Automated Personalized Goal-setting in an Activity Coaching Application

Miriam Cabrita[1,2], Harm op den Akker[1,2], Reinoud Achterkamp[1,2], Hermie Hermens[1,2] and Miriam Vollenbroek-Hutten[1,2]

[1]*Roessingh Research and Development, Telemedicine Group, Enschede, The Netherlands*

[2]*University of Twente, Faculty of Electrical Engineering and Computer Science, Telemedicine Group, Enschede, The Netherlands*

Keywords: Accelerometers, Physical Activity, Goal-setting, Personalization, Telemedicine, Body Area Networks.

Abstract: The ageing population and the increase in sedentary lifestyles of knowledge workers has led to increasing concerns about the physical activity habits of the European population. Pervasive technologies and theories of behavioral change are being combined in an effort to promote physical activity. The Activity Coach is an example of one such system. Whereas the previous version of the Activity Coach set a fixed and permanent daily goal, in this work we describe the addition of an automatically adaptive goal-setting feature to this existing system. With the new feature, the daily goals for physical activity are set based on the user's routine, contributing to the personalization of the system. A technical evaluation was performed to test the system's adaptation to the user's routine. Additionally, a conversion factor between a unit of energy expenditure and number of steps was determined. The evaluation indicates that our method of goal-setting provides more challenging but still attainable goals when compared to the previous version. Additional evaluations are recommended to evaluate the user's perception and effects on physical activity behavior change of this new feature. The results of this research are implemented in the existing Activity Coach and will be used in future patient evaluations.

1 INTRODUCTION

Due to the ageing population, the prevalence of chronic disease is increasing worldwide. The growing demand on healthcare services calls for cost-effective treatments that reduce the demands on healthcare professionals. From the socio-economical point of view, the remaining labor force is responsible for covering the costs of a growing number of dependent elderly. This means that people have to work till a later age and for longer periods of time, even when not feeling in their healthiest condition. According to the European Commission, nearly 25% of the European working-age population suffers from a longstanding problem which restricts their daily activities (Directorate General for Health and Consumers, 2011), chronic illnesses being the principal cause. Provision of eHealth and Telemedicine services is widely regarded as a promising paradigm to limit the prevalence of chronic disease, reduce the burden on the healthcare system and keep employees healthy and at work. An important factor in reducing this burden is the maintenance of a healthy lifestyle in terms of regular physical activity. Regular physical activity is beneficial for everyone and the American College of Sports Medicine recommends that the majority of adults perform moderate-intensity cardio respiratory exercise training for at least thirty minutes a day (Garber et al., 2011). However, of all Dutch employees, 50% exercises too little and 44% is overweight (Hooftman et al., 2011). This not only poses a risk for the inactive subject, but can also result in increased sick leave and in a smaller active labor force to finance healthcare.

Over the past years, a telemedicine intervention to promote sustainable behavior change in terms of physical activity was designed, implemented and evaluated in several different studies (Van Weering et al., 2009; Evering et al., 2011). Subjects were given a 3D-accelerometer based sensor to assess daily activity patterns, combined with a smartphone for providing continuous visual feedback in the form of a graph. By comparing the subjects' daily activity to

Cabrita M., op den Akker H., Achterkamp R., Hermens H. and Vollenbroek-Hutten M..
Automated Personalized Goal-setting in an Activity Coaching Application.
DOI: 10.5220/0004878703890396
In *Proceedings of the 3rd International Conference on Sensor Networks* (SENSORNETS-2014), pages 389-396
ISBN: 978-989-758-001-7

a pre-defined reference activity pattern, subjects were automatically given motivational cues based on their performance at regular intervals throughout the day. The smartphone system, called the Activity Coach, and the telemedicine platform which it is part of is described in more detail in Section 2.3. Earlier studies using the Activity Coach have already shown the effectiveness of providing real time motivational cues on the users level of physical activity. However, more recent studies have shown that compliance to the intervention tends to drop after several weeks of use (Tabak et al., 2013; Dekker-van Weering et al., 2012). In order to increase long term compliance, we intend to tailor the system better to its individual users. Ongoing research focuses on tailoring the motivational messages that are sent to the users, in particular their timing (op den Akker et al., 2010) and content (Wieringa et al., 2011; Achterkamp et al., 2013). In the presented research, we describe the addition of a complex new feature to the Activity Coach, which allows it to automatically generate personalized daily goals for its users. Considering that users might have particular activity habits during the different days of the week, the new feature of the Activity Coach automatically sets daily goals based on previous measurements. In this way adaptation to the user's routine and subsequently more realistic goals are guaranteed.

The rest of the paper is outlined as follows. Section 2 describes the background on the use of mobile technologies in the promotion of physical activity, the Goal Setting Theory and the Activity Coach — the specific system under consideration here. Section 3 describes the design and implementation of the new smart goal setting module. Section 4 deals with the evaluation of the system. Conclusions, discussion and an overview of future work are given in Section 5.

2 BACKGROUND

In this section, relevant background information is given regarding (1) mobile technology for the promotion of physical activity (Section 2.1), (2) the goal setting theory that forms the theoretical basic of the generation of automated goal lines (Section 2.2), and (3) the technology platform in which the system has been implemented (Section 2.3).

2.1 Mobile Technology in the Promotion of Physical Activity

It is estimated that the penetration rate of mobile phones in 2013 is around 96% worldwide (Union, 2013). The development of new technologies and the spread of mobile technology in the general population opens a whole range of new possibilities for promotion of physical activity, combining real-time monitoring and coaching features. Around the world, several research groups evaluate the efficiency and efficacy of tailored interventions using pervasive technology. Well-known examples of exercise tracking applications, e.g. Runkeeper[1], Beeminder[2], Endomondo[3] or Runtastic[4], typically only use the smartphones built-in global positioning system sensor for providing feedback in terms of e.g. speed and distance. Applications that encourage appropriate and sufficient physical activity throughout the day are less widely available, and in most cases use external sensors. The advantage of using external sensors over sensors in the smartphone is that the external sensor is usually worn on the body continuously, whereas smartphones are typically not. Additionally, modern external accelerometers are usually more accurate than the smartphones built-in accelerometers. An example of a system using an external sensor is given in (Mutsuddi and Connelly, 2012) that combines the use of pedometers and a smartphone. The authors sent text messages to the subjects during a period of three months. The messages encouraged physical activity and were based on personalized step goals. Results showed that the subjects increased both their daily physical activity and their motivation regarding physical activity during the intervention. Other examples are UbiFit Garden (Consolvo et al., 2009) and Fish 'n' Steps (Lin et al., 2006).

2.2 Goal-setting Theory

The Goal-Setting Theory is among the most used theories of individual behavior change in interventions aiming at the promotion of healthy lifestyles. Firstly focused on the work setting, Locke and Latham's theory emerges as the result of nearly forty years of empirical research on the relationship between conscious performance goals and task performance level (Locke and Latham, 2002).

Setting goals implies the choice of the goal timeframe (when should the goal be achieved?), the goal source (who sets the goal?) and the goal complexity, or difficulty (how hard will it be to achieve the goal?). Regarding complexity, the Goal-Setting Theory defends that individuals are more likely to change

[1] http://www.runkeeper.com/
[2] http://www.beeminder.com/
[3] http://www.endomondo.com/
[4] http://www.runtastic.com/

a behavior the higher the specificity and (achievable) difficulty of a goal. At the same time, when setting a goal, one should bear in mind personal characteristics of the subject, such as goal importance, self-efficacy and feedback.

The effectiveness of different goal-setting approaches has been researched extensively (Colineau and Paris, 2010; Shilts et al., 2004). However, our empirical experience with clinical trials suggests that, within the therapeutic context, the currently available systems tend to contain three specific flaws. First, the majority of the monitoring and feedback systems use a common goal to all the users disregarding the individual health status and physical condition. As a consequence, a goal that is easily achievable for a certain user can be unattainable for others. Second, the goal is regularly maintained throughout time, not following a possible, and desired, behavior change. Third, the majority of the systems available do not concern the spread of physical activity throughout the day, setting one single daily goal. Finally, to our best knowledge, there is no study that either implements or evaluates the effectiveness of automatic tailored goal-setting, i.e. goals set to meet individuals needs. Along these lines, we propose a new feature that sets the daily goal as well as a set of successive goals spread over the day based on the users routine, while not neglecting the therapeutic objective.

2.3 The Activity Coach

The Activity Coach is a Body Area Network consisting of an activity sensor to be worn on the hip and a smartphone application and is part of the Telemedicine platform described in more detail in (op den Akker et al., 2012). The sensor device contains (among others) a 3D accelerometer sensor that can capture, process and communicate wireless full 3D motion and orientation information (Figure 1). The processed data is then sent to the smartphone over Bluetooth. The output used by the system to estimate physical activity is the Integral of the Modulus of body Acceleration (IMA), a unit that correlates to energy expenditure (Bouten et al., 1996).

In the present work, the daily goal is defined as the cumulative value of energy expenditure that the user is recommended to achieve at the end of the day. In the Activity Coach, this is seen as the final point of the goal line (displayed on the screen as a green line). The daily end point is the energy expenditure level that the user has actually reached (final point of the activity line, displayed on the screen as a blue line).

Figure 1: The Activity Coach, consisting of a smartphone and accelerometer-based activity sensor.

Previous versions of the Activity Coach set the daily goal either based on results from healthy control subjects or to be 110% of the average of the daily end points of the baseline period. The baseline period normally constitutes an initial seven days period during which the user does not receive any kind of feedback. In the older version the daily goal remained constant throughout the whole intervention. Questions regarding the efficiency of this way of goal-setting arose during previous experiments. Our goal is to create and evaluate a more efficient and effective procedure by automatically generating personalized daily goals for each user.

3 IMPLEMENTATION

The new version of the Activity Coach includes automatically self-adaptive goal-setting features. By automatically self-adaptive goal-setting we mean that the system sets goals for the upcoming days based on both the user's weekly routine and a set of parameters defined by the healthcare professional via web-portal. These parameters, explained in more detail in the following sections, are the ultimate goal, the deviation allowance factor and the breakpoints. The high level architecture of the system is explained in more detail in (op den Akker et al., 2012). The self-adaptive process is divided into two steps and is described in more detail in the following sections.

3.1 Analysis of Physical Activity Daily Routine

The daily data is analyzed in four parts: (1) average of energy expenditure per minute during different day parts (morning, afternoon, evening, and full day), (2) deviation between the user's physical activity and the goal line for that day, (3) ratio between daily end point and daily goal, and (4) a summary of the minute-by-minute IMA values (smoothed over e.g. 15 minute intervals) — referred to as *saved IMA data*. The values from the daily analysis are subsequently combined with the equivalent values from previous analysis occurred on the same day of the week. Therefore, the system keeps track of the parameters of the four sets of data aforementioned in a specific file for each weekday.

From the daily analysis the parameters used for setting the goal line are the daily end point and the saved IMA data. These values are combined with data previously analyzed using the Linear Moving Weighted Average (LMWA) — Equation 1. For example, if the system is analyzing the data obtained on a Monday, the daily end point of this day is averaged with the daily end points of all the previous Mondays using the LMWA. Afterwards the resulting value will be used for setting the goal line for the next Monday. This method was chosen instead of an arithmetical average to take into account the evolution of the user. In this way the more recent a measurement, the bigger its weight in the calculation of the average. From these steps results the *averaged end point* and the averaged *saved IMA data*.

$$LWMA(point,N)_i = \frac{\sum_{j=1}^{N} point_{i-N+j} \times (i-N+j)}{\sum_{j=1}^{N} j} \tag{1}$$

3.2 Determining the Goal Line for the Upcoming Day

By goal line we mean both the quantity and distribution of physical activity that is recommended to the user over the day. It has two main parameters: daily end goal and daily pattern, i.e. distribution of physical activity over the day. In the new version of the Activity Coach the healthcare professional sets an *ultimate goal* for the different days of the week. This is seen as an upper limit for the daily end goal and should be adjusted for each user. This ultimate goal puts a maximum on the value of the daily goal set by the system in order to avoid unattainable goals. Another value set by the healthcare professional is the *deviation allowance factor*. This factor determines the growth rate of the daily goal when compared to the averaged end point. By default this value is set to 110%.

3.2.1 Determine End Goal

After the daily analysis, the averaged end point is multiplied by the deviation allowance factor and the result compared with the ultimate goal. If the result is higher than the ultimate goal, the new daily goal has the same value as the ultimate goal. If the result is lower than the ultimate goal, the new daily goal is set as the averaged end point multiplied by the deviation allowance factor.

3.2.2 Determine Goal Line Pattern

The healthcare professional also sets the distribution of physical activity that the user should follow over the day. This happens by setting *breakpoints* — `<time,percentage>`-pair points. As an example, one can say that the user should achieve 40% of his daily activity at 12 oclock. There is no limit to the amount of breakpoints that can be set, allowing for a fine or coarse granularity of the goal line pattern. When setting a new goal line, each one of these breakpoints is compared to the percentage that the user accomplished at the same time of the day. This value is determined by calculating the ratio between the correspondent values of the averaged saved IMA data, i.e. the one at the same (or closer) time of the day, and the averaged end point. If this ratio is lower than the percentage set on the breakpoint, the percentage set in the goal line will be the average of the two values. Following the example given previously, if the user should accomplish 40% of his daily activity at 12 o'clock and he accomplished only 20%, in the next goal line for this day of the week, at 12 o'clock the user is supposed to achieve 30% of his daily goal.

3.2.3 Runtime Procedure

When the application is launched the system checks if there is data from previous days to analyze. If that is the case, the system analyzes the data of each day separately and verifies if there are days with no valid data (e.g. days when the user did not use the system, or did not wear it for a long enough period of time). In that case, the goal line is created based either on stored data from that day of the week or in the parameters set by the healthcare professional. In this way it is guaranteed that there is a goal line for every day. If the data of a day is valid, i.e. if there is a significant amount of data points, the system analyzes the data and checks if there is data stored about that day of the week. If so, it combines the new and the old data and sets a new goal line after comparison with the parameters set by the healthcare professional. If not, it uses only the data of the day to create a new goal line.

4 SIMULATIONS AND EVALUATION

The presented paper reports exclusively the technical evaluation of the new feature of the Activity Coach and not the effectiveness of the application in terms of behavior change. Ongoing research is being done on the behavior change component and results are expected during the upcoming years. Additionally, our only concern at this phase of the research regarded the daily end goals set to the user and not the ones referred to in this paper as breakpoints. Although there are clear guidelines on the amount of physical activity that should be performed per day/week, there is no evidence on the way this activity should be distributed over the day. Literature suggests that prolonged inactivity is unhealthy independently of physical activity level, meaning that single boosts of activity are not the enough to meet the benefits of an healthy lifestyle (e.g. (van der Ploeg et al., 2012)). This supports the general notion that physical activity should be equally spread over the day. However, there is no clear evidence on the exact health benefits.

The Goal-Setting Theory emphasizes the importance of setting challenging but attainable goals. To test the self-adaptive character of the system we analyzed data from subjects with Chronic Obstructive Pulmonary Disease acquired in a longitudinal study that was executed between May and November of 2012, for the European Project IS-Active. From a sample of 10 subjects, only the data of 7 patients was used. Three subjects were excluded as a consequence of the limited amount of viable data available. From the 7 remaining subjects, two were female, four were not working at the time of the study and all of the subjects had low levels of physical activity as assessed with the Baecke questionnaire (Baecke et al., 1982). The experiment design followed the one described in section 2.3. For each subject, the daily goal remained the same throughout the intervention and was defined as 110% of the average daily end points of the baseline period. From now the daily goals set based on the previous version of the Activity Coach will be referred to as *fixed goals*.

4.1 Fixed Versus Self-adaptive Goal-setting

Our aim with this simulation was to compare the challenge and attainability of the provided goals set by the previous (*fixed goals*) and newer versions (*adaptive goals*) — of the Activity Coach. To clarify, the fixed goals correspond to what was, in reality, displayed on the screen of the smartphone during the IS-Active experiment and the adaptive goals are hypothetical goals that would have displayed in case of using the automatically self-adaptive goal-setting feature. We intend to evaluate if the system would in fact adapt to user's routine as expected during the design phase. The goals were considered challenging and attainable if the ratio between the averaged of the goals and the averaged activity performed would be between 0.75 and 0.95. The exact values are to be taken as indicative. The procedure followed in this study was as follows:

1. Calculate the average IMA count per minute for each one of the days of the baseline period. All the days with less than 300 data points were excluded (frequency of acquisition is 1 data-point per minute);
2. Save the goal set by the system during the experiment (fixed goal);
3. Set an ultimate goal as 200% of the average of the end points of the baseline period. This value was chosen because it seems challenging but not impossible to double your level of physical activity;
4. Set automatically adaptive daily goals based on the algorithm described in Section 3;
5. Compare the daily IMA averages during the intervention period and the average of the fixed (step 2) and adaptive goals (step 3 and 4).

Table 1 shows the results from both methods. It is clear that the adaptive goals tend to be more challenging than the fixed goals. Especially in the case of the first three subjects, the former method of goal-setting provides daily goals that are, on average, lower than the activity during the intervention period. Clearly, this is not a desired system behavior considering that the subject would not feel challenged to increase physical activity levels.

To better evaluate the self-adaptive feature, both old and new version were analyzed graphically. Figures 2 and 3 show the results of the simulations using data from subjects isa09 and isa10, respectively. The black line shows the subjects daily activity (Daily data), the dashed line represents the fixed goal (Fixed) and the light grey line the adaptive goal (Adaptive).

Table 1: Results of the evaluation performed with data from subjects of the IS-Active project. Only days with more than 300 measured activity values were considered (**Days**). The average of IMA counts per minute during the intervention period was divided by the average per minute provided using the basic goal setting (**Fixed**) and the adaptive version (**Adaptive**).

		Goal Ratios	
Subject	**Days**	**Fixed**	**Adaptive**
isa07	40	1.05	0.83
isa09	30	1.24	0.98
isa10	38	1.26	1.01
isa11	61	0.94	0.90
isa12	53	0.99	0.93
isa13	59	0.90	0.90
isa14	36	0.92	0.74

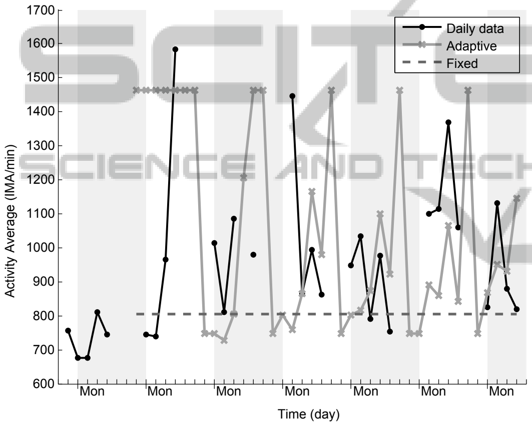

Figure 2: Simulation results comparing adaptive goals with fixed goals for subject isa09.

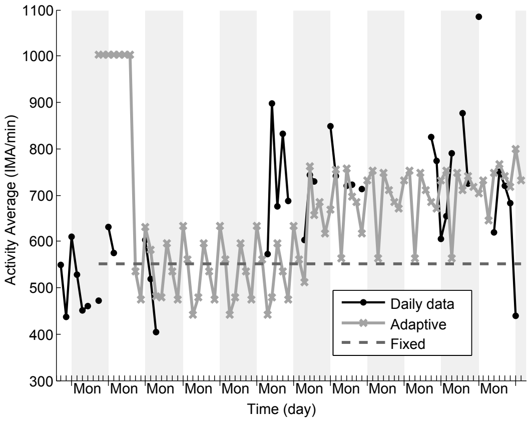

Figure 3: Simulation results comparing adaptive goals with fixed goals for subject isa10.

In both cases, confirming the results shown in Table 1, the goal set by the previous version of the Activity Coach is not challenging for the respective users. This can lead to demotivation. For the adaptive goals, it is clear that the system adapts to the users routine. This is especially visible in the seventh week. (Figure 3). The system not only sets specific goals to each day of the week but also adapts these goals over time.

4.2 Other Simulations

As part of the research we performed a study to (1) evaluate the reasonability of the default deviation allowance factor, and (2) be able to provide more concrete, understandable and specific feedback to the users. When providing feedback, it is important to assure that the user fully understands the message received. However, we are aware that, contrarily to other commonly known measures of physical activity (e.g. calories expenditure, distance and number of steps performed), IMA is not an understandable unit. In our evaluation we decided to analyze the correlation between IMA counts throughout the day and the number of steps performed.

A single-study subject was performed in order to determine a conversion factor between IMA counts and number of steps. In this small study we used a FitBit Zip[5] to measure steps taken during 11 days of free living. Over the experiment period, the value of IMA counts were compared to the number of steps performed during each 5-minute interval. The relation between the two units found after data processing is presented in Equation 2 ($p<0.0001$). The number of steps was then converted to average of minutes walking according to recommendation from American Journal of Preventive Medicine — 100 steps correspond to a minute walking. We considered that the factor would be reasonable (i.e. challenging and attainable) if it would add less than 20 minutes walking to the user. For this evaluation, we used once again the data acquired during the IS-Active project. For each subject, we calculated the total IMA added in average to the daily physical activity and converted to number of steps and respective number of minutes walking. Table 2 shows the results of this evaluation.

$$IMA_{count}(steps_{count}) = 30.24 \times steps_{count} + 1680 \quad (2)$$

When setting a new daily end goal, the average of the daily end points of that weekday is multiplied by the deviation allowance factor. Based on this first explorative study we suggest that 110% is a reasonable factor for increasing the daily physical activity of the user. However, more studies should be performed in

[5]http://www.fitbit.com/uk/zip/specs

Table 2: Total IMA (**IMA**), number of steps (**Steps**) and minutes of walking (**Minutes**) added in average to the daily physical activity using the self-adaptive goal-setting feature. Only days with more than 300 measured activity values were considered (**Days**).

		10% Additional Effort		
Subject	**Days**	**IMA**	**Steps**	**Minutes**
isa07	40	29,823	931	9
isa09	30	62,493	2,011	20
isa10	38	43,517	1,383	14
isa11	61	55,072	1,766	18
isa12	53	64,485	2,077	21
isa13	59	55,419	1,777	18
isa14	36	42,023	1,334	13

order to address the variance related to the method of measuring acceleration during different types of activities and expressing this as a number of steps per minute.

5 CONCLUSIONS

In this work we implemented self-adaptive goals in order to encourage daily physical activity, bearing in mind the importance of both the final goal of energy expenditure and the distribution of activity over the day. The level of challenge and the attainability of the goals provided to the user was evaluated with (1) data acquired during previous studies, and (2) newly gathered data from a single-subject study. From simulations using data of a 3-months-study we conclude that self-adaptive goals tend to be more challenging than fixed goals (both methods provide attainable goals).

The main limitation concerns the conversion from IMA counts to steps and consequent evaluation of the additional effort required from the user when setting a new goal. Along these lines we suggest two different studies. First a study should be performed including a larger sample of subjects in order to increase the accuracy of the conversion factor between IMA counts and steps. Second, within the same subject, various measuring contexts should be taken into account in order to get a personalized conversion between number of steps and minutes walking. Additionally, the simple study showed in section 4.2 suggests that future implementations should consider also a threshold to the additional effort required from the user. As a suggestion, the additional threshold can correspond to 10% unless the case when this value adds more than 20 minutes walking to the daily activity.

Regarding the activity pattern, at the moment of publication, there is no guideline that defines what a proper daily pattern of physical activity is. If future research gives insights into the most suitable distribution of physical activity throughout the day, the breakpoints of the goal line can be adjusted through a web-portal in order to be coherent with the new results.

To conclude, we believe that the incorporation of self-adaptive goal-setting in the Activity Coach will benefit users in their way to become more active. Also, healthcare professionals will benefit by allowing them to give more accurate recommendations to their patients as they are more aware of their physical activity routines. The results from this research will be used in future experiments using the Activity Coach and can be adapted to other ambulatory feedback systems regarding promotion of physical activity.

ACKNOWLEDGEMENTS

This publication was supported by the Dutch national program COMMIT (project P7 SWELL).

REFERENCES

Achterkamp, R., Cabrita, M., and op den Akker, H. (2013). Promoting a Healthy Lifestyle: Towards an Improved Personalized Feedback Approach. In *IEEE 15th International Conference on e-Health Networking, Applications and Services (Healthcom 2013)*, pages 677–679.

Baecke, J. a., Burema, J., and Frijters, J. E. (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *The American journal of clinical nutrition*, 36(5):936–42.

Bouten, C. V., Verboeket-van de Venne, W. P., Westerterp, K. R., Verduin, M., and Janssen, J. D. (1996). Daily physical activity assessment: comparison between movement registration and doubly labeled water. *Journal of applied physiology (Bethesda, Md. : 1985)*, 81(2):1019–26.

Colineau, N. and Paris, C. (2010). Motivating reflection about health within the family: the use of goal setting and tailored feedback. *User Modeling and User-Adapted Interaction*, 21(4-5):341–376.

Consolvo, S., Klasnja, P., McDonald, D. W., and Landay, J. a. (2009). Goal-setting considerations for persuasive technologies that encourage physical activity. *Proceedings of the 4th International Conference on Persuasive Technology - Persuasive '09*, page 1.

Dekker-van Weering, M. G. H., Vollenbroek-Hutten, M. M. R., and Hermens, H. J. (2012). Do personalized feedback messages about activity patterns stimulate patients with chronic low back pain to change their activity behavior on a short term notice? *Applied psychophysiology and biofeedback*, 37(2):81–9.

Directorate General for Health and Consumers (2011). Eu health programme, 2011. health of people of working age. Technical report, European Union.

Evering, R. M., Tönis, T. M., and Vollenbroek-Hutten, M. M. (2011). Deviations in daily physical activity patterns in patients with the chronic fatigue syndrome: a case control study. *Journal of psychosomatic research*, 71(3):129–135.

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I.-M., Nieman, D. C., and Swain, D. P. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Medicine & Science in Sports & Exercise*, 43(7):1334–1359.

Hooftman, W., Hesselink, J., van Genabeek, J., Wiezer, N., and Willems, D. (2011). TNO Arbobalans 2010: Kwaliteit van de arbeid, effecten en maatregelen in Nederland. Technical report, TNO.

Lin, J., Mamykina, L., Lindtner, S., Delajoux, G., and Strub, H. (2006). FishnSteps: Encouraging Physical Activity with an Interactive Computer Game. In Dourish, P. and Friday, A., editors, *UbiComp 2006 Ubiquitous Computing*, volume 4206 of *Lecture Notes in Computer Science*, pages 261–278. Springer.

Locke, E. A. and Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist*, 57(9):705–717.

Mutsuddi, A. U. and Connelly, K. (2012). Text Messages for Encouraging Physical Activity. In *6th International Conference on Pervasive Computing Technologies for Healthcare*, pages 33–40.

op den Akker, H., Jones, V. M., and Hermens, H. J. (2010). Predicting Feedback Compliance in a Teletreatment Application. In *Proceedings of ISABEL 2010: the 3rd International Symposium on Applied Sciences in Biomedical and Communication Technologies*, Rome, Italy.

op den Akker, H., Tabak, M., Marin-Perianu, M., Huis In't Veld, R. M., Jones, V. M., Hofs, D., Tonis, T. M., van Schooten, B. W., Vollenbroek-Hutten, M. M., and Hermens, H. J. (2012). Development and Evaluation of a Sensor-Based System for Remote Monitoring and Treatment of Chronic Diseases - The Continuous Care & Coaching Platform. In *Proceedings of the Sixth International Symposium on e-Health Services and Technologies (EHST 2012)*, pages 19–27, Geneva, Switzerland.

Shilts, M. K., Horowitz, M., and Townsend, M. S. (2004). Goal setting as a strategy for dietary and physical activity behavior change: a review of the literature. *American journal of health promotion : AJHP*, 19(2):81–93.

Tabak, M., op den Akker, H., and Hermens, H. (2013). Motivational cues as real-time feedback for changing daily activity behavior of patients with COPD. *Patient Education and Counceling*.

Union, I. T. (2013). The world in 2013: Ict facts and figures. online.

van der Ploeg, H. P., Chey, T., Korda, R. J., Banks, E., and Bauman, A. (2012). Sitting time and all-cause mortality risk in 222 497 Australian adults. *Archives of internal medicine*, 172(6):494–500.

Van Weering, M. G., Vollenbroek-Hutten, M. M., Tönis, T. M., and Hermens, H. J. (2009). Daily physical activities in chronic lower back pain patients assessed with accelerometry. *European journal of pain London England*, 13(6):649–654.

Wieringa, W., op den Akker, H., Jones, V. M., op den Akker, R., and Hermens, H. J. (2011). Ontology-Based Generation of Dynamic Feedback on Physical Activity. In *Proceedings of the 13th Conference on Artificial Intelligence in Medicine (AIME)*, pages 55–59, Bled, Slovenia. Springer.