the acknowledgement are available through a tablet computer only, whose sound is not loud enough and which requires more steps to be taken.

The medication classification that has been designed in cooperation with the nurses was intuitive and was received well. The coloring scheme makes it easy to directly see which care receivers are incompliant on which days, as it colors medication intake time red if it is taken too late.

The electronic device was tested in the second pilot phase. Notably, compliance (defined as the ratio of number of timely taken medication to the total number of medication prescribed) was much better with the electronic dispenser. Although both are tested using only one care receiver for one week with the medication prescribed twice a day, electronic dispenser compliance was 89% vs. 30% for the manual dispenser.

Because of the loud noise the electronic dispenser makes when medication is due, people rather stay home and wait to take the medication, as doing so makes the noise stop. Even though the device allows to prematurely dispense a pouch in case of e.g. appointments outside. On the other hand, the manual dispenser makes no noise when medication is due, although there is the (as mentioned) less loud notification on the tablet. Moreover, it does not automatically record intake times, as it is just a simple medication box. This makes it less user friendly.

3.2 Usability

3.2.1 Care Receivers

In this section, we investigate perceived ease of use of the system as we want to assess the usability. Figure 2 shows perceived ease of use among the care receivers. It is based on the UTAUT questionnaire. Perceived ease of use is measured using 5 effort expectancy statements answered on a Likert scale of 1 (totally disagree) to 5 (totally agree).

The results of this evaluation among 8 users of the system are shown in Figure 2. It was executed after the users got familiar with the system, i.e. halfway during the first pilot phase. On the left, a large spread in the answers is noticeable. This stems from the difference in how the system is valued by the users. Some are quite positive, but some are quite pessimistic. This variety is clearly visible in the right part of the figure, which shows a histogram with the answers per user.

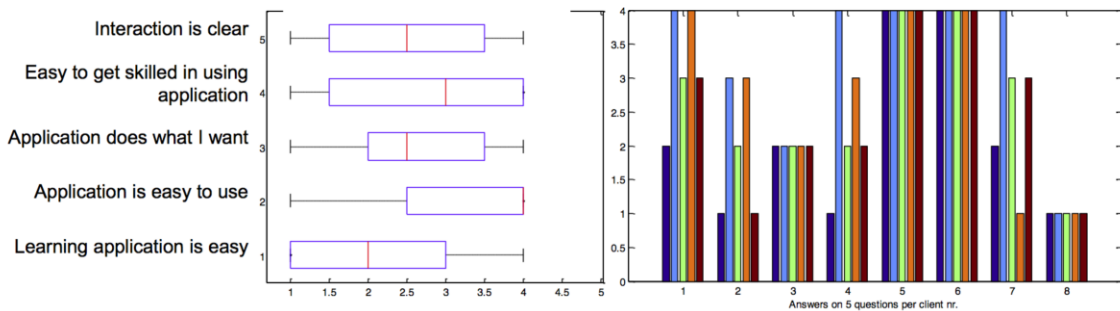


Figure 2. Care receivers results. On the left the box plot shows the dispersion of answers. On the right, the histogram shows per-user answers.

3.2.2 Caregivers

Also the caregivers (who had to train the care receivers in using the system) were inquired regarding their perceived ease of use of the system. Figure 3 shows their perceived ease of use. A more optimistic result is found in comparison to the care receivers. This may relate to better familiarity with technology in general and ICT in particular. Even though some of the caregivers never used a tablet computer before.

There are also complaints. From the Computer Usability Satisfaction Questionnaire and the interviews it is clear that there are 2 eminent problems: if the system does not respond as supposed, it is unclear what the

cause of the problem is. If the system reacts slow, it is also unclear what is the cause. The first problem has to do with the unclarity of error and exception messages, which were not always understood or understandable by the users. The second problem relates to in some locations poor wireless internet connection.

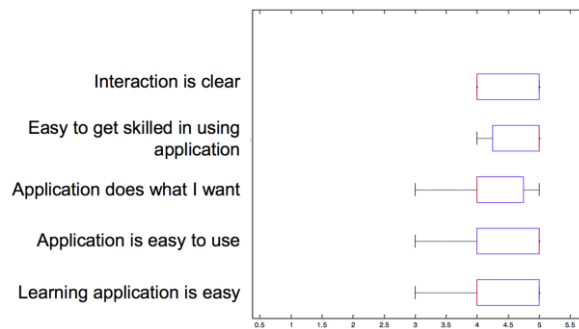


Figure 3. Caregiver results.

3.2.3 Comparing Caregivers and Care Receivers

Table 3 shows the results of the Computer Usability Satisfaction Questionnaire [Lewis, 1995]. The 4 caregivers and the 8 care receivers answered the questions (on interval scale 1 – 7) related to system use, information quality, interface quality and overall satisfaction. Again, the results show a positive score for the caregivers and an average score for the care receivers. Notably, the standard deviation (σ) measured in caregivers is lower in all parts of the questionnaire than it is in care receivers: again, this questionnaire shows more spread in the answers from care receivers, and less spread in the answers from caregivers.

The largest differences between caregivers and care receivers are found in understanding the information (information quality) and system use. Understanding the information is more difficult for the care receivers. The use of the system, including facets as speed, effectiveness and efficiency, scored low especially in some care receivers. The interface quality on the other hand is received positively.

Table 3. Computer Usability Satisfaction Questionnaire mean and standard deviation (σ) scores (8 care receivers and 4 caregivers, interval scale 1 – 7)

Score Name	Care receivers		Caregivers	
	Mean	σ	Mean	σ
Overall	3,7	1,3	4,8	0,62
System Use	3,2	1,8	4,4	0,76
Information Quality	3,5	0,95	4,9	0,66
Interface Quality	4,7	1,6	5,3	0,81

3.2.4 Infrastructure

The infrastructural facilities needed to be improved somewhat during testing. The three main issues are discussed below: network availability, power and wireless signal strength.

In the pilot, a dependency between the integration tier and the application tier showed up, not found in prior lab testing. This resulted in application response being very slow in one case of a network outage of the integration tier server, which was located in a different network than the application tier. The blocking connection was removed the same day after this was found, to improve the independency of the components.

A power outage due to construction works also resulted in a short unavailability. For the second pilot phase it was hence decided to move the servers to better-protected server rooms.

In the nursing home where the tests took place, a WiFi network was installed prior to the tests. However, coverage needed to be improved as some inhabitants of the nursing home had very poor connection on their measurement and tablet devices.

In conclusion, the infrastructural aspects such as power, network availability and wireless signal strength played a crucial role during the evaluation. Hence it was important to be able to react quickly for not having end users lose trust in the developed technology.

3.2.5 Hardware

The sensors performed well during the pilot. The most important remark was that it takes a long time (i.e., some seconds) before measured values using the sensors become visible on the tablet. This is due to different tiers and 2 webservice interconnections involved, even though the devices could be next to each other. Nevertheless, measured values are directly visible on the sensor itself. One care receiver started writing down all measured values, but after a few days she noticed that they were indeed sent correctly to the system.

Between the manual and electronic medication dispenser there was a great preference for the latter one, despite the higher cost of ownership. The ability to notify care receivers and the integration with the rest of the system to review compliance is valued by the caregivers.

Android tablets used were considered 'not ideal'. There are too many buttons, it is too sensitive to operate and notifications are not produced loud enough. One caregiver noticed regarding this piece of hardware:

"Informing the care receivers was difficult. Most users did not know how to deal with the messages. The standardized notification font size also was too small. It was not the ideal way to inform. Despite various attempt with different notification sounds and setting the maximum volume, it was not a reason to hold the tablet to see what the notification is about. These are material limitations."

4. DISCUSSION

Frequently, introducing complex innovations on goes hand in hand with growing pains. This section discusses some lessons learned during the pilot testing. Example given, one caregiver noticed:

"This is really a generation of people that is afraid to press a button, afraid to do something wrong. So it can result into frustration, a feeling of powerlessness."

This could indeed be true for the current generation of care receivers. On the other hand, it is wise to test such systems after development on small scale, to be prepared for when they can be used on larger scale in the near future. Also, technical stability has to be verified when developing such a middleware platform. Verification in practice is then preferable over lab testing only, because it is more realistic. Moreover, organizations become better aware of and get experience with technological possibilities through such pilot studies.

Executing such pilot studies in different phases means that the time in between can be used beneficially: for improvements and to react on unforeseen events. Of course, one has to take care when performing controlled trials to keep the interventions the same in both phases. In this study that was not relevant because there were only different cohorts of tests.

As said, the users involved are aware of the fact that the tests are preliminary tests. Nevertheless, we asked how they thought about the platform. One caregiver envisions:

"For use in home care situations, where caregivers are not in the neighborhood directly, it is very suitable. Especially the measurements. For example when a care receiver does not feel well (and knows how the system works), he/she can arrange a voice connection with the caregiver. This way he/she can get the tasks to measure certain values and get adequate and fast follow-up to the problem. E.g. calling the general practitioner, 112, no action, a sign of comfort, or the announcement how long it will take a caregiver to reach the care receiver."

4.1 Graphical User Interface

In general, the design of the GUI did not receive much criticism, because it was tested beforehand regarding both various technical and usage scenarios. In the care receivers, the interface quality component was scored the highest in the CSQ evaluation (see Table 3).

One interesting issue in fact was that the interface was designed to work best in portrait mode, but due to protective covers added, the device was mostly hold in landscape, at the loss of having the overview of all items on one page. Another issue was that the goal of the home-icon (go back to the start screen of the system) in the application was not reached in full: the Android tablets chosen for the pilot also have a home button with a physical home icon. Not surprisingly, this led to occasional confusion.

Android in that sense also caused inconvenience regarding the lack of being able to start a Skype VoIP session to another person, based on a URI in the web browser. Nevertheless, some care receivers enjoyed video contact with both family and caregivers.

4.2 Application Logic

The application logic controls the actual content visible in the graphical user interface. It provides the logic necessary for the services to work, but is not directly visible as it resides 'under the hood'. The functionalities offered by the application logic in the different services have been described in 3.1, here we will focus on the important logic aspects that were tested but have not yet been covered: session management, publish/subscribe, and scheduling.

The session management was set up in such a way that care receivers, once identified, did not have to enter passwords again. This is important because entering information on tablets is more difficult than just viewing information, and for the care receivers the latter was the main intent. This way, authentication remains but becomes more user-friendly.

Publish/subscribe was introduced to update the views on the system directly in case of new events. This is important because it reflects the ad-hoc aspects of care: it must be possible to issue alerts or reminders as necessary, and not only on scheduled or request-response basis. We notice that this kind of logic is crucial in this kind of platform.

Scheduling on the other hand is important because many care tasks are recurrent, such as activities of daily life. Functionality that allows scheduling and initiates action whenever scheduled items are due, is important for support of the task and the escalation path in case the task is not well fulfilled.

4.3 What's in it for me?

Figure 2 clearly shows the variety of attitudes within this test group. If the care receivers are not motivated to learn the innovation they do not like to use it and as a consequence do not use it a lot. On the other hand, motivated care receivers felt there was something in it for them so they spent time in learning the system and tried to perform the tasks asked. One care receiver even asked if she could keep the sensors and tablet in between the two phases of the pilot. This was because self-measurements gave her clear personal advantages: she did not have to get up anymore at fixed times in the morning; she did not have to get dressed and then wait for the measurements to be taken anymore; and the system gave her more independence; it improved her self-management. She had better overview over her own health condition using the system.

The tailoring was set, such that in case of abnormal measurement values a caregiver would come by anyway. This still gave her the feeling of security.

Another care receiver was motivated to use the tablet due to the new possibility to read e-books on the tablet. Not the first application intended, but nevertheless very useful: due to her paresis it was much more difficult to read normal books.

5. CONCLUSION

Section 1 listed research questions that were used in the evaluation described here. In this last section, we summarize our answers.

1. *Is the system usable in day-to-day care situations?* The system is usable in day-to-day care, especially when tailored by caregivers to situations in which care benefits from the services provided by the system. The services include medication dispense and compliance monitoring, and telemonitoring of vital signs. For social interaction, the system is not usable for all users involved because operating the devices can be too complex to learn and to do.
2. *Compared to care as-is, does it provide added value?* Dependent on how the system is tailored, the monitoring and escalation path features of the system provide added value for caregivers. For some care receivers, the system provides added value for information gathering, self-management and social interaction.

3. *Is the system user-friendly?* Caregivers were generally satisfied with the user-friendliness of the system. They are able to use the system. Satisfaction in care receivers varied. They have difficulties learning and operating the new technology. A part of the users persisted in learning to operate the device, and got attracted to it. They found it user-friendly. But others got demotivated and frustrated. They did not find it user-friendly.
4. *Is the application infrastructure feasible?* In between the pilot phases it was rendered necessary to improve some of the services and to improve the technical stability of the pilot. During the second pilot phase, only speed improvements were needed to improve the user experience.
5. *What is the effectiveness of the various system parts?* In sum, the health monitoring and medication services showed to be effective. The social interaction and activity services showed to be not very effective at this moment. Nevertheless, these functionalities are in part necessary for the health monitoring and medication services. The architectural decision to separate integration issues from user-application is adequate, and the web-based interconnections are reliable, albeit from time to time perceived slow.

The system developed worked in everyday care practice. It has shown to be a feasible application infrastructure. It aided in saving caregivers' time in aspects related to medication and health monitoring. Usability was considered positive by the 4 caregivers that used the system, and neutral by the 8 care receivers.

In future, it is recommended to fine-tune system performance, and test it on larger scale in home care settings, and focus these tests on health monitoring and medication support. Focus on training and learning to operate the devices is very important as well as having a proper technical infrastructure. For social interaction and activity management the system is less suitable because it is not effective; they do not have enough advantages over current practice. Nevertheless, these services are anyway necessary for the working of the other services, because of agenda and notification requirements.

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