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To Alison Cawsey and Fiorella de Rosis

Preface

The past years have witnessed unprecedented levels of investment in the e-Health sector, both in terms of research effort, and in terms of funding, as well as a great public interest. e-Health can be broadly defined as the application of IT (especially Internet technologies) to improve the access, efficiency, effectiveness and quality of any processes (clinical and business alike) related to health care. In the e-Health vision, intelligent systems would, for example, enable:

- citizens to take more control of their well-being, by accessing personalised and qualified health information, both medical and pedagogical, and accessing appropriate medical care from their homes;
- health professionals to manage their activity more efficiently, by receiving relevant and timely updates; and
- teams of health professionals to work together more effectively, coordinating their activities, sharing their knowledge about the patients they are collectively taking care of, and ensuring the best coordinated care is provided.

The 3rd workshop on Personalisation for e-Health intends to consolidate the trend started with the past editions of the workshop, held at UM 2005 in Edinburgh and at UM 2007 in Corfu, followed by a special track of the 21st IEEE CBMS conference in Jyväskylä, Finland in 2008, and which successfully brought together researchers from both the computational and the medical/public health perspectives to share theoretical results, experiences, and best practices in providing better personalised services for the consumers of health care.

Like the past editions, this workshop focuses on the many aspects of personalisation for health delivery, related to e-Health environments, with contributions coming from various perspectives.

We take the opportunity to warmly thank all our reviewers, who did an excellent job in giving detailed feedback on the submitted papers, so contributing to what we hope will be an exciting event.

July 2009

Floriana Grasso
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Static and Dynamic Population Clustering in Personality Diagnosis for Personalized eHealth Services

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ABSTRACT

In this paper we present two different approaches to personality diagnosis, for the provision of innovative personalized services, as used in a case study developed at San Raffaele Hospital in Milan, where diabetic patients were supported in the improvement of physical activity in their daily life. The first approach presented relies on a **static** clustering of the population, with a specific motivation strategy designed for each cluster. The second approach relies on a **dynamic** population clustering, making use of recommendation systems and algorithms, like Collaborative Filtering. We discuss pro and cons of each approach and a possible combination of the two, as the most promising solution for this and other personalization services in eHealth.

KEYWORDS

Personalization, Motivation strategy, Collaborative Filtering, Contextualization, Dynamic Clustering.

INTRODUCTION

According to the World Health Organization, only a few major risk factors account for a significant proportion of all deaths and diseases in most countries [1]. The field of Preventive Medicine has shown how modifiable behaviours, including specific aspects of diet, overweight, inactivity, and smoking, account for over 70% of stroke and colon cancer, over 80% of coronary heart disease, and over 90% of adult onset diabetes [1]. For diabetes in particular, intervention trials recently showed that a correct diet in combination with exercise programs can reduce the risk of developing diabetes by 60% in subjects with impaired glucose tolerance [2]. Also, in the last two decades attention has shifted towards the quality of life in living with diabetes, especially in terms of physical activity [3]. Most people are aware of healthy recommendations (e.g., about diet, physical activity), but they often find them very difficult to put into practice in their daily life, or fail to associate daily micro-behaviours (e.g., driving to work, rather than cycling or walking) with long-term health consequences. It is therefore important to create awareness in the citizens of the impact of their daily choices and behaviours on their health, not only in the short term, but also in the medium-long term. To this aim, it is crucial to understand how to promote physical activity to diabetic patients taking into account the psychological determinants of exercise behaviour.

The European research project PIPS (Personalised Information Platform for Health and Life Services) [4] investigated the use of a eHealth platform for health promotion. In an intervention aimed at promoting physical activities among diabetic patients, a platform was designed, together with a methodology, which used a feedback based support system for the improvement of personal performances in physical activity [9]. This methodology relies on a pedometer for correctly assessing the patient's daily activity, and on a motivational strategy to provide a personalized support. The designed strategy is specific for a particular cluster of population (that have in common a specific *health personality* or, in the specific case, a common *motivational status*), which was **statically** determined by San Raffaele Hospital psychologists. During the PIPS project, some attempts to introduce a **dynamic** clustering have been proposed with promising, yet partial, results. This paper will present both approaches and some possible combination and comparison of the two.

STATIC CLUSTERING: MOTIVATION STRATEGY

The motivational strategy designed in the context of PIPS was personalized along several dimensions and delivered through ICT solutions and devices, allowing to constantly support the patients during their daily lives; the proposed strategy has been designed with the aim of exploring the effectiveness of an e-health platform jointly with appropriate motivational tools for health promotion.

The level of personalization in the support tools has been implemented including socio-demographic and individual characteristics. PIPS introduces a motivation assessment determining the stage of behaviour change the user is at, as well as a detailed profiling and medical assessment.

There are a number of significant theories and models that underpin the practice of health promotion describing in various ways the individual's attitudes towards the change, among which Health Belief Model, Theory of Reasoned Action, Trans-theoretical (stages of change) Model, Social Learning Theory, Social Cognitive Theory, the Theory of Planned Behavior can be cited. On the other hand, our task is to understand why users would make use of an ICT platform in order to perform a change in their attitude towards health (i.e. use the Internet or a mobile phone to encourage them to increase physical activity and to support them in the whole process, etc).

Two questionnaires have been elaborated in order to assess the motivational stage, one towards physical activity and one towards e-health. These questionnaire position the user in different stages of change. The 'physical activity' questionnaire for example states the stage of change proposing 6 clusters (Precontemplation: currently has no intention of being active; Contemplation: not active, but intends to be soon; Preparation: trying, but not yet regularly active; Action: regularly active, but for less than six months; Maintenance: regularly active for six months or more; Relapse).

The 6 stages have been then coupled, forming 3 clusters and according to the stage of behavior change the user is at, messages are sent with different communicative goals in order to move her/him to the next stage of attitude.

- Precontemplation + contemplation: the goal is to raise awareness about physical activity and diabetes, knowledge on risks and benefits of physical activity, encouragement towards a positive attitude
- Preparation + Relapse: the goal is to provide knowledge on action modality, how to reach the reach the change, how to increase self efficacy
- Action + Maintenance: the system provide support with new motivation force, encouragement emphasizing good results, stimulate new challenges

PIPS then provides a personalized and incremental target in terms of number steps, walking time, speed and caloric consumption and gives the patient a pedometer, that has been demonstrated to be a valid monitoring and motivation tool. With the pedometer walking data are constantly updated and corrective/motivational messages are delivered just-in-time to the user mobile phone, thus supporting patient compliance with a real time response.

A Motivational Message is a message received each day of the week one or more times per day, with the aim both to give feedback to the patients on their performance and to motivate them to do better, giving advice to support their walking activity.

During the course of the program the patients receive several kinds of motivational message: a standard message is sent Monday to Thursday, a "Friday Special" message includes suggestions for the weekend, or a "Sunday Summary" message provides an overall judgement on the week performance. Moreover, a "Recover" message is sent on days in which the patients significantly underachieve the daily target, around the time when they are supposed to have completed the activity they committed to: this message is an alert but also contains advice on how to achieve the target before the end of the day.

Messages are personalized along several dimensions:

- Motivational Stage assigned to the user through a questionnaire that position the user in one stage of change. The main communicative goal for each message is set with respect to the current motivational stage of the patient (e.g. for Perceived Susceptibility "Did you know that a regular and constant physical exercise makes the heart more resistant to possible ischemia?");
- Performance Level - the messages contain an evaluation of the patient performance level detected by the step counter with respect to the daily target, considering three clusters of target achievements (<50%, 50%-80%, >80%). E.g. with 85% achievement: "Very Good! You're keeping up with your performance', with 60% achievement: "Not bad, but you can do much more!", with 40% achievement: "Poor performance, you must try to recover tomorrow." Etc.;

- Emotional Status – the patients can input aspects related to their day as emoticons in a "diary". They can at the moment choose to comment on the level of gratification at work on that day, their perception on the social relationships on the day, the weather, and an overall emotional orientation, or "mood". A correlation between this and the daily performance is included in the message (e.g. with an 80% achievement and a bad mood: "Excellent performance! Probably walking helps you to relieve your stress.");
- Progress along the exercise path - at the beginning of the training program some comments, especially in case of low performances, are made softer and more encouraging (e.g. "Don't be discouraged! Changing habits is a process that evolves along time: the difficult part is mostly at the beginning.");
- User preferences - while providing suggestions on how to improve the performance level, a set of tips is considered which are relevant to the user profile (e.g. the suggestion to walk the dog is only given if the patient owns one, or to one of parking the car farther on the way back home is only given if the patients drives to work);
- Location - the "Friday Special" message gives suggestion for the weekend. Depending on the weather forecast for the place where the patient lives, a suggestion for an indoor or outdoor activity is proposed (e.g. "The Weather Forecast says it will be probably raining this weekend. Why don't you go and visit an exposition near your town?");
- Perceived walking obstacles - if the patient constantly fails to achieve his target, a failing strategy is activated. The patient is asked to indicate which are the reasons why he is not walking and in turns specific tips to overcome the indicated obstacles are included (e.g. "If you think walking is boring, change your pace varying your speed every few minutes with a Walking Workout. Do different workouts on different days.");

On the last day of the month the patient also receives a report of the month, which is intended to provoke some thoughts on the reasons of success/failure, so as to increase self awareness and eventually modify personal strategies, and the patient can comment on the system's deductions. Finally, the system sends a message containing a proverb related to the positive/negative factors that influenced the target achievements or a suggestion/encouragement for the next month.

In order to implement this motivation strategy and generate messages automatically, a message structure was identified consisting of three main blocks, each of which related to personalization factors:

1. Comment on the achieved performance, personalized with respect to:
   a. Stage of Change
   b. Walking Performance Level
   c. Progress in the programme
2. Recognition: this part relates the performance to the values in the diary, personalised with respect to:
   a. Walking Performance Level
   b. Diary Values
3. Suggestion to improve the performance, personalised with respect to:
   a. Preferences and Habits
   b. Reason for Failure

In the current solution, the generation of the messages is achieved by means of a composition algorithm using constraint satisfaction techniques, which select among roughly 1000 canned text segments. Each message consists of the various segments, each of which is filled in by one canned message from the dataset. In order to fill in a segment, all the canned texts are selected that are appropriate to the current situation of the patient, and among these, one is selected at random.

EVALUATION OF THE STATIC CLUSTERING

The PIPS walking Program underwent different validation phases throughout the whole implementation process, from the scenario design to the implementation of the different parts of the pilot, evaluating the user experience through technology and service knowledge, up to the evaluation of the impact of the system use by final users.

In a first, informal evaluation, diabetes medical doctors and psychologists were asked to comment on the pilot. They agreed that the integration of a Motivation strategy through e-health tools is feasible and desirable in Diabetes clinical practice. The Motivation strategy should take into account of the specific factors related to Diabetic patients.

A second evaluation involved about 50 patients selected within the Outpatients Diabetes Care Centre of San Raffaele Hospital aged between 45 and 70 were interviewed. As a result 75% of the patients interviewed said they were more inclined to increase their physical activity and to use technological devices as a support to the diabetes management. Out of these 50 patients, 10 patients were called back for focus groups. They had the opportunity to wear the pedometer for 15 minutes, to see the graphical representation of their walking performance and to see examples of the personalized messages composed after entering some selected information (e.g. diary, preferences, habits). Users were asked to express opinion on mobile phone usability, information effectiveness, messages motivational level, exercise plan usefulness, diary/report comprehension etc. Foreseeing the usefulness of such a program for their motivational status towards physical activity, their clinical benefits and considering technological attractiveness, they all provided their availability to be involved in an extensive experimental activity.

Currently, a National, monocentric (Diabetes, Endocrinology and Metabolism Department, FCSR, Milan) randomized, open-label, intervention study is ongoing enrolling patients from San Raffaele Diabetes Outpatient department. The study protocol, approved by San Raffaele Ethical Committee, sees the enrolment of 60 patients for a duration of 6 months each (2 run-in weeks, 3 months intervention period, 3 months control period), randomized according to two branches: the control group receives PIPS Pedometer as monitoring tool and standard diet/exercise care, the intervention group receives PIPS pedometer and mobile phone, a personalized walking target path (steps/min and total minutes) and information and motivation feedback. Inclusion criteria consider patients with Diabetes Type 2, aged 35-70, with no physical or psychological impairment and with a BMI<35. The primary objective of the study is to demonstrate the effectiveness of PIPS, which integrates a technological platform and a personalized motivation strategy, to achieve a personalized exercise target and to improve patient compliance. As secondary outcomes is considered the effect of physical activity on patient's clinical and metabolic status (BMI, blood pressure, abdominal circumference, HbA1c, glycaemia, cholesterol, triglycerides, adiponectin).

Patient were profiled according to the stage of behaviour change both towards exercise and towards technology [11]: preliminary results for exercise attitude report 30% patients are in contemplation stage, 20% are in preparation, 20% are in action, and 30% are in maintenance. For technology use, 20% is unaware on e-health potentialities, 30% find technology difficult to use, 10% have positive attitude and 40% are in maintenance stage. First results report an improvement in the metabolic profile of the patients after 3 months of physical activity supported by PIPS strategy; they reported that, by having a tool which monitors and provides feedback, they are more willing to walk, and find it useful to receive feedback on their achievements. With respect to the messages, they found they were relevant to the actual target achievement, but sometimes they felt they were repetitive, so they tended to read them with less interest as the study progressed.

TOWARDS A MORE EFFECTIVE SOLUTION: DYNAMIC CLUSTERING WITH RECOMMENDATION SYSTEMS

One of the shortcomings of the afore mentioned solution is that the choice of a message among a set of equally relevant ones does not take into account the projected outcome of this message in terms of improving the patients performances. While an accurate measure of the message effectiveness would require a very sophisticated user model, including also emotional and cognitive factors, some prediction could be achieved by using knowledge coming from other users, or the same user in other similar situations. Our proposal is therefore to apply to the choice of which message to present the user with, techniques coming from works on recommender systems. In particular, our assumption relies on a Personality Diagnosis [12], that is the probability a user is of the same "personality type" as other users, influence the probability that the user will adopt a new behaviour (e.g. like new items, buy a product etc.).

The typical recommender system has the aim to predict user's preferences towards some products to buy or examine, on the basis of information acquired on the community of the system's users. Algorithms in use can be of various sorts [5][7][8], and come from diverse areas, like information retrieval, information filtering, data mining, or machine learning. Depending on the algorithm, we can have three basic types of recommender systems:

1) Collaborative filtering systems (based on the relationships among users)
2) Association rule systems (based on the relationships among products)
3) Classifier systems (based on the content of the knowledge base)

For example, in a system recommending books there usually are two sets, a set of users U (e.g. the readers) and a set of items I (e.g. the books), and a utility function r between the two sets (e.g. the rating the users gives to the books). In its most common formulation, the recommendation problem is reduced to the problem of estimating ratings for the items that have not been seen by a user, selecting for each user $u \in U$ the item $i' \in I$ that maximizes the user's utility. More formally:

$$\forall u \in U, i'_u = arg \max_{i \in I} r(u,i)$$

In our specific case the set U of users is the set of diabetic patients, while the set of items I is formed by the set of all the possible messages to be sent to the patients. The relationship between the two sets, instead of being a rating, is a "success" function. The hypothesis is that, if a motivational message was "successful", it might have impact on the patient's activity on the following day, therefore we would expect performances to improve. The success function is therefore determined by the walking results, measured as the percentage (%) of achievement of the target. To understand if a feedback message was useful (in other words to determine the $r \in R$), the system needs to verify the results of the following day of walk. A successful message is one that produces a satisfactory target achievement the day after.

Of course not only the message influences the walking result, for this reason in PIPS the implemented solution corrects the percentage based on the diary values. This will be better detailed in the following section.

Messages, as well as the patient profile, can be considered as vectors, described by a set of parameters. For example for the message we can consider the parameters:

- type (messages can give a strong o a mild encouragement),
- subject (some of them are related to the body, other to health in general, other to social aspect of physical activity, etc.),
- length (different person may like short messages, other complete information),
- value (some messages are more positive, e.g. "if you walk you will feel the benefit", other are more negative, e.g. "if you don't do you physical activity you will have complications…", etc),
- attitude (some message can be more friendly, other more formal).

In this case we can present each message $i \in I$ as:

$$i = (i_1, i_2, \dots, i_m)$$

For the patient, we can consider the dimensions explained in the previous section, for example motivational stage, performance level, preferences, perceived obstacles, etc.

In this way we can consider each element $u \in U$ as a vector described by its dimensions:

$$u = (u_1, u_2, \dots, u_n)$$

With this model, two recommendation services are possible:

1. the patient will be provided with messages similar to the ones that worked better in the past (content-based recommendations);
2. the patient will be provided with messages that worked with people with similar characteristics and preferences in the past (collaborative recommendations).

In content-based recommendations systems the goal is to identify similarities between items, and that's the final purpose. In collaborative recommendation this is just an intermediate step used to identify similarities of "tastes" between users. In our case study, the first service model seems preferable, because it has the advantage that the cold start problem, typical of the recommendation systems, is limited: the patient receives at least one message per day (more if underperforming), a Friday special, a Sunday special, and the monthly report. In average we can consider from 40 to 70 messages per month, or 480 to 840 messages per year, which makes a lot of data available to the system.

To calculate similarity, a recommendation system typically takes into account all items that are co-rated by two different users. In our case we will choose the subset of I, $I_{xy} = I_x \cap I_y$, where I_x are all the items rated by patient x and I_y are all the items rated by user y. Collaborative Filtering algorithm can determine the nearest neighbours of user x without computing I_{xy} for all users y. In the correlation-based approach, the Pearson correlation is used to calculate the similarity [7][8]:

$$sim(x,y) = \frac{\sum_{i \in I_{xy}} (r_{x,i} - \bar{r_x})(r_{y,i} - \bar{r_y})}{\sqrt{\sum_{i \in I_{xy}} (r_{x,i} - \bar{r_x})^2 (r_{y,i} - \bar{r_y})^2}}$$

In the cosine-based approach, the two users x and y are treated as two vectors in m-dimensional space, where $m = |I_{xy}|$. Then, the similarity between two vectors can be measured by computing the cosine of the angle between them:

$$sim(x,y) = \cos(\vec{x}, \vec{y}) = \frac{\sum_{i \in I_{xy}} r_{x,i} r_{y,i}}{\sqrt{\sum_{i \in I_{xy}} r_{x,i}^2} \sqrt{\sum_{i \in I_{xy}} r_{y,i}^2}}$$

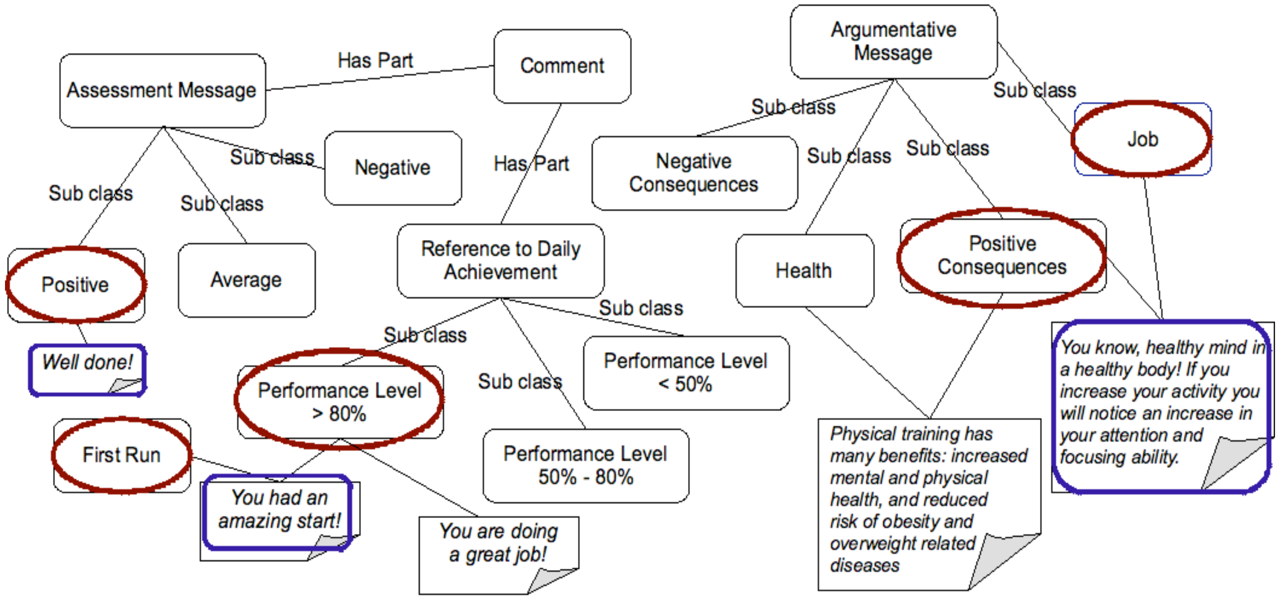

Figure 1: Discourse ontology, an instance

The best similarity function has not been identified yet, because of the lack of sufficient data in the San Raffaele ongoing study to compare the two approaches.

IMPLEMENTATION OF THE PERSONALITY DIAGNOSIS METHOD IN PIPS

The basic idea is, as said above, to consider the appropriate message to present to a patient as the most "recommendable" message, on the basis of how the message to propose (or others in a similar class) was evaluated in the past either by the same patient or by other patients in the same situation of the user. A good evaluation is considered, broadly speaking, one when, after receiving the message, a user did improve his performances: so when the target patient has similar characteristics and similar past performances, one can assume the same message may provide the same outcome. The interaction of a user with a typical recommender system is however explicit: the user browses some products, or purchases them, or provides an evaluation for them. In our case, the only way in which a patient can interact with the system is by providing the daily performance, or updating his data. The approach used, therefore, is the one of creating a relationship among the performance and its derivative, the messages, and the diary values.

In PIPS, the characteristics of the message to recommend come from an ontology of discourse [10] devised after analysis of the motivational message samples provided by the psychologists collaborating with the project. This ontology contains all information related to the messages, and all the factors that allow personalisation, but more importantly it encapsulates the structure itself of the message. From the message analysis we extracted a taxonomy, which was particularly useful for the purpose of modelling the argumentative component and the suggestion. In the case of the argumentative messages, the examples provided by the psychologist were partitioned into classes, on the basis of the characteristics of the user model that were more relevant to the class. This allows to choose the argumentative messages which is more personalised to the aspects of the patient's life, the one he is likely to be more susceptible to. The description of the ontology in more detail is provided in [10], and an example of message instance is in Figure 1. For the purpose of the discussion in this paper, in particular, three classes from the ontology are relevant, each with its sub-classes:

- Argumentative message, that is message providing support to a claim by means of argumentation schemas (like appeal to positive/negative consequences, message promoting "values" like health or well-being).
- Assessment message, a brief personalised message reflecting the level of performance;
- Aid to introspection message that is messages relating the user's performance with entries in the diary.

Other relevant classes in the ontology come from the patient's profile, such as:

- Family: Family habits, affects, family businesses, …

- Job: Memory improvement, attention and concentration, organisation, daily tasks and persistence, self confidence, efficiency, …
- Health: Weight, glucose level, life expectancy, diseases, caloric calculations, risks, energy levels, …
- Money: Savings, …
- Social life: Peers, friend circles, feel good factors, …
- Mood: Wellbeing, satisfaction, fun, …

The motivational message is however not the only factor that influences the performance of the patient: others factors considered in the diary are very important, such as the weather for the day or the day at work, and some of these are determinant of the performance no matter how good the motivational message was. In this sense “recommending” a message is not the same as recommending a product.

Messages are composed dynamically, combining more than 1000 canned texts. Even in the unlikely event that two identical messages are produced, they may have a completely different impact on the person depending on the *context* in which the *specific* user is. It made therefore sense to consider, in computing the evaluation, both the *message* and the *context*. Thus, $I' = I \times C$ is the new extended item set for our recommendations, where *I* is the set of all the possible messages and *C* is the set of all the possible contexts. Formally we can say that each element $i' \in I'$ has the following components:

$$i' = (i_1, i_2, \dots, i_m, c_1, c_2, \dots, c_p)$$

The idea of extending the recommendation by including contextual information was proposed also for a movie recommendation system [5], where the suggestions showed meaningful improvement by adding contextual information, such as when, where, and with whom a movie is seen. In our preliminary implementation we considered as context the parameters that the patient inputs on the daily diary, but one can think, assuming to be able to rely on monitoring system and on internet public services, of adding more descriptive contextual variables, such as: environmental parameters: temperature, humidity, weather (a sunny day may be more inviting than a cloudy day, even if temperature and humidity are the same), pollens concentration (people with particular allergies could suffer outdoor activities in particular period of the year), external light, etc; physical parameters like blood pressure; other personal parameters like chronotype (it is a common experience that the subjective levels of energies and the tone of mood are strongly influenced by the brightness of the environment); social interactions, from events in the user’s diary.

In the current implementation, the evaluation of effectiveness considers values of the diary and it puts them in relationship with the performance on the same day and the message of the day before (or, in case of recover message, with the final target achievement of the day). The system considers not only the performance of the day, but also the difference between that performance and the results achieved the previous time. In case it registers an improvement of the performance, the value of the message sent is updated positively, while if it registers a worsening of the performance, the value of the message is penalized.

The factor by which the value of a message is modified depends by the context, given by entries in the user’s diary. Entries in the diary with a positive orientation (e.g. a good day at work) cause a lesser increase in the value of the message when the performance improves (the idea being that the user might have been motivated by the positive experience, rather than the message), and cause a greater decrease when the performance deteriorates (representing the fact that the message was not effective in spite of the positive attitude). Similarly, entries in the diary with a negative orientation (e.g. a bad day at work) cause a greater increase in the value of the message when the performance improves, and a lesser decrease in the value of the message if the performance deteriorates.

The actual factors by which this happens are at the moment established in an arbitrary manner on the basis of the analysis of the performance of patients during a first trial with the system. From these data it emerges mood and the day at work had a limited influence on the performance (correlation around 3-4%) while weather and social relationships had a significant influence (correlation around 30%). So, the patients walked more on a nice day, and when there actually was something negative on their social lives.

A first approximation of the formula was then set at:

PIPSImpact = Target - R + susc(p,m) + f1 + … + fn

Where:

- *Target* is the percentage of achievement of the target, which could even exceed 100%, as proved by the observed data;
- *PIPSImpact* is the expected percentage of achievement of the target for the given message, given the motivational state of the patient;

- *R* is a factor coming from the motivational strategy and it is a value between 0 (if the message has not been proposed for the past 3 days) and 5% (capturing the assumption that a repeated message is less affective);
- *susc(p,m)* is a personal patient value which accounts for the greater or lesser susceptibility of the patient to that message, it derives from the initial questionnaire and it increases or decreases if that message influenced more or less the patient. it is not more than |20%| of Target value;
- *f1 + ... + fn* are the influence factor of some variables from the diary. They are not more than |30%| and their influence has previously explained.

The work on fine tuning the formulae is still ongoing, and is based on the result of preliminary questionnaires where patients were asked to evaluate the messages produced with the original method. In the study, patients were presented the messages produced by the system as it currently is, and were asked to evaluate on a scale [high, medium, low, not at all] each message with respect to four dimensions: 1) Personalisation level, 2) Pleasantness to read, 3) Motivational level, 4) Usefulness of the practical suggestion to improve.

The objective of this analysis, for our purposes, is to obtain some *a priori* values for starting the system up, and possibly a set of benchmark values for evaluation.

DISCUSSION AND CONCLUSIONS

The static and dynamic clustering are important bases for providing personalized services. Both approaches present advantages and disadvantages.

The Static clustering has the advantage that the reference model (e.g. the motivational status psychological theory) is known a priori. Correlation between relevant factors is identified from the start and the support feedback is designed to maximise effectiveness. On the other hand, if the model is not descriptive enough of the process, or if many uncontrolled variables influence the final results, the static approach is less personalised and contextualised, and may become repetitive.

With dynamic clustering the disadvantage is that the correlations between relevant variables are not known a priori, but, on the other hand, they become clear during the processing and can change when new data are taken into account. The ability to cluster the population based on patients' behaviour makes this approach very promising to predict future behaviours, thus to provide the proper support feedback. The dynamic clustering suffers from all the problems typical of recommendation systems, in particular from the *cold start*, when there are not enough data about the users or about messages.

PIPS started the clinical trial described above making large use of a Static Clustering approach, that classified the patients' health personality based on their *motivational status* and provided specific messages, validated by psychologists, to bring a change in the patient's motivation and actions. A first attempt was also made to use also the dynamic clustering and, even if results are still very preliminary, they seems very promising. The lesson learned is that probably the best solution would be a combination of the two clustering. This, in our case study, can be done in two ways:

1) Using the static clustering when a new user enters the system, until there are sufficient data about him to start using the dynamic clustering. This approach has the advantage to reduce the problem of the cold start of the recommendation system, and that in the second phase it will fully adapt to the behaviour of the user. On the other hand, messages provided to the user in the second phase are *uncontrolled* by medical personnel, thus a patient may receive a message that would not have been selected for the same patient by the static, controlled method, so a message which could not have been pre-approved by the medical experts.
2) Using the dynamic clustering on a set of messages that have been preselected to be appropriate to the static cluster to which the user belongs. In other words, we apply first the static clustering, preselecting the subset $I_x \subset I$, of all the items (messages) appropriate for user *x* based on the users' motivational status. We can then use this subset of messages to calculate the new item set $I'_x = I_x \times C$, as the item set to which apply the collaborative (finding similar users) or content based (finding messages similar to the ones that in the past worked for a specific user, which in a traditional Recommendation System could be compared with his preferences) recommendations. This approach is safer from the point of view of medical validation, but will lead to less variability.

In both cases, it is crucial to ensure that the monitored variables are descriptive enough of the factors impacting on user's decisions and behaviours, and are as complete as possible.

To summarize: in this paper we presented two possible approaches for determining the health personality of patients, with the purpose of tailoring specific personalized strategies and services. The case study presented, in particular, describes a service for physical activity support, where (diabetic) patients receive motivational feedbacks to improve their performances.

The first approach presented is based on a **static** population clustering, relying on a novel motivation strategy for physical activity promotion in diabetic citizens, by means of the e-health platform realized in the PIPS project. We have introduced the key strategy components and discussed the personalization elements.

The second approach presented is based on a **dynamic** population clustering. In this second case the strategy is not decided a priori for a cluster, but it is calculated automatically time after time, trying to predict the motivational message that will have highest success with a specific patient. The most promising algorithms for this solution are the typical algorithms used in recommendation systems, such as Collaborative Filtering.

The two approaches were compared in terms of complexity and effectiveness with respect to the case study. A formal evaluation of the first approach is currently under way with a randomized trial, while for the second it is envisaged a less formal evaluation, due to the experimental nature of the approach.

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Personalised mobile services supporting the implementation of clinical guidelines

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***Abstract*—Telemonitoring is emerging as a compelling application of Body Area Networks (BANs). We describe two health BAN systems developed respectively by a European team and an Australian team and discuss some issues encountered relating to formalization of clinical knowledge to support real-time analysis and interpretation of BAN data. Our example application is an evidence-based telemonitoring and teletreatment application for home-based rehabilitation. The application is intended to support implementation of a clinical guideline for cardiac rehabilitation following myocardial infarction. In addition to this the proposal is to establish the patient's individual baseline risk profile and, by real-time analysis of BAN data, continually re-assess the current risk level in order to give timely personalised feedback. Static and dynamic risk factors are derived from literature. Many sources express evidence probabilistically, suggesting a requirement for reasoning with uncertainty; elsewhere evidence requires qualitative reasoning: both familiar modes of reasoning in KBSs. However even at this knowledge acquisition stage some issues arise concerning how best to apply the clinical evidence. Furthermore, in cases where insufficient clinical evidence is currently available, telemonitoring can yield large collections of clinical data with the potential for data mining in order to furnish more statistically powerful and accurate clinical evidence.**

Keywords—Telemonitoring/treatment, Body Area Networks, personalised feedback, biosignal processing, clinical guidelines.

I. INTRODUCTION

Telemedicine services such as patient monitoring and treatment are emerging as some of the most compelling applications of Body Area Network (BAN) technology. In this paper we discuss two BAN-based telemedicine systems, one from Australia and one from Europe. The European team defined a generic Body Area Network as "a collection of (inter) communicating devices which are worn on the body, providing an integrated set of personalised services to the user" [1]. If these services are related to healthcare we call this specialization of the generic BAN a health BAN. Further specialization to a set of condition-specific services supporting a particular clinical application leads to a variety of specific health BANs such as a BAN to monitor cardiac arrhythmias (cardio-BAN), a pregnancy-monitoring BAN and so forth. Currently in the European Myotel project a BAN for providing myofeedback to chronic pain patients is being developed. Here the BAN devices are sensors for measuring surface EMG (electromyography), a local biofeedback device and a PDA which receives and processes sensor data and transmits it to a remote health professional via WiFi, GPRS and/or UMTS (see Fig. 1). The patient receives local feedback from the myofeedback BAN and remote feedback from the therapist with the aim of improving muscle relaxation and reducing pain.

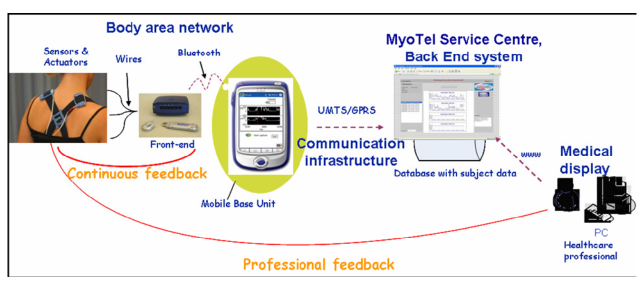

Fig. 1. European BAN for chronic pain patients

In trials BAN data can simply be presented to the clinician as a visualisation, however large scale uptake of such m-health services necessitates automatic analysis and interpretation of biosignal data. At present we apply a procedural approach to biosignal interpretation, however we are beginning to investigate in what circumstances it is feasible and useful to apply AI technology to the problem of analysis and interpretation of BAN data. In this work-in-progress paper we refer to the example of dynamic risk assessment for patients undergoing cardiac rehabilitation, a new application being investigated by the Australian team. The intention is to build on current mobile monitoring systems for cardiac patients and develop a more intelligent, evidence-based monitoring and treatment application for home-based rehabilitation following myocardial infarction. The idea is that the cardiology team establishes the patient's individual baseline risk profile and equips the patient with a cardiac rehabilitation BAN. This extension of the cardio-BAN incorporates a set of body worn sensors and transmits the captured biosignals to a remote healthcare location. Analysis of biosignals is performed locally on the BAN and/or remotely. As well as providing continuous cardiac monitoring, as the current systems do, the proposed BAN application will also continually reassess the patient's current risk level, enabling the system and/or a remote clinician to give appropriate personalized, timely advice, support and if necessary, intervention. The intention is to support secondary prevention by optimizing rehabilitation activities and minimizing dynamic risk whilst maintaining vigilance in respect of adverse events or trends (the latter being already implemented in the existing cardio BANs).

In section II we introduce the two existing health BAN systems, one from Sydney and one from Twente. Each has been prototyped and successfully trialled on different patient groups. In section III we outline the example application, namely personalised BAN-based support for patients in home-based cardiac rehabilitation. This application could be implemented as an additional service running on either of the BAN systems. In section IV we discuss exercise during cardiac rehabilitation and in section V we raise some of the issues which were encountered in the knowledge acquisition phase.

II. MOBILE MONITORING AND TREATMENT SYSTEMS

First we describe the monitoring systems developed by two research groups. The Telemedicine Group at the University of Twente in The Netherlands and the Personal Health Monitor Group at the University of Technology, Sydney, are both researching the use of Body Area Networks to provide mobile health services to patients and health professionals. Both systems have been used successfully in trials with a number of different patient groups, with clinical applications and user requirements defined by the health professional users. Both the European BAN and the Australian BAN incorporate a set of body-worn devices including one or more sensors and a processing and communication platform (a mobile phone or PDA). Fig. 2 shows one variant of the European MobiHealth BAN [1-4] incorporating electrodes and respiration sensor and Fig. 3 shows the Australian PHM system [5-8] using in this case a blood pressure monitor and ECG.

At Twente the emphasis has always been on telemedicine, ie. using "extraBAN" communication between the patient BAN and a remote healthcare organisation or clinician. A generic architecture for Body Area Networks (BANs) and a supporting m-health service platform have been developed, referred to respectively as the MobiHealth BAN and MobiHealth MSP. Based on the generic architecture, a series of specialised BANs and applications have been developed for different patient groups from a number of specialties including cardiology.

Fig. 2. Another variant of the European MobiHealth BAN

Biosignals measured by body worn sensors are transmitted to a remote healthcare location where they can be viewed by clinicians. Automated or clinician-initiated feedback and treatment completes the (macro) loop for BAN-based m-health services. Since 2002 several telemonitoring and teletreatment applications for a variety of (chronic and acute) clinical conditions have been trialled on different patient groups over the course of a number of collaborative projects (IST MobiHealth, IST XMotion, eTEN HealthService24, Freeband Awareness). The system is currently further developed to provide context aware teletreatment services in the eTEN project Myotel.

The group at the University of Technology, Sydney, began researching a contrasting approach where the original emphasis was on local (micro-loop) processing, offering local monitoring and personalised services to patients to support self-care. The PHM has been trialled on 70 low-medium risk cardiac patients at the Sydney Royal North Shore Hospital (Cardiology Department) in Australia and is currently under commercial development. An extensive description and comparison of the two systems (European and Australian) can be found in [9].

Fig. 3. Australian Personal Health Monitor

Both the European and Australian systems can be classed as health BANs according to the definition given in Section I. In both systems captured biosignals undergo a series of processes starting with low level signal processing and ending with high level clinical analysis and interpretation to various levels of abstraction in order, for example, to detect medical emergencies or adverse trends. Both include detection of cardiac arrhythmias as one of the offered clinical applications.

The sensors currently integrated into the Personal Health Monitor are: ECG, weight scale, accelerometer, blood pressure monitor, blood glucose meter, pulse oximeter and GPS. The sensors that have been integrated into the MobiHealth BAN to date are: electrodes for measuring 3, 4 and 9 channel ECG and surface EMG, pulse oximeter, respiration sensor, temperature sensor and activity sensors (step-counter, 3D accelerometer).

For certain clinical interpretation tasks, such as detecting when certain pre-specified thresholds are exceeded, a procedural approach suffices. Other interpretation tasks require a more sophisticated approach, involving fusion and analysis of data from multiple sensors. At a certain point procedural approaches may not be the best solution and both research groups have come to realize the necessity, in some applications, of moving to a knowledge-based approach and incorporating context awareness to the analysis and interpretation of BAN data [10-12, 3]. In the next section we describe the cardiac rehabilitation application; this is a new application and we stress that we are currently only in the knowledge acquisition phase. This new variant of the BAN has not yet been developed.

III. EXAMPLE: CARDIAC REHABILITATION BAN

Participation in cardiac rehabilitation programmes post MI (myocardial infarction) "has been shown to reduce all-cause mortality and cardiac mortality when compared to usual care" [13]. The vision of [14] was to implement continuous risk assessment for this patient group by means of intelligent real-time analysis and interpretation of BAN-captured biosignals together with context data. As well as detecting clinical emergencies and trends this extended cardiology BAN would estimate the current risk level and give personalised feedback and encouragement to support compliance (eg exercise and medication reminders) to the patient. The advice would attempt to minimize personal risk levels at any one time for example by rescheduling exercise not to coincide with elevation of risk levels caused by other factors such as stress.

The American Heart Association lists the major non-modifiable risk factors for cardiovascular disease as: age, gender and heredity (family history, race). These factors play a major part in determining an individual patient's baseline risk. The major modifiable risk factors (cigarette smoking, obesity, hypertension, high blood cholesterol, diabetes mellitus and physical inactivity) can be influenced by life-style changes and/or medication. However the impact of changes in lifestyle will usually be gradual (over weeks or months). Risk of mortality by myocardial infarction or coronary heart disease can be estimated based on these modifiable and non-modifiable risk factors. Risk is usually expressed in terms of percentage of mortality over a 10 year time span [15]. Other so-called "contributory factors" are stress, alcohol, diet and nutrition, but "their significance and prevalence haven't yet been precisely determined" [15]. In addition to the static or relatively slowly changing factors, the literature also refers to factors elevating risk in the short term. These 'triggers' include time of day, physical exertion, weekly and seasonal variations, eating a heavy meal, smoking and "meteorological stress" (ie exposure to extreme temperatures). All these triggers may lead to ischaemia, which could be detected directly through ST segment changes on the ECG. However we did not find an algorithm for detecting ST segment changes that could be implemented on the BAN at present.

The proposal was to extend the existing cardiology BAN from Sydney (the PHM system) and its software in order to monitor, where possible, these short term risk factors and dynamically estimate the changing risk for an individual patient. (The proposed application could similarly be implemented by extension of the European MobiHealth cardio-BAN.) The baseline risk would be set and regularly reviewed by the cardiologist and the system would calculate the dynamic risk on the basis of sensor data and context information and give appropriate feedback. The cardiac rehabilitation BAN proposed in [14] would consist of an extension of the PHM system, consisting of a processing platform (a mobile phone) which communicates wirelessly with sensors and context sources to continuously update the current risk estimate. The sensors would be electrodes (to measure ECG and derive heart rate), accelerometer (to detect falls and to measure duration and intensity of physical activity), temperature sensor and blood pressure monitor. Context sources would include the internal clock of the mobile phone (time of day) and calendar (for seasonal variation in risk). For some factors the patient would be required to enter data (eg. heavy meal, cigarette), since not all dynamic risk factors identified can currently be measured using existing sensors or external context sources.

At Sydney a first selection of static and dynamic risk factors was established following a literature search and a first attempt at formalisation of the knowledge was attempted, resulting in a model for dynamic risk assessment and an algorithm incorporating a scoring system [16]. The concept was to define a personal baseline risk based on the cardiologist's assessment including the particular fixed and voluntary characteristics of the individual patient, and then on a moment-by-moment basis to dynamically increment or decrement the current risk score according to changing factors known to influence risk in the short term. SCORE risk functions [17] were preferred over Framingham [18] since the target group are already diagnosed with cardiac disease or have suffered a cardiac event. The resulting model can be regarded as a first approximation based on a literature search only, still requiring validation by clinical experts. However even at this early stage many issues emerged; here we discuss some points arising from the evidence relating to the role of exercise during rehabilitation.

IV. EXERCISE DURING CARDIAC REHABILITATION

Exercise is a central component in cardiac rehabilitation. The NICE clinical guideline on secondary prevention following a myocardial infarction includes as a key priority that "Patients should be advised to undertake regular physical activity sufficient to increase exercise capacity" and that "Patients should be advised to be physically active for 20–30 minutes a day to the point of slight breathlessness" [13]. Some health authorities offer a hospital-based rehabilitation programme including exercise sessions which are monitored closely by clinical staff. According to the definition of phases of comprehensive cardiac rehabilitation found in the UK National Service Framework for Coronary Heart Disease, (Appendix F of the full guideline [13]), "structured exercise sessions to meet the assessed needs of individual patients" are introduced for eligible patients in Phase 3 of rehabilitation, four weeks after the acute cardiac event. Since physical exertion itself can be a trigger for further cardiac events, the exercise prescription must be adapted to the individual patient and carefully monitored. Phase 3 is usually implemented as a hospital based outpatient programme. After this phase, exercise and other lifestyle recommendations will be made for Phase 4: "long-term maintenance of changed behaviour". Long term regular exercise has been "shown to reduce all-cause and cardiac mortality in patients after an MI" [13]. However the guideline notes that "Maintenance of these lifestyle changes in patients after an MI has been shown to decline following the end of the patient's participation in coordinated comprehensive cardiac rehabilitation" and identifies the key research question: "What encourages the maintenance of regular exercise … beyond the period of comprehensive cardiac rehabilitation?"

We investigate whether a BAN-based monitoring application could additionally provide patients in Phase 4 with support in maintaining and optimizing their long term home-based rehabilitation by tracking and helping to minimize personal dynamic risk levels and by giving personalised feedback, encouragement, reassurance and a sense of safety.

Currently we are examining the complex set of rules in [16] to see if a Clinical Decision Support (CDS) approach could offer a better solution than the procedural approach.

V. Discussion and conclusions

The preparatory work to date on the cardiac rehabilitation application has been largely concerned with the knowledge acquisition phase, involving searches of the medical literature including relevant clinical guidelines to provide the base clinical knowledge. Knowledge engineering was initially attempted by expressing individual risk factors in rules and procedures using flowcharts and a scoring system. The rules, which are quite complex, can be found in [16]. Currently we investigate expressing the knowledge in a suitable KR formalism for processing using CDSS technology to analyse and interpret BAN data and context data. Some issues we encountered are outlined below.

Degrees of uncertainty. Probabilistic evidence on some of the risk factors is sometimes expressed with *large ranges, variance or margins of error.* An example is the estimation of *ventilatory threshold* based on HR_{max}. The threshold is used in one of the rules in [16]. At first sight this appears to be a simple question of estimating and applying a threshold. Although both ventilatory threshold and HR_{max} can be measured directly by a cardiac stress test, such tests are inadvisable in post-MI patients (indeed this would violate the rules in which they are referenced). Therefore an estimate is used in [16] where ventilatory threshold is estimated on the basis of HR_{max}, which is in turn estimated by the formula commonly used in exercise physiology of *220 minus age in years*. However this HR_{max} formula has been criticised (eg. in [18]) as being clinically unfounded: "Research since 1971 has revealed the error in HR_{max} estimation, and there remains no formula that provides acceptable accuracy of HR_{max} prediction." A number of alternative formulae are reviewed in [18], but the conclusion is that more research is required to establish a more accurate method of estimation. Furthermore, the formula for estimating ventilatory threshold in relation to HR_{max} is itself expressed with a wide margin of variability: "The ventilatory threshold corresponds with approximately 85% of HR_{max}. But this may vary between 50% and 90% of HR_{max}" [16]. The concern is that such high degrees of uncertainty or imprecision will multiply up casting doubt on the likelihood of reaching useful conclusions.

Another point is general *lack of consensus* over risk factors "Risk factors for cardiovascular disease have been defined by various groups and experts for decades. Unfortunately, the lack of consensus among these groups and the periodic changes in risk factor listings have led to confusion among health care professionals" [19].

Finally separate items of clinical evidence, often expressed probabilistically, were found in the literature but the issue of finding evidence supporting *how to combine, normalize and weight these separate items* however seems to us to be problematic, and the weights assigned in [16] were in many cases arbitrary first 'guesstimates'. We feel the need for expert opinion or further evidence in order to *combine, normalize, weight and tune* the knowledge base relating to the different risk factors.

To summarise this work-in-progress, we pose the general question: in what circumstances it is feasible and useful to incorporate knowledge based systems into BAN monitoring and treatment applications? Further, in the particular case of real-time cardiac risk assessment, we ask if the cardiac rehabilitation BAN concept itself is clinically valid, useful and achievable given present knowledge and technology. If the concept is valid, we see potential for cost efficient delivery of effective cardiac rehabilitation. NHS Lothian's Heart Manual programme has demonstrated that properly planned and managed home-based cardiac rehabilitation can be as effective as hospital-based rehabilitation programmes [21]. Augmenting this with real-time monitoring and feedback systems for home use by patients could further enhance such home-based programmes, hence the proposed BAN-supported home-based rehabilitation application might have the potential not only to support Phase 4 cardiac rehabilitation, but possibly to replace the hospital-based Phase 3 of current programmes. The application also has potential for monitoring health under extreme circumstances, eg. for deep sea divers repairing oil pipe lines, or workers at high altitude, athletes in training or military personnel on the battlefield. In Twente we also investigate an application of CDSSs using Actor-Agent Communities (AAC) based on Bayesian networks. That study [22] focuses on rehabilitation for chronic pain patients.

If the concept is valid, but (in the cardiac rehabilitation application or other applications) insufficient clinical evidence is currently available to support the application, an alternative contribution by our technology might be found in data aggregation. Data routinely collected from patient health BANs can furnish large collections of clinical data with the potential for data mining in order to yield more statistically powerful and accurate clinical evidence. Such data aggregation effort however requires standards relating to representation of biosignal data and the associated metadata needed to compare and interpret them.

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The Personal Health Monitor is supported by the University of Technology, Sydney and is currently under commercial development.

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MobiDay: a Personalized Context-Aware Mobile Service for Day Hospital Workflow Support

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ABSTRACT
The quality and the effectiveness of the communication between patients and clinicians is a key aspect of an eHealth system. Mobile communication technologies can help addressing this problem providing ubiquitous and personalized information access. In this paper we illustrate the architecture of a mobile service, integrated in the hospital information system, aimed at supporting the user task in a day hospital scenario. The mobile device provides to the patient information messages related to her disease or her current task. Message delivery time is personalised using recommendation technologies that exploit contextual data such as the patient's position and current activity, and the history of user's previous message reading behaviour.

Keywords
Mobile Services, Recommender Systems, Personalization, Message Push.

1. INTRODUCTION
Mobile phones are becoming a primary platform for information access [4][13]. Hence, it is important to understand the capabilities of this channel and the information access behavior of mobile users, in different contexts of usage [5], and in particular in eHealth applications in the hospital environment [10][5][15]. Moreover, as the amount and complexity of information services increases, it becomes more and more difficult for users to navigate their user interface, and find the right information or to complete a particular task. For this reason, in the last years, many Web-based information systems have been augmented with Recommender Systems (RSs). RSs are information filtering and decision support tools aimed at providing product, information, and service recommendations personalized to the user's needs and preferences at each particular request context [1] [16]. RSs have been largely used in eCommerce applications supporting PC clients, but are now emerging as useful techniques for improving information services accessed by mobile devices (PDA, mobile phones) [14]. In this scenario the main issues are related to the limitations of the user interface, i.e., small screen and keyboard, and limited computational power [9]. Moreover, other important limitations and constraints come from the context of usage, i.e., the user is typically accessing the system when she is on the move and several disturbances and interruptions make the interaction more complex, intermittent and shorter [9].

At the same time, the evolution of mobile devices, e.g., personal digital assistants (PDAs) and mobile phones, the ubiquitous availability of wireless communication services (e.g., wireless LAN and GPRS/UMTS) [17] and the development of position detection techniques (e.g., RFID beacon-based and GPS [18][19]) have fostered the development and commercialization of new and sophisticated location-based services suited to the needs and constraints of mobile users [4] [13].

In this short paper we illustrate the motivations and the state of the development of MobiDay; a mobile and personalized information service in the hospital, aimed at improving the quality of the communication between the medical staff and the patients in a day hospital scenario. MobiDay is using pervasive technologies and contextual information in an oncology unit, to provide up-to-date, context dependent information to the patients and to let them to enter various information required by the doctors to asses their state. The ultimate goal of this system is to provide not only a valuable set of information to the patients (e.g., what to do next, or information about their status) but also to learn from their actions (opening and reading messages) better and better strategies for delivering personalized support. The practical effect of the learning procedures is to increase the effectiveness of the information and the user interface. We carried out our entire project in close collaboration with clinicians. During the design of MobiDay, we used feedback from the clinicians to iteratively refine it and in the next future this new mobile service will be fully integrated in the existing information system of the hospital in Meran-Merano (South Tyrol, Italy).

The rest of this paper is organized as follow. Section 2 describes the system functions and Section 3 illustrates a typical usage scenario to give a better overview of MobiDay functions. Section 4 describes the system architecture and Section 5 illustrates the key technical issues and solutions that we faced. We conclude this short paper by describing the experimental evaluation that we plan to run in the next months (Section 6) and providing some concluding remarks (Section 7).

2. SYSTEM FUNCTIONS
MobyDay system is aimed at supporting the patient in a typical day hospital scenario of an oncology unit. Its main function is the personalization of the messages sent to the patients, and the support for filling user questionnaires (e.g., on quality of life). Messages sent to the patients can provide tips about how to improve the quality of life on certain circumstances, or simply instruct them about what to do next. This information flow is ultimately aimed at supporting the user task execution (analysis, treatment, and doctor's interviews) with the help of a mobile device (a mobile phone with Wi-Fi connectivity) used by the patients during the full day hospital process. The main functions of MobiDay are listed below:

- **Personalized instant messages:** information that is of interest for a patient, in a specific step of the day hospital workflow, is generated by MobiDay and forwarded to the patient on a time identified by the system. MobiDay is aware of the user context (location and current activity) and can decide whether this context is appropriate for the user to receive the message.

- **Questionnaire and form filling:** questionnaires about the quality of life, which are provided and analyzed by CHES, are converted into a format that is suited for the mobile device. CHES is a system developed at Innsbruck Hospital enabling questionnaire filling on a tablet PC, and data analysis [12]. We aim at providing an additional input channel, which could be as usable as the standard paper-based and PC-based versions. The questionnaires are displayed and filled on the patient's personal mobile device. The filled questionnaires are sent back to CHES for data analysis and reporting.
- **Workflow support:** the day hospital's workflow is integrated and exploited by MobiDay. This means that the mobile component is aware of the status of all the patients in the workflow: it is informed when a task is finishing and when a new task is starting. The patients, by means of the mobile system, may get a better overview of their therapy's status and see when the next steps should be executed (see [6] for a similar functionality).
- **Identify the user-context with active RFID tags:** an important aspect of the user-context, in addition to the user's activity, is the user location (e.g., the waiting room or the doctor office). In our day hospital environment MobiDay exploits an indoor localization technique based on active RFID transponders. The user position is checked to decide the best time for the user to receive such messages.
- **Web interface for the medical staff:** in addition to the information delivered to the patient (mobile device) the medical staff can operate the system by providing additional information and by sending instant messages to the patients. Similarly to the automatically generated messages, the decision about when to send the messages is optimized by MobiDay.

3. SCENARIO

This section describes a typical usage scenario to give a better overview of the MobiDay system functions and how they are used in the day hospital. An oncology patient enters the hospital for a scheduled visit and treatment. She approaches the registration desk where a nurse is waiting for her. At the registration the patient receives a badge (active RFID transponder) and a mobile phone (Nokia N958GB). After that, MobiDay can recognize the patient using the RFID transmitted data, and can send to her a welcome message.

The nurse informs the patient to proceed to the waiting room and to wait there. The patient can see on her mobile device that the next activity is blood analysis. Then, she receives a new message informing her that a nurse is waiting for her in the therapy room for the blood analysis. The patient moves there and the blood sample is taken. After this step, she is sent back to the waiting room.

MobiDay recognizes from the current patient's context that the patient may have time to fill out a questionnaire about her quality of life. Because of that, MobiDay retrieves the right questionnaire from CHES and sends it to the patient. The patient's mobile device vibrates and shows an information message. "Prof. Brown would like to know some more information about your state". The patient is presented a questionnaire (see a snapshot in Fig. 1).

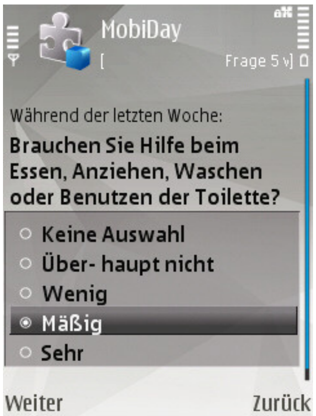

Figure 1. MobiDay user interface

The patient can fill out the questionnaire and confirm her choices. After a while, the questionnaire is sent back to CHES, the doctor is informed and can analyze the questionnaire.

Then, the patient receives a new message with feedbacks on this questionnaire. MobiDay has recognized from the patient's context description that she may be interrupted by this message (she is back in the waiting room). The patient gets an additional message telling her that the doctor Brown is waiting for her in room E354 for the next ward round. The patient also gets a message instructing her about how to deal with some collateral effects of the therapy she has received today.

4. ARCHITECTURE

MobiDay comprises a server component, which interacts with the departmental systems of the oncology unit, including CHES and ONCONET, and two client components: one used by the patient and another by the nurses and the doctors (see Figure 2). CHES manages the questionnaires on the patients' quality of life. These questionnaires are displayed on MobiDay Client, running on the patient's mobile device (Nokia N95 phone). ONCONET is used to retrieve the patient's personal record and the workflow data. MobiDay server is responsible for collecting these data and to generate instant messages and questionnaires for the patient.

MobiDay server stores log data describing the user activity on the mobile device: actions performed in context (reading messages, reply to questions). This information is then used to learn how to process future messages for the patients, identifying the right user-context for sending them.

The client application is a J2ME (Java 2 Micro Edition) midlet that is installed on the patient's mobile devices. Each patient is also wearing an active RFID tag that is sending identification data to a collection of RFID readers deployed in the hospital. This identification data is used to provide the localization information to various components of MobiDay.

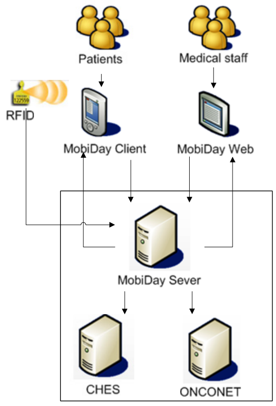

Figure 2. MobiDay architecture

In addition, the medical staff can interact with MobiDay using a Web application (MobiDay Web). MobiDay Web can send instant messages that can't be generated automatically by MobiDay Server. In this way, the communication between medical staff and patients can be further improved. Finally, this application provides also an overview of the patient's current workflow and interaction with the mobile application (e.g. the questionnaires already filled by the patient).

5. TECHNOLOGIES

5.1 Mobile User Interface

In the design of the MobiDay Client application we addressed two key issues. The first relates to how to better respond to a set of questions that the patients may have:

- Do I have new interesting information to consult?
- Do I have a questionnaire to fill out for the doctor?
- What are my next activities?

The second key issue relates to the fact that patients will access the system in various contexts; when sitting in the waiting room, or under the therapy procedure or when they are on the move. The success of this mobile service is therefore also determined by the interaction design that must facilitate system usage in various contexts [9].

First of all, we designed the mobile interface with standard usability heuristics. The patient should have a clear and simple overview about what should be done next. Therefore, the interface offers a main panel where on top a status message is informing if any messages should be read or a questionnaire is to be filled out. In the lower part of the interface, the patient can access an overview of the current and next workflow activities. In this way, the patient can easily check at any time and context (e.g., when he is walking or sitting) the most important information.

Urgent incoming messages or questionnaires are automatically displayed on the screen without user intervention, when the user is not interacting with the system. The VibraCall ring is used to get the patient's attention, without disturbing other patients. This speeds up the interaction and guides the patient faster through workflow activities (e.g., the questionnaire has to be filled out).

Questionnaires are somewhat longer actions (5-10 minutes to fill out a questionnaire) compared to other activities performed with the help of the system. Therefore, questionnaires are only sent when the patient can dedicate to them the needed attention. We think that this will occur only when the patient is in the waiting room and she is not engaged in a particular activity. We tried to make it as simple as possible to fill out the questionnaire, avoiding in particular open ended questions that require the usage of the text input on the mobile device. Most of the input requires only joystick navigation and multiple choice selections.

Most of the user-context information is collected in the background by the mobile device application. Therefore, the patient is normally not concerned with that data collection. An exception is made when we require an explicit user feedback, when we want to obtain some reliable knowledge on the appropriateness of some messages. The patient interaction is simplified by following the rules listed below:

- The explicit feedback is only requested rarely.
- The request of an explicit feedback ("have I disturbed you?") is integrated in the message text at the end of the message. No additional dialogs are popping up requiring additional user interaction.
- If the patient has not read the message in 10 minutes after it was received, the message is not displayed anymore on the screen. This fact provides also an indication that the time we sent the message was not appropriate. Actually this may have other motivations, e.g., the patient did not have time to read it because she was doing another activity, or because she was not interested to read the message. We will further investigate this issue in the course of the project.

5.2 Push Messages

Personalized information services are either based on (i) passive (also known as organic), (ii) pull or (iii) push information delivery techniques [16]. The first technique provides item recommendations related to the user's currently viewed item (e.g., the feature "customers who read this item also read…"). The second technique provides information to the user when she is explicitly asking the required information. Both techniques are seen as non intrusive because the user is consuming information only when she is receptive of doing it. On the other side, the last technique, i.e., "push", provides information to the user when the service provider thinks that it may be beneficial for the user. However, this technique often leads to annoyed users, who are getting overtaxed by unsolicited information at the wrong time and place. The same may hold for a patient in an oncology day hospital. As already mentioned before, one of the aims of this project is to identify a methodology for learning the right user-context for sending messages using pervasive technologies in an oncology unit. We want to achieve this by concentrating on three types of messages (identified by the clinicians) that will be sent to the patients:

- **Workflow dependent messages:** these messages are connected with the patient's workflow, e.g., a patient has to do blood analysis test now. Hence, a message is generated to invite the patient to perform such activity. Workflow dependent messages are triggered on specific moments, i.e., when the activity must be executed.

- **Information on possible side effects of the therapy**: these messages contain information about the therapy side effects observed in the patient in the last weeks. The messages are intended to give tips about how to avoid or deal with certain side effects. Normally, the content of such messages is equal for all the patients. This is normally identified by the doctor during the ward round. After that, the doctor decides which side effect tips should be sent to a patient. MobiDay will then decide when to send them exactly.

- **Dynamic messages:** the content of such messages can't be defined in advance and they provide a way for the doctor to freely interact with the patient. The content changes dynamically during the therapy and is inserted by the medical staff manually. These messages do not have a precise temporal or workflow dependency.

As we mentioned above we want to improve message management with a personalized context-dependent recommendation process. During the experimental phase of this project (see Section 5), we will collect precise, contextually tagged, usage data. The contextual information is basically including the following two types of information:

- **Logical location:** patient's location is the most important data that is collected. We obtain it with active RFID technologies. In fact we decided to mark some precise locations of the hospital (e.g., the waiting room or lab) and we are able to identify in which room the patient is located.
- **Workflow step and time of the current action:** the workflow management system in the day hospital (implemented by ONCONET) is a crucial component and source of contextual data. But, this information is not always correct, e.g., it may indicate that a patient has to undertake a chemotherapy task but she might have already finished that task, and the medical staff missed to update the system. However, this information, in conjunction with the location information provides strong clues about what the patient is doing.

Moreover, the push message service will use some other user data such as demographic and disease information. We also plan to use information about the psychological state provided by CHES (to personalize the presentation of the information). Finally the explicit and implicit feedbacks of the user to the delivered messages will be stored. We have implemented a specific interface that, in-context, is asking the patient if the message arrived at the right time or not. We will sample the user reaction in a pseudo-random approach. In addition to that, implicit feedback will also be collected, e.g., the reading actions of the patients. The data will be analyzed and several context-based recommendation technologies will be tried. First of all the contextually tagged data will be analyzed for understanding what contextual data are actually relevant for deciding what messages to push. This will be based on wrapper methods that try to automatically check the relevance of contextual data while making the message relevance prediction [2]. Secondly we plan to use some techniques, which have been exploited in the personalization of the human-computer interaction process, and that are based on reinforcement learning techniques [11].

5.3 Localization with Active RFID

We think that the patient location is of primary importance in order to provide appropriate contextual-dependent messages to the patients. Considering the day hospital environment, localization techniques based on GPS, network cell towers or Wi-Fi access points do not offer the precision or convenience required for determining the room visited by a patient at a certain time instant. Therefore, to deal with that situation an approach based on RFID technologies has been followed.

Radio-frequency identification (RFID) techniques allow the identification of objects by means of radio waves [19] [18]. In this approach landmarks (objects) are tagged with RFID transponders (tags). The market offers two types of RFID tags:

- passive RFID tags, which require an external power source to initiate signal transmission;
- active RFID tags, which are powered by a battery and can transmit their signal autonomously.

We have selected the second type because active RFID support a longer transmission range, which is roughly 25 meters in a typical indoor situation (with the particular kind of transponders that we have used). As mentioned above, active RFIDs are able to receive and transmit data, and can be programmed so that it is possible to exploit a peer-to-peer model of communication between tags [3]. Moreover, transmission power can be modulated to customize the transmission range to the specific needs of the environment (in our case approximately 5 meters). This feature has been exploited in our project and allowed to detect and broadcast "contact" events, for example, two transponders seeing each other, i.e., being in communication range.

We have deployed a system configuration consisting of one transponder for each room taking part to the workflow of patients. Moreover, each user participating to the experiment also wears a tag. This simple design enables the identification of the previously mentioned "contact" events between patient and room transponder, thus locating the user among one of the tagged spaces. To receive the signals transmitted by these transponders, in the area of the day hospital unit three RFID USB-readers have been installed in fixed locations. Each reader is then connected to a laptop that receives the packets broadcasted by transponders and, through a local network, it can forward the received information to a server for further processing. Here the server processes the transponders' packets and provides the computed position of the patient to MobiDay server. The transponders and RFID readers that we used are developed by OpenBeacon.org.[1]

6. EXPERIMENTAL EVALUATION

In the next months we plan to conduct an experimental study in Meran-Merano hospital. We want to first identify possible major usability issues of the user interface of the mobile system (we already performed a heuristic evaluation with the clinicians).Indeed, deploying mobile technologies as those presented here can raise several usability and privacy issues that

[1] We would like to thank C. Cattuto and ISI Foundation for their help in setting up the system. They have provided to us the devices, the knowledge and the software needed to acquire and process the patients' positions.

must be considered and faced with appropriate solutions [8][15]. In fact, the main objective of the study is to compare the quality of the support provided by the mobile device, in the questionnaire filling task, with that offered by the CHES Tablet PC application, and with the standard paper-based form. In this experimental evaluation the system will collect precise log data of users' interactions with the system in order to perform the analysis described in Section 5.

We plan to use a within-group experimental strategy where users will use for a period of time the mobile device and then, for the same period, one of the other two variants (Tablet-PC or paper). Two other groups will perform the same experiment but in the reverse order. This study will involve approximately 40 patients (10 per group). Hence, the study will be subdivided into two phases: in the first one, consisting of two sessions of one day treatment in the day hospital (separated by two weeks) the patient will use one type of interface. In the second phase, which also consists of two sessions of one day, the patient will use another technology. We will measure the subjective user's evaluation using one quiz test after each single phase, and in a final questionnaire the users will be asked to express their preference over one of the two form filling methodologies that they have used. Our basic hypothesis is that the mobile system can be as much usable as the tablet version and will be positively accepted by the younger patients. We also expect a more efficient interaction, because of the simplifications we made to the user interface.

7. CONCLUSION

This short paper describes the current status of a research on a mobile, personalized information service in the hospital, aimed at improving the communication between the medical staff and the patients in a day hospital scenario. We have defined the main system functions, the system architecture, and addressed the key technical issues related to the required techniques: the user interface for the mobile client, the personalized context-dependent push messages service, and the localization technique exploiting active RFID transponders. The development of this system is completed and we are now pilot testing the prototype before executing the experimental evaluation. The future work will consist in testing our research hypothesis about the usability of the mobile service, and in testing a set of recommendation technologies used to learn the best context for each type of message delivery. It is worth noting that this system is addressing a limited context of usage, i.e., the day hospital. In the future we would like to offer a better communication and support when the patient is at home.

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Personalisation of Internet-Mediated Activity Support Systems in the Rehabilitation of Older Adults – A Pilot Study

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Abstract

The inclusion and autonomy of older people in the society where large parts of the life is organized with computer and Internet use as means is addressed in an ongoing project in the rehabilitation and health domains. Part from investigating the potentials of using ICT for rehabilitation of older people with limited or no computer skills, the aim for the project is to develop methods and tools for the purpose, and also for the interaction design domain where systems are developed for older people. This paper reports results from using activity theory and the notion of ZPD for prototype development and evaluation of decision and activity support systems as a common tool for the patient and professional in the rehabilitation process. The results include a protocol for capturing the users' development of skills in Internet-mediated activity. The protocol is used for informing the design of the system in an iterative process.

1 Introduction

Computer use is widely spread in society, with Sweden as an example of a country among those with the highest level of access to Internet in the world [1]. Activities are, to an increasing extent, re-organized to involve the web as a means, as source of information and entertainment, channel for communication, base for social environments and for administration of individual's personal and social life. This trend excludes persons who have not access, knowledge or the skills to use computers and Internet facilities from a large part of the society and often also parts of the social life of the immediate family. To a large extent, older persons are characterized by this exclusion and would benefit from purposeful designed systems aimed at supporting the execution of activities of their choice. This category of aids to overcome hindrances to perform needed activities in daily life, ranges from environmental-based cognitive tools in ambient assisted living projects, smart homes, memory aids or aids comprising less computer-based intelligence such as regular wheel-chairs. They constitute a significant asset for occupational therapy interventions. As part of the professional reasoning to evaluate activity barriers in individual clients, the adjustments of the environment in which the activity is to be performed is done on a regular basis in the rehabilitation process. In this process computer based aids could to a larger extent serve as important facilitators for activity and individuals' autonomy. Therefore, the professional assessment of the needs for relevant computer and Internet based aids such as ambient assisted systems is an activity that will increase in importance by the increased demands of ICT-mediated distributed activities in people's daily lives.

The rehabilitation process is also a process distributed over time and location, sometimes involving additional actors such as family, where members often are located in other parts of the country. Computer and web based tools for investigation and follow-ups could easily overcome these factors, and may consequently enhance the client's role and influence over his or her rehabilitation process if used as a common tool for choices and adjustments of interventions. Therefore, a pilot study was initiated with the aim to investigate to what extent ICT can be used as a common tool in the rehabilitation process by both an occupational therapist and an older patient who may not have any or very limited experience of computer use.

This work takes as starting point the occupational therapist's assessment of an individual's ability to perform important and desired activities for the purpose of intervening for increasing autonomy and health. The domain is rehabilitation of older people and their activities that may be supported by Internet-based tools. Interventions in this perspective comprise adjustments in the individual's environment, including computer tools, in order to compensate for physical or cognitive dysfunctions. We focus on the phase before the possible integration of systems, where the needs of individuals are assessed as part of a professional evaluation and motivations for adjustments of the environment can be generated. This is currently being done by rehabilitation experts, however, they lack tools for matching individuals' changing needs with the possibilities that lie in the new technology. We also focus on how evaluating the effects of changing the environment for improving activity. For accomplishing this, a protocol for assessing development of skills and ability when performing Internet-mediated activities is being developed.

Seen from a system development perspective, the current user-centered design methodologies are limited when heterogeneous groups such as older persons are to be involved in the design process, who may not be articulate about details in user interface design [22]. Furthermore, there are few descriptions in research literature of methodology that assess possible impact on health in older persons that can be associated to computer use [20, 21]. There is also a limited number of tools described that can be used for informing re-design in a system development perspective. The assessment protocol presented in this paper serves as a tool in observations of users involved in an iterative design process for developing systems for older persons and in evaluation studies for the abovementioned purposes.

2 Methods

An activity-oriented participatory design process with heavy emphasis put on the activities in focus was applied, involving two occupational therapists (OT), a computer scientist (CS) and a group of older volunteers. This was accomplished by using activity theory as the theoretical framework for data gathering, analysis and re-design [6, 7, 8, 9]. The activities observed ranged from occupational therapists investigating the participants, the participants performing activities of their choice, and the dialogue between the two for the purpose of follow up on interventions. Interviews and questionnaires were used continuously. Observations of the participants performing activities were both done without interference and with purposeful interference as "a more skillful peer" depending on the situation and its purpose.

2.1 Assessment and Preparation Phase

With a starting point in the occupational therapist's evaluation of activity status, activity hinders were identified as well as personal resources, needs and interests in eight older persons who volunteered to participate in the study. Persons included in the project where those who did not have any or very limited experiences of using computers and none using the web. The subjects comprised one man and seven women between the ages of 65-75 in the initial phase. The professional instruments used for the OT evaluation were the instruments Assessment of Motor and Process Skills (AMPS) [10], Occupational Case Analysis Interview and Rating Scale (OCAIRS-S) [11] and the MNPS interest checklist [12], supplemented with open structured interviews.

The data gathered in observations of the evaluations and in interviews were analyzed using activity theory [6, 7]. The results were categorized into themes of activities based on purpose and what needs the activities were expected to fulfill, as expressed by the participants. A similar pattern was shown in the eight participants, which emerged to a few main themes that were considered the most important to the participants. Based on these themes use scenarios were created enriched with the user's own descriptions of important and interesting activities they would like to be able to do. The scenarios were also analyzed using activity theory. A structured protocol emerged (Assessment of Autonomy in Internet-Mediated Activity, AAIMA), which were used for valuing and documenting the individual's development of skills and ability in Internet-mediated activity. The AAIMA protocol was also used to formulate questions for interviews and computer-based questionnaires, structured partly as open questions and partly as likert scales. These were used after each session for assessing the subjective views and attitudes towards different aspects of computer use.

2.2 Evaluation and Re-Design Phase

Based on the activity analyses and a literature review, initial prototypes of a virtual café environment were developed and integrated in an already existing physical Internet café environment for older people provided by the municipality. The café metaphor was used in the pilot study since it suited the municipality's ambition with their participation in the project. The environment was chosen because the location was well known by the inhabitants, localized in a special home for older persons with additional services provided to persons in the neighborhood such as rehabilitation services. The environment was considered as an intermediate location solely for the purpose of the pilot project in the process of moving parts of the rehabilitation activity out from the clinic towards the individual's home environment. Using the concept of a virtual café environment for the prototypes was also considered suitable in an initial phase, since the main benefits of the desirable activities expressed by the subjects were related to perceived social gains from computer-supported activities.

The subjects participated in seven to eight organized occasions of 1,5 hours, during a period of two months in this environment. Four of the participants also had access to a computer in their homes in part of, or the whole investigation period. One woman did not proceed to participate in the café environment due to health reasons.

The dynamic properties of activity theory, and the notion of Zone of Proximal Development (ZPD) were used in the study to investigate the progress of novice users in mastering the computer-based tools for activity during the eight sessions of computer use [6]. After each session an assessment was done for each individual based on observations by marking which actions of the activities in the AAIMA protocol (Table 1) were mastered autonomously and which lied in ZPD, while the ones beyond ZPD were left unmarked. The observers acted as the more skillful peers when this was required, in order to identify limits in knowledge and skills and guide towards a higher level of mastery. In parallel, reasons for breakdowns were identified that could be referred to the design of the computer applications. Obvious obstacles were removed and requirements for future applications were identified, while some aspects were integrated in re-designs of the prototype between sessions in an iterative process. Some of these aspects of re-design concerned general aspects of design, while other concerned matching the design to advances in knowledge and skill development in individuals. Viewed in a longer perspective beyond this pilot study, requirements for a system that may act partly as the more skillful peer were also identified, forming a base for an intelligent support system to be used in the rehabilitation domain.

Based on the activity analysis, the AAIMA protocol and the user analysis, a set of questions was formulated and used for evaluations in order to capture subjective views on activities and performance in addition to observations and interviews. The participants expressed their views in an evaluation section integrated in the prototype, as part of each session.

3 Results

The results from this pilot study will be limited in this paper to results relating to the AAIMA protocol. The results are categorized as follows: 1) activity analysis, including an introduction to concepts of activity theory and the resulting assessment protocol, 2) user analysis and development of ability to perform activity, and 3) prototype development and evaluation.

3.1 Activity Analysis and the Assessment Protocol

The purposeful activities described and valued by the subjects were categorized by their purposes, or goals. The underlying needs that the activities contributed to were also identified and three main themes emerged: 1) having knowledge and feeling in control, 2) feeling safe and secure, and 3) feeling good, healthy, engaged and active, having fun. Corresponding activities were: 1) search and find information, become informed, keep up with news, 2) communicate with others, and 3) performing activities in the fields of interest, i.e., hobbies, organizations, etc. Using an activity theoretical interpretation of levels of activity, the third category of activities represents *main activities*, while the first and second are sub-*actions* necessary to complete the main activity (Fig. 1).

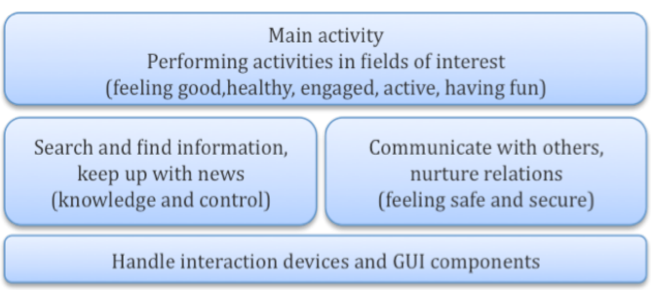

Fig. 1. Hierarchy of activities integrated in the study, structured based on activity theory. Corresponding needs the activities aim to fulfill are set in parentheses.

One additional category of tasks was identified, which corresponds to the *operation* level in terms of activity theory, e.g., handling interaction devices, components in the user interface and language (Fig. 1). In the case of an experienced user, this category does not serve needs that can be expressed, nor do the operations serve a goal in itself but goals defined at higher levels of activity. However, this category plays a significant role in the valuation of novice users' development of computer-related skills and in evaluation of the transparency of a system [9]. Typically, operations are done without conscious thought on the execution, and when conscious reflection occurs the operation is per definition changed upwards in the complexity hierarchy into an action. In order to identify the different levels of independence in computer-supported activity for individual users, four levels were defined for the operation category (see Table 1). Levels of independence were also defined for the higher-level actions and their sub-actions, which correlate to the demands each action puts on the user. As an example, instant messaging is judged to be more difficult compared to e-mail. Having another person waiting while writing is for many a stressful insight. E-mail has a physical correspondence in mail, where it is understood that a message is delivered to the other after a certain time, and that can be answered to in due time. However, the distinctions between activities are made in a general sense, and at a higher level of activity and interaction, since the design of different applications within the same category affects the complexity.

One key property of activity in terms of activity theory is the phenomenon of *transformation* between levels of activity. When the skills are insufficient for performing the subtasks of the main activity, breakdowns occur, which force the subject to shift focus from the main activity to an action at a lower level in the activity hierarchy in order to identify the problem, solve it and then go back to the original activity. In the case of a novice user who has not yet internalized the use of interaction instruments, the lower level actions need to be executed as main activities for the purpose of learning and developing basic skills. In the use of the protocol, the transformations were seen also when a person was judged independent. However, as soon as a person needs guidance from another person to be able to proceed further, the activity was judged to lie in the user's ZPD.

Activity theory provides a model for capturing development and reasons for development and change, which is highly valuable when designing systems for this purpose. The transformations between levels of activity are caused by events denoted *breakdowns* and *conflicts,* which also enforce development of knowledge, skills, procedures or tools [6, 7]. Activity-Theoretical models are used in the human-computer interaction domain for developing and evaluating interaction designs [13, 14, 15], in developmental work research [7, 16, 17] and in developing knowledge and knowledge systems [18, 19]. This development can be described in activities performed by both individuals and groups. In order to capture individuals' potential level of performance and knowledge, the notion of Zone of Proximal Development (ZPD) is applied in domains such as education and rehabilitation. For performing activities within this zone, it is presupposed that the individual is dependent on more knowledgeable peers to move through the zone and internalize the new necessary skills and knowledge, in the process of becoming an autonomous actor [6]. Consequently, activities that can be placed beyond ZPD in an individual refer to activities that the individual simply cannot do, even if a more skilful peer assists. However, these activities may enter the ZPD of an individual when activities within ZPD have become mastered.

Table 1. Protocol for Assessment of Autonomy in Internet-Mediated Activity (AAIMA). Levels of independence in relation to web-mediated activities are defined. The four main categories of activities identified at baseline are marked in bold face.

Level of activity	Activity description	Serves needs	Level of independence	Causes of breakdowns
Operation	**Interaction with interaction devices, GUI components and terminology**	**-**	*Autonomous /activity in ZPD /activity beyond ZPD*	
Level 0	Basic tasks having a goal in itself, i.e., executed as *activities*			
Level 1	Basic tasks having partly been integrated in activity as actions among other actions			
Level 2	Basic tasks are partly operationalised, causes breakdowns but is handled by the individual			
Level 3	Basic tasks are operationalised			
Action	**Search and find information, become informed, keep up with news**	**Knowledge and control: participation in health, societal, politic issues**	*Autonomous /activity in ZPD /activity beyond ZPD*	
Level 0	Finding the way around within the structured web-site			
Level 1	Receiving and taking part of e.g. news feeds without actively searching new sources			
Level 2	Actively searching for new sources via search engines or entering web addresses			
Level 3	Being able to save, organize and find the way back to information			
Action	**Communicate with others, nurture relations**	**Feeling safe and secure: social network including important people, society**	*Autonomous /activity in ZPD /activity beyond ZPD*	
Level 0	Does not actively communicate with others, dependent on others to make contact			
Level 1	Sending messages in the controlled environment			
Level 2a	Communicating through e-mail in a controlled environment			
Level 2b	Communicating via IM services in a controlled environment			
Level 3a	Being able to use public e-mail services			
Level 3b	Being able to use public IM services			
Activity	**Performing activities in fields of interest, i.e., hobbies, organizations, etc.**	**Feeling good, healthy, engaged and active, having fun**	*Mark as above for each activity*	
Level 0	Passively being interested in but does not read about, participate in or perform the activity			
Level 1	Reading about activity but no connection to performing activity			
Level 2	Actively and independently participating in or performing activity without others being directly involved			
Level 3	Actively participating in or performing activity involving others			

3.2 User Analysis and Development of Skills and Autonomy in Activity Performance

The major purpose of occupational intervention is to increase autonomy in performing activities in fields of interest and of importance for each individual. In this project, the aim for the sessions was to provide the subjects opportunities to perform the identified purposeful activities as soon as possible, in order for the OT to evaluate the effects. Therefore, the content of the web pages was formed based on the OTs' initial assessments and therefore highly relevant to the individuals. This was done with the assumption that the individuals need to find the activities meaningful, and there is no meaning from a rehabilitation perspective in using activities that are not relevant to the user. In this perspective, the design of the computer environment including applications is vital for the design not to be a hinder for activity but a mediator of activity in terms of activity theory. It was obvious in the AAIMA assessments when lack of skills in lower levels of activity prevented the individual to perform at the higher, more meaningful levels. When a person did not find the information needed to do what was intended, the main activity was interrupted. When there is an interest in a certain activity such as genealogy, there are also different levels of complexity in the way that this activity can be performed. In the study three of the participants reached the level of independence to the extent they were able to use the computer and applications to actively and independent perform the activity, and by this add qualities to the activity (Activity level 3 in Table 1). The rest could do this with some assistance (ZPD for Activity level 3) and all participants were independently using the computer to "passively" read about topics related to their interests (Activity level 1 in Table 1), however, in a very active way often becoming involved in discussions with people around them about what they had read (ZPD for Activity level 2-3).

Different reasons for participating were expressed by the persons in the sample. Four of the eight persons were skeptical and less motivated initially, and were primarily encouraged by family members to participate. Even if the sample is too small to generalize the results, interesting indications for future studies were seen, such that how motivation changes, reasons for changes and how such changes affect results. Such parameters are interesting both for evaluating rehabilitation outcomes and outcomes of design choices. Within this group, three of the initially skeptical persons changed their views and became motivated to continue using computer-based tools for activity, while one person remained skeptical and did not want to continue after the test period. A difference between these individuals were that the three persons who were becoming more motivated, had initially difficulties knowing what would be the benefits for them, while at the end of the project they had gained a clearer view of the benefits. On the other hand, the person who remained skeptical had initially a clear view of what the benefit would be. This person did also not subjectively experience an increasing autonomy and level of skill, while the observations showed a significant increase. This difference was explained by identifying what was considered a satisfactory level of skills for the individual at the different levels of activity. For this person mastering all tasks at the highest level were considered a satisfactory result.

To summarize the gains reported by the subjects by the end of the final session, all of the participants discovered new values that could be added to their activities by using computers and the web as tools. This includes new and easily accessed sources of information and knowledge, channels to organizations in society where they are engaged, finding and communicating with old friends and family, developing interests and productivity in genealogy and art. In addition, four persons expressed that it is simply fun to use the computer and that the enjoyment increases with control and skills. This is said in contrast to the one remaining skeptical person who saw little use for, or enjoyment in computer-supported activities, part from using the computer for keeping up with news.

Summarizing the results of the OT assessments and evaluations based on standardized instruments after the period of activity in the controlled environment, an increase in activity at a general level was seen in five of the seven subjects. Furthermore, an increase of ability in factors such as *roles*, *abilities*, *view of own ability*, handling the *physical environment* and *interests* was seen in one to four of the subjects, which represented in total an number of 13 positive changes distributed over all seven participants. One of the persons (the remaining skeptical person) showed an increase in the *abilities* domain, but also a decrease in ability related to *roles*. However, it should be noted that these results can not be explained only by the introduction of computer based tools in activity. Rather, the results must be interpreted as being an effect of factors such as the change of weekly activities, the contribution of the social environment, the attention and social gains of meeting other persons in a public space, etc, since these aspects are evaluated at a general level embracing different viewpoints on the activities in daily life of an individual.

3.3 Prototype Development and Evaluation

The AAIMA protocol informed design of the system in several ways. The identification of the ZPDs of each subject served as a base for re-design of the prototype, together with aspects of the design of the prototype which may prevent the user from performing in an optional way, based on breakdown situations. In addition, an assessment was made by the OT of the need for support for the individual to be able to perform the important activities identified in the initial phase. To supplement these assessments with the participants' own view on his or her performance, computer based questionnaires were used with questions formulated based on the AAIMA protocol. The questionnaires were supplemented with interviews, in order to enrich the answers given by the participants. These assessments were synthesized into individually designed web pages, based on level of skills, interests and motivation with a basic structure common for all, which remained largely unchanged.

Three levels of complexity in web pages were described by Dickinson and colleagues [6] where the first level could be seen as a “walled garden”, hiding large parts of the web from the user with content fully controlled by the development team. The second layer allowed some external content that adhered to high standards of accessibility and navigation structures, while the third allowed any content of the web. A similar approach was taken in this study, increasing the complexity judged based on what lied in the next zone of development and based on what the individuals’ wished to do during the next session. Since all participants wanted to do things eventually, which involve external web pages handling such events were included in later sessions as part of their main activities. A couple of subjects even tried on their own in their homes but got lost among frames, different routines for logging in, etc. Maintaining a consistent basic structure was necessary in order to reduce the amount of new things to internalize. A resistance to change of structures was expressed, the participants wanted to be able to reuse knowledge as much as possible and not having to deal with several different ways of doing what they perceived as being the same thing. Several participants found it hard to grasp differences between similar phenomenon, and one way to distinguish between them was by the procedure to use them (e.g., web addresses vs. searching by keywords, logging in). One strategy to handle breakdowns was to start over from a point where they were familiar, which was a role the basic structure served. Therefore, this basic structure, which essential served as a home page, was adjusted to become more distinct from the rest of the web pages and easy to recognize among many open windows.

The iterative process of evaluation and re-design during the period of use, enabled the participants to contribute to the design of the system by trying to do what they wanted to be able to do, reflecting on their own performance and experienced computer-related phenomenon, without having to express explicit opinions about design choices. The latter seemed to be very difficult, since they did not distinguish differences between pages, objects, their properties, etc., to the extent that was necessary for having a specific opinion, and even less having the vocabulary to express an opinion in interviews or in questionnaires. What they did express though, was general desires for alternative ways of interacting with the computer and reduction of the information on the screen including undesired pop up frames that are difficult to handle. Suggestions of voice-controlled and “mouseless” solutions came up and easy ways to get rid of commercials in news pages were asked for. Also to be able to simply ask the computer for help was a desirable scenario for the future. These desires were confirmed in the observations of how the complete novices approached the basic computer artifacts mouse, keyboard, menus, links, applications, windows, scrollbars, etc. In spite of the simplified initial designs with introduction and support to practice basic skills, they had significant difficulties in particularly controlling the mouse and using controls in the user interface.

Concerning the application as tool for rehabilitation and health promotion, the requirements, which are basic for any design for older people to use, are essential to take into consideration to the extent accessibility recommendations exists. In addition, particular adjustments to individual needs must be possible to integrate as interventions in a rehabilitation process. A particular feature that was integrated in the study was the use of a mashup for the OT to modify the content in a simple way, based on a dialogue with the individual. Assuming that the older person may not be able to do this him or herself initially, the adjustment done by the OT can be viewed as any individual adjustments done to other aids in a person’s environment. However, the results from this part of the pilot study are preliminary and indicate that further development is needed in order to integrate a natural transformation of use from the controlled environment towards any web pages, and also for the older person to actively influence the content.

4 Discussion

This work contributes with an assessment protocol developed by applying activity theory in the analyses of eight older novice potential computer users’ view on activity and computer use. The purpose of the protocol is to evaluate novice older users’ development of skills and autonomy in Internet-mediated activity. Although the structure and content emerged based on a convenient sample of eight individuals, the resulting hierarchy of activity and corresponding needs are general and are most likely applicable also in other cases of older novice users. However, this must be investigated in future studies, involving also more fragile older potential computer users. The generalization done in this work is on themes of needs and goals, activities meeting the needs, and levels of complexity in the activities that were relevant to the eight subjects. Most likely there are needs and goals not accounted for in the protocol, needs that the eight subjects may have but did not express in the initial assessments. Then these are probably needs that they are able to fulfill already on their own and are not relevant in this rehabilitation situation. Since the subjects were comparably healthy, needs such as aid for activities of daily living were not expressed, except difficulties and limitations due to mobility problems. To what extent the set of needs, goals and activities defined in the AAIMA protocol is relevant to other individuals remains to be investigated. The design methodology used in this work, where the initial assessments done by the OT (on which also the creation of user profiles and scenarios of use were made) is analyzed using activity theory, resulting in a protocol similar to AAIMA can be generalized to other design projects. Also, using the resulting protocol for the iterative process of design and redesign, involving non-articulate potential users is a result that can be transferred to other user groups within the elderly population or other domains. This is especially valuable in domains where the introduction of ICT is expected to generate a change in skills and autonomy in performing activities.

Whether computer use promotes wellbeing in older people is a topic discussed in literature, and summarized by Dickinson and Gregor [20]. Attempts to investigate the effects on older adults have shown that it is difficult to distinguish wellbeing caused by an increased face-to-face social contact with people who introduce computers from the computer use alone. Even when this was controlled, no effects were found [21]. [20] also reports on results that it is unlikely that computer use alone would decrease isolation in vulnerable older persons, rather function as an additional tool to keep in contact with an existing social network.

In our work, we do not assume that computer use alone can facilitate either wellbeing or health, rather the opposite: computer use alone has no effects either on wellbeing or health in older adults. By setting the focus on activities perceived as important and desirable for the individuals, analyzing these by means of activity theory and identifying needs the activities respond to, the computer use becomes sub-ordinary and receives the correct mediating role in a wider purposeful perspective. A general observation in this study, which will be further investigated in future work, is that in the novice volunteers' perspective, computer use was perceived mainly as a social activity. In sessions as an example, the participants used the computers to socialize to a degree that was rather unexpected, which also is a factor to consider in experimental settings [5]. The participants were active seniors, however, some with physical problems preventing them from performing activities that they were used to do. Therefore, they were more inactive than they wished to be and used to be. In this perspective, the potential role of computer use is regaining earlier capacities in performing desired activities, preventing isolation and inactivity, and, consequently, promoting health and wellbeing. The hierarchy of activity that emerged in the analysis of the individuals' view on their activities is visualized in Fig. 1 where the basic assumption is that the sub-actions need to be mastered before the main activity can be performed in a satisfactory way. Since it is the main activities that meet the needs of wellbeing and health, these needs cannot be met if not the sub-ordinary needs are met: knowledge and control, and feeling safe and secure.

In novice older users the operational level generates major difficulties, preventing the user from performing at a purposeful level of activity. [20] describes the relatively consistent finding that complete novice users and especially frail older persons need considerably more support and were not able within the time constraints of studies to become independent users of computers. In this context, the presented method for assessing development of skills and autonomy in novice users may contribute to exploring further the potentials of purposeful designs of computer systems for facilitating and supporting activity performance for older adults. Inappropriate interventions for older persons can also be avoided by identifying what is beyond individual's zone of proximal development. Target activities that need to be supported can be identified as part of the rehabilitation process, and suitable interaction modalities or devices and level of complexity in user interfaces can be defined in individual cases at the lower level in the task hierarchy.

The idea that computer applications may replace and function as the "more skillful peer" in terms of activity theory, which guides the user to autonomy earlier, is also expressed by Dickinson and Gregor [20]. There are obvious potential benefits in such scenario, in reduction of frustration and quicker mastery of purposeful activities at higher levels in the activity hierarchy. This is also the motivation for continuing with the development of the support system to further explore these issues in a rehabilitation setting. Furthermore, this perspective on computer use can only be developed using a multi-disciplinary approach, as exemplified in this study.

Concerning alternative technologies or means for communication in a rehabilitation perspective, this is a subject for the OT to assess in the rehabilitation process, and to provide interventions for if needed. ICT is only supplementary in cases where ICT support is judged beneficial for increasing activity performance and satisfaction. This work also aims at providing the OT means to make this judgment. In a general perspective, means and channels for communication are constantly being developed, but mainly targeting the young and middle aged population that quickly take new technology into use. This excludes the older people of today and makes this work more relevant.

The occupational therapists interacted with the person during the activities, thus also when issues regarding the ICT came up. ICT can in this case be seen as a means to perform the activities that the individuals wanted to be able to perform, which the OT therefore needs to evaluate and discuss with the person. The skills assessed using the AAIMA protocol is currently translated to the rehabilitation process by comparing the assessment with the outcome that the OTs found using their structured instruments for assessment. To our knowledge, there are two instruments currently being developed in the OT research field with the purpose of assessing older persons' ability to perform activities using ICT technology. Both are focusing specifics about interacting with technology, such as handling traditional types of input devices and common software. These instruments provide more of a static evaluation of performance using existing technology of today. What is also needed is an instrument that supports the evaluation of an individual with respect to possible enhancement of ability through existing more advanced and future ICT technology that are currently being developed. Therefore, and more challenging and interesting from a research perspective, is in what way the outcome can be used for designing supportive systems for persons who need tailored support that often also needs to be adjusted to a changing health situation. In this context, the use of notions such as breakdowns and conflicts in the use situation can capture such changes. For instance, if certain breakdown situations are identified, and may be captured in an individual's daily computer use, a progressing cognitive disease such as dementia may be identified. An intelligent system may in these cases adapt to the decrease of or fluctuations in ability, and compensate for loss of cognitive functions that affect activity performance.

To use the protocol and ZPD basic knowledge in the concepts of activity theory is needed. Observation skills are also needed, however, using a structured protocol may provide aid for the observer to focus on relevant phenomenon.

5 Conclusions

This paper reports results from a pilot study that investigated the use of activity theory for prototype development and evaluation involving older novice computer users in the process. Additional purposes were investigating in what way a common tool for the rehabilitation process can be designed, which integrates both support for decision making and individually tailored activity support. A starting point for development is taken in the purposeful and desired activities to be supported, identified in eight individual cases. Activity-theoretical concepts, such as breakdowns, transformations, the dynamic hierarchy of activity and zone of proximal development were used in the process, resulting in an assessment protocol (AAIMA). AAIMA was found valuable for capturing the individual user's development of skills and autonomy in Internet-mediated activity. The protocol was used for informing the design of the system in an iterative process of re-design, use and evaluation. The seven older novice computer users who participated in the organized sessions increased their autonomy in computer-mediated activity to the extent that they are able to perform activities of their choice independently or with occasional support, and by partially using a structured web interface as starting point in case of breakdowns. By setting focus on the activity and using the AAIMA protocol as base for assessing reasons for breakdown situations, the participants were able to contribute to the design process by reflecting on their performance of activities of their choice, without having to express explicit preferences among design choices or mastering computer-related phenomenon and terms.

The method described appears to be highly valuable in the context it has been used in this study, which is developing a prototype application for the rehabilitation and health domain where the older novice actors need purposefully designed computer-based tools for increasing their autonomy and skills in daily activities. Therefore, the protocol will be further evaluated and developed in future projects.

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Online tailoring of physical exercise to enhance self-management of fibromyalgia

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Abstract. This paper describes the design and development of an online gymnasium that proposes personalized exercise videos to users affected by fibromyalgia. Fibromyalgia syndrome is a chronic condition characterized by widespread pain in muscles, ligaments and tendons, usually associated with sleep disorders and fatigue. Physical exercise is considered as an important component of non-pharmacological treatment of this pathology, and internet is praised as a powerful resource to promote and improve physical exercise. Yet, while online personalization of health interventions to consumers must be grounded on empirically based guidelines, guidelines for fibromyalgia-targeted exercises are scant. By moving from a health communication perspective, we illustrate how we reached definition of the relevant factors for tailoring online exercise videos in relation to fibromyalgia, and we describe the implementation of our approach.

1 INTRODUCTION

The following article discusses the design and development of an online gymnasium tailored to users affected by fibromyalgia syndrome (FMS). According to the American College of Rheumatology [1], fibromyalgia is a condition characterized by chronic widespread pain and tenderness in 11 or more of the 18 specific tender point sites. Although the medical evidence is still lacking precise diagnostic criteria for FMS, there are three major symptoms that are usually associated with the disease: pain, sleep disorders and fatigue. Alongside these somatic factors, there are other psychological dimensions that are observed in fibromyalgic patients, such as anxiety, stress, depression and many more. People affected by FMS usually face other occurring conditions including diabetes, high blood pressure and back pain. The FMS is currently treated with both pharmacological and non-pharmacological interventions.

Considering the non-pharmacological option, it is particularly important for individuals to learn how to manage their disease following an appropriate self-management program. Achieving good results in improving self-management ability is, however, not a trivial issue.

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The effectiveness of self-management programs for chronic conditions requires practice, help and constant support. A growing body of literature shows that, in this scenario, the internet can play a decisive role. For patients who can use a computer, different kinds of interventions have proven to be effective in enhancing their self-management, such as through online-support groups [2], tailored messages [3], online exercises [4] and a combination of these strategies in a unified online self-management program [5]. The present investigation is in accordance with these studies.

Since 2004, the Institute of Communication and Health of the University of Lugano started a research program focused on the enhancement of self-management through a web-based application called "ONESELF". This platform, originally dedicated to chronic Low Back Pain (cLBP), provided a combination of information and interactive services to users. The overall structure of the website and the findings of previous research about its effects are described elsewhere [6]. In June 2008, a new version of the ONESELF website was released, including a new section that is addressed to people affected by FMS. Both thematic areas are managed by experts in health communication and by health professionals. To lead users to exercise more often, we created an interactive gymnasium. This gymnasium is based on a 'tailored' approach. 'Tailoring' has been defined by Rimer and Kreuter as the process to create individualized communication by gathering and assessing personal data related to a given health outcome. This process works in the perspective of determining the most appropriate information or strategies to meet a person's unique needs [7].

According to the tailoring concept, online interventions that are fixed, static and standardized in terms of multimedia contents for every user undertaking a certain health program risk being ineffective. Users can better adhere and be more compliant in respect to a health proposal if its contents are offered in a personalized fashion. Thus, our main goal was to create an online gymnasium tailored to the specific needs of every specific user of our program. This goal posed many challenges and proved to be critical in terms of design. In the next sections, we introduce these challenges and explain how we dealt with them. Finally, we illustrate how the results of our analysis have been implemented technologically.

2 THE TAILORED GYMNASIUM

2.1 What we know, we do not know

Our approach to tailoring is a revisited version of the one proposed by Kreuter and colleagues [8]. Traditional tailoring aims to persuade an intended audience to change or reinforce behavior, and it is designed on a set of behavioral theories [9]. In our perspective 'tailoring' aims to maximize the appropriateness of the treatment exercises to the specific situation of users. To do so, we developed a tool to extract from a pre-existing corpus of exercises a selection of the most adequate for a user in a specific condition. This corpus, defined with the help of physiotherapists who are active in the Italian speaking part of Switzerland (Tessin), consists of 39 different exercises specifically addressed for FMS affected users.

Reaching a rationale to extract the most opportune exercises for each user was a problematic aspect of our project. As pointed out by Lustria et al. [3] having valid guidelines at disposal is a necessary requisite for the realization of a tailored intervention of quality. As we suggest, the list of possible tasks include:

(1) *Matching with high-quality criteria*. The review on health-related web interventions conducted by Eysenbach in 2002 emphasized the accuracy of the contents as one of the main quality criteria for these applications [10]. By *accuracy*, Eysenbach refers to the need for health information to match with Evidence Based Medicine criteria. These reliable criteria represent the starting point for designing a tailored application that can produce high quality content.

(2) *Translation into algorithms*. Algorithms are, by definition, finite-state procedures to solve a certain problem. The construction of a tailoring algorithm requires a procedure to extract relevant content which has to codified in clear rules. In cases where this prerequisite is not reached, it may be impossible to translate general guidelines into a tailoring algorithm.

(3) *Refinement of the tailoring rules*. There is a direct relationship between the level of details of the guidelines and the level of refinement of the extraction procedure for tailoring. Specifically, the more detailed the guidelines are, the more the tailoring procedure will result in a refined extraction of contents.

(4) *Boosting the testing phase*. Having clear guidelines at disposal is essential to boost the testing of the tailoring application. The testing is conducted by examining if the contents extracted by the system agree with the guidelines. The more defined the guidelines, the easier to compare results from case tests.

(5) *Increase the data extraction validity*. One of the main outcomes to evaluate the face effectiveness of a tailoring application is the overall validity of the selected contents. When clear guidelines are at disposal, a straight comparison can be made between the system suggestions and the ones that would result from the guidelines.

If there is, then, a need to have clear and evidence-based guidelines, in dealing with FMS we were faced with the evidence that these guidelines are still not well defined or are somewhat controversial [11]. For example, Hauser and colleagues [12] conducted a systematic review of the guidelines to manage FMS, which showed an inconsistency even at the highest level of recommendations for treatments. The American Pain Society (APS) and the Association of the Scientific Medical Societies in Germany (AWMF) consider aerobic exercise among the high-priority treatments, while the European League Against Rheumatism (EULAR) indicates a set of pharmacological options as the best practice to address FMS.

In the following section, we explain how we remedy to this lack of specific information, and reached understanding of the determinants for designing the online gymnasium.

2.2 Methodology

There are many important factors that can influence the efficacy of a tailored health intervention but are not directly related to the health problem addressed. We refer, particularly, to the specific characteristics of the population to be served. Indeed, in the perspective of tailoring a health message, it is crucial to investigate the values of the audience, its cultural norms and living patterns.

We conducted this investigation in order to determine how to discriminate among the different exercises and to propose specific set of exercises to each individual user. The analysis of the determinants for the tailoring process was grounded on previous research for fibromyalgia and focused on the general characteristics of the syndrome, management strategies and indications, and physical exercise [11] [12]. Alongside reviewing the literature, we collected original data through semi-structured interviews with a team of 5 FMS experts and 5 patients. Interviews were repeated during the development of the tool, in order to verify that the design of the tailored gymnasium was correctly addressing the problem and that the choice of determinants was prudent. The technique known as 'knowledge acquisition' was chosen as the preferred strategy to gather necessary information. More specifically, we have directly asked experts for knowledge [13]. Different possible variables were investigated and discussed with health professionals with the aim of defining which one could be used in the actual tailoring application.

The result of our investigation is a set of determinants that can make an exercise fit for a specific fibromyalgic user. As we explain below, some of these determinants have been included in the tailoring algorithm, while others were not considered as discriminant factors.

2.3 Results

2.3.1 Included determinants

Available Time: An exercise session and program needs a dedicated period of time. This is a simple and unmistakable factor in determining which (or how many) exercises can be proposed to users. Proposing too long (or too many) exercises might discourage a user who would feel unable to complete the session. Offering too few exercises would be a "waste" of very important resources; not just the time, but also the drive to exercise.

Pain: From the very beginning of the research pain was identified as one of the most important determinants. In people affected by fibromyalgia the level of pain can change drastically from one day to another, or even between different moments throughout the day. A high level of pain can prevent individuals from doing many exercises, but some selected physical activity can be of great help even when the pain is acute. On the other hand, days where the pain is not high should be fully exploited with proper exercise sessions that can help to strengthen and reinforce the muscles, reducing the likelihood of increasing pain in the future. The kind of exercises that can be suitable and useful for the patient can therefore change definitely according to the current level of pain. This determinant should be assessed before any training session. Auto-assessment in this case can be partially misleading. Some people often tend to define their pain as very high, even if it varies a lot over the course of several days. For this reason we decided to compare the level of pain perceived when starting an exercise with the perceived level of pain on an average day.

Time of day (Level of Fatigue): Depending on the time of the day, we can make assumptions regarding the amount of fatigue that users feel. FMS sufferers are often more tired in the morning, since the syndrome is usually linked to sleeping disorders. However, they can also be very tired in the evening, due to the amount of activity conducted during the day. When they are extremely tired, some kind of exercises are better fit than others, while other kinds should be avoided. When they are not tired, more difficult but rewarding exercises could be proposed in order to reinforce the muscles and reduce pain. Furthermore, there is a general distinction amongst the kinds of exercises that should be done in different times of day, regardless of fibromyalgia or other pathologies. For example, laborious exercises should not be executed in the evening, while stretching can be of great help in getting a refreshing night’s sleep.

Available Tools: Some exercises might require specific tools, such as balls, exercise mats or chairs. If users do not have such material available, they would not be able to do these specific exercises. A good system should avoid disappointing the user by suggesting unfeasible actions. This could be overcome in two different ways: by excluding exercises that have a material component, or by assessing which objects the user has at their disposal. In our approach we decided to ask users about the availability of a few common objects that are used in many of the suggested exercises. In this way, we could include some very useful exercises without having to ask the user too many different questions.

Localization: Fibromyalgia can lead to more acute pain in specific parts of the body. Thus, it is useful to focus the exercise on parts of the body that are more in need of training and reinforcement. In some situations it can also be important to avoid exercising the wrong areas of the body, particularly where the pain is more severe. We considered the possibility of asking users about which parts of the body hurt the most and which parts they would like to train. In the final implementation we decided to focus on the preferred body parts of choice to train, thus narrowing the possibilities to arms, legs and the torso. While the attention to more specific parts of the body and to the problem of localized pain appears to be significant, we did not manage to properly include this level of refinement in the tailoring algorithm and final implementation. Indeed, the definition of narrow guidelines in reference to specific pain localization did not encounter sufficient agreement among the experts.

Level of Difficulty: Some exercises are more difficult and tiresome than others. Even if the perception of the level of difficulty of an exercise can change drastically between different people, it is possible to classify individual perceptions on a general level of difficulty scale. More strenuous exercises can be more helpful in improving the muscle strength and decreasing the level of pain. Yet, it can also be very hard and frustrating. Even if exercises for fibromyalgia are usually light and rarely imply very difficult movements, individuals should only undergo exercises that they feel comfortable with and are willing to address.

Experience: Having new exercises at every session can be very challenging and interesting for a patient, and therefore lead to a more assiduous use of the tool. However, when users find an exercise that they like, it is likely that they want to repeat it and gain specific experience in that training. We can foresee a distinction between users that always want new content and others that stick to the old ones. They can, thus, be asked at the beginning of any session if they prefer to receive exercises which are new or already tested.

User judgment: Among the different exercises suggested by the system during the training sessions, each user has their own favorite and disliked exercises. A good tailoring tool should propose and focus more on the exercises that users prefers than on those that they dislike. Questions can be ask to chose among best exercises according to their preferences. When choosing between two exercises that a new user has never tried before, the strategy is to select the one to present according to what other users have preferred during their training sessions.

2.3.2 Excluded determinants

Sex: Sex proved not to be a relevant determinant when assigning exercises to users. The same exercises can be fit for both men and women; no differences in training indications were found in relation to sex. Fibromyalgia mainly affects females, however, gym groups are attended by both sexes in traditional exercise sessions, and no difference in the physical activity level can be observed.

Age: Users' age was not considered a key determinant. The suggested exercises are suited to any age group. Elderly people tend to lighten the exercises by reducing movements' size, time or repetitions. Nevertheless, they can usually benefit from the same exercises as younger people.

Additional FMS information: Other information about the state of the syndrome was taken into consideration as possible determinants such as, for example, the duration of the syndrome and whether or not it prevents people from conducting daily work activities. In the final assessment these variables were, however, not considered since they do not seem to influence the types of exercise that users should do.

In conclusion, 11 variables have been considered and discussed with the experts and eight of them have been included in the tailoring process.

3 IMPLEMENTATION

3.1 General Tailoring Framework

A tailored application is usually composed of two main modules: an assessment component, used to retrieve the data needed to tailor an intervention according to the characteristics and needs of an audience, and a feedback component that displays a tailored message to users. Data provided by users are elaborated through algorithms that produce the results shown in the feedback.

The development of the gymnasium moved from the following elements: a) the corpus of video recorded exercises previously introduced, b) the list of eight determinants and c) a set of rules to combine them. Our algorithms serve the purpose of relating patients' conditions to specific exercises.

In the *assessment module* of the tool, users are asked to answer a series of questions leading to the evaluation of the eight determinants. In this phase the system receives a self-reported set of data which represents the starting point of the algorithms. Some of the questions are optional and if the patient chooses not to answer such parameters, this will not influence the extraction procedure.

The *feedback module* of the tailored gymnasium shows in the beginning five warming up exercises that remain the same in every session for each patient. The patient is asked to execute them for ten minutes before continuing to the tailored training. Personalized exercises are shown one at a time, once the warm-up phase is concluded. Each tailored exercise is introduced with a video which presents its execution and a textual step-by-step description. Exercises can also be rated on a 1 to 5 scale. Users can leave comments about each exercise and its performance, and have the further option to stop the training session at any moment. Upon completion of the exercises (or when users decide to end the training), they receive a recapitulation of the performed exercises.

The tailored gymnasium has been designed in the perspective of being used repeatedly over time. To extract exercises that are specific for contingent conditions, the assessment should be repeated each time that a new exercise session is started.

Finally, the gymnasium also includes a *tracking module* used to record users' interactions with the application. This component stores all the answers received from an individual user, the list of the actual videos shown in any single session and all feedback received (including votes, textual comments and whether an exercise has been completed or not). This information is stored in a database and is available for use in the tailoring algorithms.

3.2 Raw and Intermediate Variables

The first two phases of implementation of a tailored intervention consist in the definition of Raw Variables and the computation of Intermediate Variables. Raw Variables contain the data collected directly from the participant or from a user profile, in the original format in which they are registered. Intermediate variables are created by transforming Raw Variables into a more usable form. Transformation can include mathematical calculations, categorization, summarization and other techniques (usually expressed through a formula). In the case under investigation, we have moved from the eight determinants to the definition of Raw and Intermediate variables. A synthesis of these variable is presented in *Table 1*. Our approach combines data from the assessment with information stored by the tracking component through the use of the tailoring tool itself.

3.2 The Matching Algorithm

The matching algorithm selects those exercises that best fit the information provided by the user in the assessment phase. It works in a threefold dimension.

First, it excludes all exercises whose performance requires specific tools - as rubber balls or theraband – if users do not have such material at their disposal.

In a second step, all the remaining exercises are ordered in a list expressing the suitability of an exercise for each user's present situation. This is done according to the goodness of the exercise metadata in comparison with the information provided by the user: the first exercise in the list is the more suitable one. A suitability score is computed by taking into account a weighted mean of six different dimensions, namely: 1) the adequacy of the exercise's difficulty to user's pain level and 2) to user's preferred difficulty, 3) the adequacy of the exercise to the request of obtaining a new or already seen exercise, 4) users' eventual previous votes , 5) other users' eventual previous vote of the exercise as expressed in previous training sessions and 6) the adequacy of the exercise to the part of the body the user wants to train.

The third step is a classification of each exercise of the ordered list in functional categories, namely: relaxation, mobilization, stretching, stabilization, massage. According to the moment of the day and to the intensity of pain expressed by users, each category has a specific probability that the exercises it includes will be shown in the feedback phase. The extraction procedure selects, one at a time, the first available exercise from the category-ordered lists and presents it to the user during the feedback phase. The procedure continues until a set of exercises adequate to users' available time is arranged. Exercises are delivered to each user one by one in order of extraction.

4. CONCLUSION

The purpose of this article was to describe the design and implementation of a tailored intervention to enhance self-management in patients affected by FMS. The main results can be summarized in a) the definition of the relevant variables for tailoring exercise videos to people ethat xperience this peculiar and chronic condition and b) the implementation of an algorithm to automate the tailoring process. The evaluation of the tool is currently ongoing. There we aim to derive data to refine the ranking and extraction algorithm and, in a second phase, to assess the impact of a tailored Gymnasium on FMS sufferers' strategies of self-management.

So far, an important limitation of our study is due to the methodology we used to elicit the relevant guidelines and variables. In the absence of clear medical guidelines for FMS, the knowledge acquisition approach cannot guarantee exhaustiveness in the identification of the determinants. Further investigation is needed to assure a comprehensive overview of the grounding criteria to tailor messages to fibromyalgic patients. One (unexplored) attempt could be to match the general criteria for exercise prescription defined by the American College of Sport Medicine (ACSM, 2005).

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Determinant	Variable name (Type)	Description	Values (if Raw) / Formula (if Intermediate)
Time Availability	Available TimeTimeAvailable (R)	The amount of time that the user declares to have at disposal.	10 = less than 10 minutes 15 = 15 minutes 20 = 20 minutes 30 = 30 minutes 31 = more then 30 minutes
Pain	PainLevelGeneral (R)	Assessment of the actual pain level of the patient.	From 1 (very low pain) to 10 (very strong pain)
	PainLevelRelative (R)	Assessment of the actual level of pain compared to the "average" pain.	1 = pain is stronger than usual 0 = usual pain -1 = pain is lower than usual
	PainLevel (I)	Estimation of the pain level, according to values from the assessment.	R_PainLevelGeneral + R_PainLevelRelative
Time of day	ActualTime (R)	Time of the day in which the session is started (calculated according to server time).	A time of the day, expressed in hours and minutes: HH:MM
	I_PartOfTheDay	Actual part of the day.	IF R_ActualTime <12 THEN "morning" ELSE IF R_ActualTime > 18 THEN "evening" ELSE "afternoon"
Available tools	SmallBallAvailable (R)	Does the user have a small ball to use for exercise?	True / False
	BigBallAvailable (R)	Does the user have a big ball to use for exercise?	True / False
	PartnerAvailable (R)	Does the user have a partner that can help them exercise?	True / False
	MattressAvailable (R)	Does the user have an available exercise mat?	True / False
	TherabandAvailable (R)	Does the user have a theraband to exercise?	True / False
Localization	PartOfBody (R)	Users preferences for a specific body part to train.	0 = no preference "Arms" = arms "Legs" = legs "Torso" = torso
Level of difficulty	Difficulty (R)	Users preference for harder or easier exercise.	0= no preference "Harder" = harder exercises "Normal" = normal exercises "Simpler" = simpler exercises
Experience	NewExercises (R)	Users preference for new exercises or already seen videos.	0 = not answered 0 = no preference "New" = new exercises "Known" = known exercises "Both" = both kind of exercises
	ExPerformed (R)	This variable expresses whether a given exercise X has been assigned to the actual user in a specific session, and has been actually performed.	True = exercise performed False = exercise not performed
	TimesExPerformed (I)	The number of times that a certain user "UserX" performed a given exercise "exerciseX".	COUNT (*) WHERE Exercise = "ExerciseX" AND User = "UserX" AND R_ExPerformed = True
User judgement	ExVote (R)	This variable expresses the vote that an exercise received from a specific user in a given tailoring session	0 = exercise not judged by the user From 1 (exercise that the user did not like) to 5 (exercise firmly appreciated by the user)
	UserVote5 (I)	The average vote that the exercise "exerciseX" received from "UserX"	AVG(R_ExVote) WHERE Exercise = "ExerciseX" AND User = "UserX" AND R_ExVote > 0
	UsersVote5 (I)	The average vote received from exerciseX, considering all application user.	AVG(R_ExVote) WHERE Exercise = "ExerciseX" AND R_ExVote > 0

Table 1. Raw and Intermediate variables - (R) = Raw variable, (I) = Intermediate variable

Towards the Second-Order Adaptation in the Next Generation Remote Patient Management Systems

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Abstract

Remote Patient Management (RPM) systems are expected to be increasingly important for chronic disease management as they facilitate monitoring vital signs of patients at their home, alerting the care givers in case of worsening. They also provide patients with educational content. RPM systems collect a lot of (different types of) data about patients, providing an opportunity for personalizing information services. In our recent work we highlighted the importance of using available information for personalization and presented a possible next generation RPM system that enables personalization of educational content and its delivery to patients. We introduced a generic methodology for personalization and emphasized the role of knowledge discovery (KDD). In this paper we focus on the necessity of the second-order adaptation mechanisms in the RPM systems to address the challenge of continuous on-line (re)learning of actionable patterns from the patient data.

1 Introduction

Remote patient management (RPM) systems offer a potential for reducing hospitalization costs and worsening of symptoms for patients with chronic diseases, e.g., coronary artery disease, heart failure, and diabetes. An RPM system both monitors vital signs and provides a feedback to the patient in terms of appropriate education and coaching. Although the large volumes of data collected by RPM systems provide an opportunity for tailoring and personalizing information services, there is a limited understanding of the necessary architecture, methodology, and tailoring criteria to facilitate personalization of the content.

In our recent work [7] we presented an architecture of the next generation RPM systems that facilitates personalization of educational content and its delivery to patients. We also introduced a generic approach for personalization of RPM and thereafter focused on (off-line) knowledge discovery from patients' data from a clinical trial.

In this paper we go one step further highlighting the importance and the necessity of continuous on-line (second order) adaptation in RPM systems, i.e., developing a mechanism which would adjust or adapt the behavior of the adaptive system.

The rest of the paper is organized as follows. We briefly review the state of the art in RPM systems and present our view on the next generation of RPM systems in Section 2. In Section 3 we discuss the potential of second-order adaptation mechanisms in RPM systems and consider a few hypothetical examples of gradual and abrupt concept drift, reoccurring contexts and context-aware learning. We conclude with brief discussion and outline the directions of the future work in Section 4.

2 Remote Patient Management Systems

Existing commercial RPM systems normally provide an end-to-end infrastructure that connects patients at home with health professionals at their institution. The patients at home are equipped with a number of sensors measuring vital signs to obtain objective measurements about their physical condition. The vital sign measurements (e.g. weight, blood pressure, glucose) are transferred to the monitoring and management server. Subjective measurements (e.g., symptoms and quality of life scores) are collected from the patients via questionnaires. Objective and subjective measurements (referred to as RPM data) are presented to the medical professional who, based on the indicated deviations from the normal values, adjusts the patient's treatment plan, including medications and lifestyle goals (e.g., nutrition and physical activity).

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The majority of commercial RPM systems only have the link between the patient and professional that enables uploading patient data to the professional for review and treatment changes; these systems are typically referred to as remote patient monitoring systems as they provide only monitoring, but not the management part.

The current commercial systems typically send the same generic non-personalized content to all the patients, regardless of their current health condition, knowledge level, or a mental state.

Research on personalization is ongoing in e-Learning and there is a number of successful implementations of adaptive hypermedia systems like AHA!, Interbook, etc. [1]. However, existing architectures are not adopted in eHealth applications such as RPM systems. Furthermore, in the mentioned systems, the adaptation and personalization is pre-authored and thus remains highly static and often subjective based on some domain expertise translated to the machine readable form.

Developing personalized RPM systems is possible only if we can learn key (potentially changing and dynamic) characteristics of the patients and track them continuously. Personalization can be organized using individual and group (or stereotype) user modeling. In a stereotype approach, the users are classified into several groups. In eHealth applications users can be classified according to their main disease, background in medicine (patients, nurses, and physicians), general education background (no degree, college degree, doctorate, etc), and their tasks (consultation, education, and emergency cases). Individual patient (user) models, besides the user's medical profile, could include also individual characteristics such as cognitive and psychological individual peculiarities, the interaction parameters – the last visited pages, used links, number of the particular pages visits, resource usages etc. Table 1 gives an overview of possible features of various data classes that can play a role in the patient model of an RPM system. A feature can be *static*, e.g. gender, residence, language, or *relatively static*, e.g., age, cognitive impairment (which a patient can develop during the usage of RPM system) and *dynamic*, e.g., values of weight measurements or system usage. The example given is for heart failure, but can be generalized to any of chronic diseases given a specific set of relevant symptoms and vital signs for that chronic disease.

Dynamic features plays an important role in the patient model of RPM system. This calls for the second-order adaptation mechanisms in the RPM systems to address the challenge of continuous on-line (re)learning of actionable patterns from the patient data.

Table 1. Typical features included in a patient model template

Data class	Feature	Changes	
		Static	Dynamic
Demographic	Gender	x	
	Age	x	
	Country	x	
	Language	x	
Living status	Single/Family	x	
Baseline data	Weight		x
	Height	x	
	Body Mass Index		x
	Edema		x
	Biomarker values		x
Medical history	Cause of disease	x	
	Co-morbidities		x
	Implantables	x	x
Symptoms	Ankle swelling		x
	Breathlessness		x
	Depression		x
	Anxiety		x
Vital signs (Frequencies of values out of band)	weight		x
	heart rate		x
	blood pressure		x
	diastolic blood pressure		x
System usage (Frequency of measurements	weight		x
	blood pressure		x
	heart rate		x
Learning styles	Verbaliser/Imager	x	
	FD/FI	x	
Cognitive function	Reduced eyesight	x	
	Dementia	x	

Legend: *Frequency of vital sign measurements* - how often the patient has been using a sensor for a measurements (1 – every day, 0- not at all), *FD/FI* – field dependent/independent.

3 Second-order adaptation

In our recent work [7] we suggested a general architecture of an personalized RPM system in which we followed general principles of personalization in e-Learning systems with KDD process as one of the key integrated components. Figure 1 depicts a part of the architecture that could provide a possible foundation for the next generation adaptive RPM systems.

The key components of the system that facilitate personalization and adaptation include: (1) patient (user) model, (2) domain model, (3) adaptation rules, (4) adaptation engine, and (5) KDD process. Further, there are authoring and management tools allowing medical experts and professionals to monitor, control and manage patient models, domain models and adaptation rules.

In this section we consider briefly the role of knowledge discovery for patient modeling and provide motivating examples for handling gradual and sudden changes in

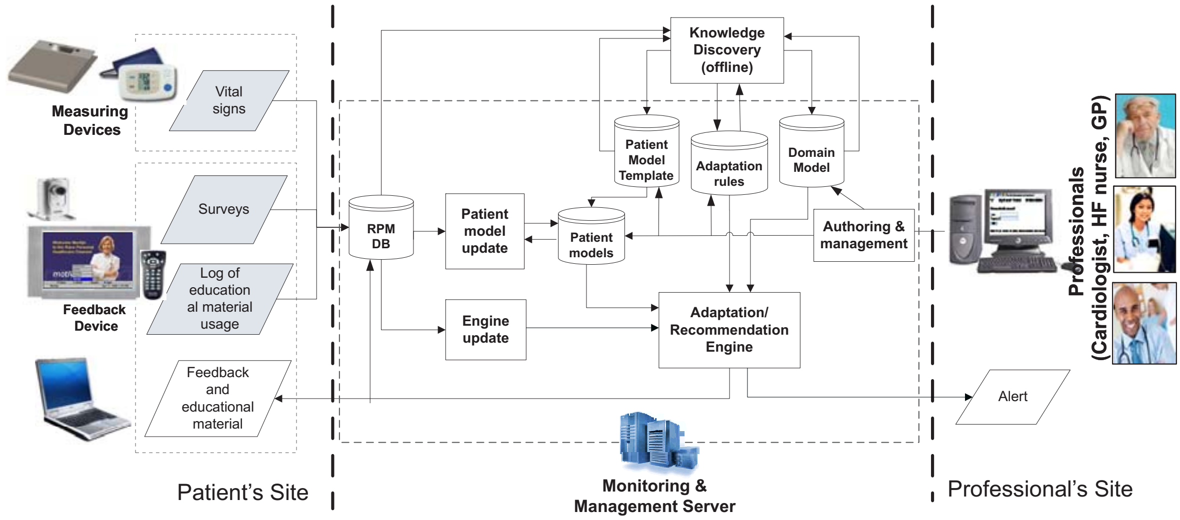

Figure 1. A high level view of the next generation RPM system [7]

the modeled concepts, and for learning contextual features describing reoccurring contexts.

3.1 Knowledge discovery for patient modeling in RPM systems

The *KDD process* is essential for discovering relevant actionable patterns that are the basis for creation of the patient model and the adaptation rules. This KDD process is (initially) done "off-line", using stable historical data available from an existing RPM database or from completed clinical trials relevant for the disease in question. Via this KDD process we obtain relevant patterns that are used to build a *patient model template*. The same patterns are utilized to build the *adaptation rules* and *domain model* of the available content material that is stored in corresponding databases. The KDD is highly iterative and interactive and involves considerable effort from domain and KDD experts. Moreover, this is by no means one-time activity. With accumulation of new evidence and possible contextual changes, models and rules might need an update or extension.

Even-pattern and time-series analysis are particularly helpful in getting a better understanding of what features and relations between them may potentially describe patient current state and its short-term and long-term dynamics.

In general different types of approaches can be used for discovery of useful patterns, including association analysis, subgroup discovery, etc. In this study we search for discriminating patterns by defining corresponding classification tasks. For example, we searched for rules that would predict next symptom status and change in next symptom values, using the last symptom status, gender, age, and frequency of daily system usage in the period between two symptoms (typically one month) as predictive features.

Table 2 illustrates example patterns found (with the help of popular J48 and JRIP classification techniques) for two most prominent symptoms, breathlessness and swelling of ankles. We obtained off-line the exact number for the level of the usage of the system (i.e., $freqOfWeightUsage$), but have replaced that with a parameter (Low, Medium, High) because it changes over time. We discuss extensively in the next section how this parameter changes in the context of necessity for second-order adaptation. From Table 2 we can observe that women in general are at higher risk to remain breathless (P1) and remain with swelling ankles if they do not use the system regularly (P4-P5). In general, patients are in risk if they are under-utilizing the system (P2-P3), while male patient population above 75 is at risk for worsening of their condition (P6). We refer an interested reader to [7] for a more detailed discussion of the KDD process and a particular case study.

In Table 3 we present possible adaptation rules based on previously discovered patterns P1-P6 2. These rules mostly identify patients at risk for worsening of their condition, notify the medical professional about risk, and send adequate content to the patient so that worsening can be prevented. E.g., the first rule based on pattern P1 would send content material to the patient to help her master her breathing, while at the same time notify the medical professional that this woman is at risk to remain breathless. Similarly the second rule based on patterns P2-P3 would identify patient at risk and send appropriate educational and instructional material to the patient and notification about risk to the professional. In this case a patient needs to be motivated to use the system, and properly instructed how to do so.

Level of system usage (denoted $freqOfWeightUsage$

Table 3. Examples of adaptation rules

P#	Possible Rule	Desired effect	
		Patient	Medical professional
P1	If Sex=F and BreathlessSymptom=B then Send videos with breathing exercises	Regain control over the breathing	Notification for patient at risk
P2, P3	If BreathlessSymptom=A and Age=(37.5-81.5] and (feqOfWeightUsage <0.4 or freqOfPulseUsage < 0.4) then Send Motivational content	Motivation, instruction for using the system, education on breathlessness	Notification of patient at risk
P4	If SwellingSymptom = 'B' and Sex = 'F' and freqOfWeightUsage < 0.6 then Send Motivational video	Motivation, instruction for using the system, education on swelling ankles	Alert for additional action
P5	If StartSymptom = 'S' and Sex = 'F' and freqOfWeightUsage < 0.6 and Age < 74.5 then Send motivational content		Notification of patient at risk
P6	If SewllingSymptom = 'S' and Sex = 'M' and Age > 74.5 then Send educational content	Motivation, education on importance of managing condition	Notification of patient at risk

Table 2. Examples of discovered patterns

	Patterns	Symptom
P1	(StartSymptom = 'B') & (Sex = F) => NextSymptom = B	Breath-lessness
P2	(StartSymptom = 'A') & (Age = '(37.5-81.5]') & (freqOfWeightUsage < 0.4) => NextSymptom = 'B'	
P3	(StartSymptom = 'A') & (Age = '(37.5-81.5]') & (freqOfPulseUsage < 0.4) => NextSymptom = 'B'	
P4	(StartSymptom = 'B') & (Sex = 'F') & (freqOfWeightUsage < 0.6) => NextSymptom = 'B'	Swelling of ankles
P5	(StartSymptom = 'S') & (Sex = 'F') & (freqOfWeightUsage < 0.6) & (Age < 74.5)=> NextSymptom = 'W'	
P6	(StartSymptom = 'S') & (Sex = 'M') & (Age >=74.5) => NextSymptom = 'B'	
Legend: Start/Next Symptom: G = good (no problem), S = small problems, A = average, B = bad (many problems), W = worse, I = improved		

in Table 3) is one of the user model parameters that clearly has significant impact on adaptation. We consider the possibly changing nature of the $freqOfWeightUsage$ concept to motivate the necessity for second-order adaptation in terms of handling a concept drift.

3.2 Coping with sudden and gradual changes

The user parameters discovered in the patterns, such as level of system usage is likely to change over time due to (i) change in patient motivation to use the system because of the educational and instructional material that has been sent, (ii) change in patients'lifestyle habits impact of these to the usage of the system), (iii) change in seasonal patterns as patients tend to measure themselves differently during summer compared to winter or during working days compared to public holidays, or (iv) any other hidden context. The system needs to be able to detect and adapt to the changes quickly and without additional input from the patient, e.g., by collecting additional evidence for motivation or lifestyle habit changes[1].

Consider the following example presented in Figure 2. It shows how the progression of the disease can develop over time. The patients could be placed on the system with only one co-morbidity, and due to their age and progression of the chronic disease (heart failure) could develop a number of other conditions. The bottom figure shows what could be the effect of additional conditions to the system usage. Namely, with the increase in number of conditions the patients' overall health could significantly decade (while possibly keeping the main parameters of heart failure still in the normal ranges), directly influencing the patient's motivation and ability to measure him/herself.

Another example is the change of the patient's cognitive abilities. The decline in cognitive abilities could occur for patient over time and it could possibly effects the usage of the system. For example, the patient could become more forgetful, develop initially very mild, mild, or sever case of dementia. This could directly impact his ability to use the system - (s)he would start forgetting to weight or measure blood pressure, initially sporadically, and then more and more often.

It is rather intuitive that besides system usage, such parameters as patient's weight and weight change can trigger

[1]Even if one would like to measure motivation by asking the patient, that would be least preferred option as already patients are faced with many symptom questions they need to answer on daily basis.

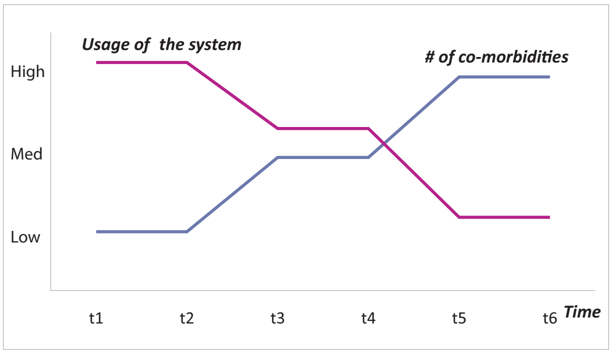

Figure 2. Changes in co-morbidities and expected system usage over time.

different The weight of the patient could increase over the time. Normally the rule for alerting the care giver about the risk of heart failure is very simple: if weight increase is more than 2 kilos over 1-2 days, raise an alert. However, there are patients who decompensate with slow increase of weight over period of 10-15 days. Hence, it could happen that the patient gets hospitalized without the alert being raised due to slow increase. The system should be able to learn the slow increase in weight for these patients and adopt the alerting rules accordingly. Furthermore different external events like national and religious holidays can affect normal eating habits. Such events can be recognized from the data and model adjusted accordingly, or proactive handling of possible change could be implemented,

As discussed, in RPM systems (and eHealth domain in general) the concept of interest (user parameters) depends on a changing context that is not necessarily given explicitly in the form of predictive features. Hence, stationary data distribution assumed by majority of traditional data mining techniques in no longer the case. Rather, here we are faced with *concept drift* [11], i.e., unforeseen changes over time in the phenomenon of interest. The phenomenon here would be the usage of system behavioral pattern relevant to current potentially hidden context. The concept we are trying to learn (value of the level of system usage) for the true patient model parameter depends on the observed behavior.

Changes in the hidden context may not only be a cause of a change of the target concept, but may also cause a change of the underlying data distribution. Even if the target concept remains the same, and it is only the data distribution that changes, this may often lead to the necessity of revising the current model, as the model's error may no longer be acceptable with the new data distribution (e.g., more females added to the system may change the behavior). The need to the change of current model due to the change of data distribution is called *virtual concept drift* [10].

Three approaches to handling concept drift can be distinguished: (1) instance selection; (2) instance weighting; and (3) ensemble learning [8]. In instance selection, the goal is to select instances relevant to the current concept. The most common concept drift handling technique is a sliding window and consists in generalizing from a window that moves over recently arrived instances and uses the learnt concepts for prediction only in the immediate future [11].

Instance weighting uses the ability of learning algorithms such as Support Vector Machines (SVMs) to process weighted instances [2]. Instances can be weighted according to different features such as "age" or competence with regard to the current concept. Klinkenberg [2] demonstrates in his experiments that instance weighting techniques handle concept drift worse than analogous instance selection techniques.

Ensemble learning is among the most popular and effective approaches to handle concept drift, in which a set of concept descriptions built over different time intervals is maintained, predictions of which are combined using a form of voting, or the most relevant description is selected [4]. Street and Kim [6] and Wang *et al*. [9] suggest that simply dividing the data into sequential blocks of fixed size and building an ensemble on them may be effective for handling concept drift. Stanley [5] and Kolter and Maloof [3] build ensembles of incremental learners in an online setting, starting to learn new base classifiers after fixed intervals, while continuing to update the existing ones.

3.3 Reoccurring contexts and context-aware adaptation

Figures 3 and 4 show an example of changes in the level of system usage due to seasonal patterns. Seasonal "index" (based on simple average) is used for seasonal construction. Two types of seasonality are shown: period of the year (fall, winter, spring, summer), and week days (Monday to Sunday). Expected seasonal behavior of male patients from Figure 3 would be to use the system at most in fall while female patients in winter and fall. In summer both male and female patients use the system less, and in spring men use the system (in average) more than women (less than average). Figure 4 shows a tendency of both men and women to use the system less during weekends, and to use the system at most on Friday. Additionally, local behaviors, such as, holidays can change the seasonality concept as during the holiday (regardless of the day of the week) patients are under-utilizing the system.

Thus, there exists seasonality behavior in the level of the usage of the system for different patients, which changes the concept. This behavior can be detected and handled by methods which learn from data under the assumption of concept drift. Once the seasonality is discovered, features

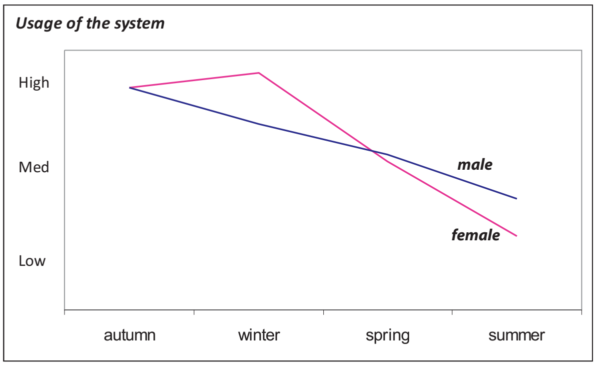

Figure 3. Seasonal index (per periods of year) of the use of the system.

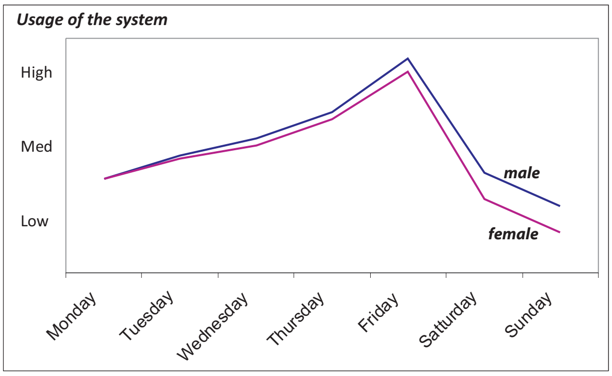

Figure 4. Seasonal index (per days of the week) of the use of the system.

representing seasonal context, such as holiday, season, and week day, become a part of the observation set that the system is monitoring. Thereby, in the summer or during the holidays the adaptation rules should be modified to include, for example, additional content that would motivate the patients to use the system. Examples of additional rules are given in Table 4. The difference between rule P8 and rule P10 is due to the expected decline in usage of the system during summer, compared to winter. Hence, when the level of usage of the system is Medium, an alert is sent only in the winter. Note that behavior described with these additional rules can further change over time.

Table 4. Examples of additional rules

#P	Additional rules
P9	Season = Winter and Sex = Female and freqOfWeightUsage = Medium then send additional motivational content, alert medical professional
P10	Season = Winter and Sex = Female and freqOfWeightUsage = Low then send additional motivational material, alert medical professional
P11	Season = Summer and Sex = Female and freqOfWeightUsage = Medium then send motivational material, do not alert
P12	Summer = Winter and Holiday = False and freqOfWeightUsage = Low then send alert to the medical professionals
P13	Summer = Winter and Holiday = True and freqOfWeightUsage= Low then do nothing

The direct potential relation between co-morbidities and usage of the system considered in the earlier example implies that the rules triggering an alert due to non-usage of the system might need additional conditions that would take into account number of co- morbidities. The context of co-morbidities could be known in the system, e.g., the patient goes to the clinical assessment and notifies caring nurse, but it could also be hidden in the sense that the patient does not notify the caring professional about the new disease (which could be as simple as breaking the leg or falling, or as complex as diabetes or renal failure).

The possibility that usage of the system declines with the similar rate of decline of patient mental abilities should be reflected in the system. The system should (i) be able to detect the pattern of slow decline of the system usage, (ii) when that is detected, send appropriate cognitive tests to reconfirm the cognitive decline, and (iii) potentially modify the alerting rules such that they incorporate the cognition ability and thereby have the threshold of alerting based on the usage of the system different. Moreover, the delivery of care should be modified to possibly include cognitive ability tests more regularly.

4 Conclusions and further work

Remote Patient Management (RPM) systems are expected to be increasingly used in the near future. The current generation of RPM systems follows the one-size-fits-all approach despite of the wide acceptance of the benefits of personalization and adaptation of information services.

In our work we focused on the data driven approaches to adaptation. We considered motivating examples which illustrate ideas behind patient profiling and tailoring the educational or motivational content. This allowed us to come closer to the following challenge – the second order adaptation in RPM systems. We illustrated with further more detailed consideration of naive seasonal and generally time-changing patterns, the benefits of online learning, concept drift handling mechanism, and discovery and use of contextual features for adapting the set of adaptation rules, and user modeling procedures.

In this paper we considered mostly either hypothetical or rather fragmented examples of patient modeling in the context of the second order adaptation. Our further work includes knowledge discovery from data collected during the real clinical studies to justify the advantages of systems equipped with concept drift handling and context-sensitive learning mechanisms.

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